TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT:

BATTERY CHARGERS AND EXTERNAL POWER SUPPLIES

March 2012

U.S. Department of Energy
Assistant Secretary
Office of Energy Efficiency and Renewable Energy
Building Technologies Program
Appliances and Commercial Equipment Standards
Washington, DC 20585

This Document was prepared for the Department of Energy
and by staff members of Navigant Consulting, Inc.,
D&R International, Ltd.,
and Ernest Orlando Lawrence Berkeley National Laboratory

TECHNICAL SUPPORT DOCUMENT:
BATTERY CHARGERS AND EXTERNAL POWER SUPPLIES

Table of Contents

CHAPTERS

APPENDICES

CHAPTER 1. INTRODUCTION

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the development of the notice of proposed rulemaking (NOPR) of this rulemaking for battery chargers and external power supplies (EPSs).

1.2 SUMMARY OF NATIONAL BENEFITS

DOE's analyses for EPSs indicate that the proposed standards would save a significant amount of energy–an estimated 0.95 quads of cumulative energy over 30 years (2013 through 2042). This amount is equivalent to 77 percent of the energy used annually by electronics in U.S. homes. In addition, DOE Expects the energy savings from the proposed standards to eliminate the need for approximately 0.53 gigawatts (GW) of generating capacity by 2042.

The cumulative national net present value (NPV) of total consumer costs and savings of the proposed standards for products shipped in 2013–2042, in 2010$, ranges from $0.67 billion (at a 7-percent discount rate) to $1.64 billion (at a 3-percent discount rate).[a] This NPV is the estimated total value of future operating-cost savings during the analysis period, minus the estimated increased product costs, discounted to 2011.

In addition, the proposed standards would have significant environmental benefits. The energy savings would result in cumulative greenhouse gas emission reductions of 44.84 million metric tons (Mt)[b] of carbon dioxide (CO_2) in 2013–2042. During this period, the proposed standards would result in emissions reductions of 37 kilotons (kt) of nitrogen oxides (NO_X) and 0.24 tons (t) of mercury (Hg).[c] DOE estimates the net present monetary value of the CO_2 emissions reduction is between $0.19 and $2.84 billion, expressed in 2010$ and discounted to 2011. DOE also estimates the net present monetary value of the NO_X emissions reduction, expressed in 2010 $ and discounted to 2011, is between $5.90 and $60.61 million at a 7-percent discount rate, and between $10.58 and $108.74 million at a 3-percent discount rate.

The benefits and costs of the proposed standards can also be expressed in terms of annualized values over the 2013–2042 period. The annualized monetary values are the sum of (1) the annualized national economic value, expressed in 2010$, of the benefits from operating

---

[a] DOE uses discount rates of 7 and 3 percent based on guidance from the Office of Management and Budget (OMB Circular A-4, section E, September 17, 2003). See section IV.G for further information.

[b] A metric ton is equivalent to 1.1 short tons. Results for NO_X and Hg are given in short tons.

[c] DOE calculates emissions reductions relative to the most recent version of the Annual Energy Outlook (AEO) Reference case forecast. As noted in section 15.2.4 of TSD chapter 15, this base case accounts for regulatory emissions reductions through 2008, including the Clean Air Interstate Rule (CAIR, 70 FR 25162 (May 12, 2005)), but not the Clean Air Mercury Rule (CAMR, 70 FR 28606 (May 18, 2005)). Subsequent regulations, including the currently proposed CAIR replacement rule, the Clean Air Transport Rule, do not appear in the base case.

products that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase costs, which is another way of representing consumer NPV), and (2) the monetary value of the benefits of emission reductions, including CO_2 emission reductions.[d] The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The monetary costs and benefits of cumulative emissions reductions are reported in 2010$ to permit comparisons with the other costs and benefits in the same dollar units. The derivation of the SCC values is discussed in further details in chapter 16 of this TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of EPSs shipped in 2013 –2042. The SCC values, on the other hand, reflect the present value of all future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts continue well beyond 2100.

Estimates of annualized benefits and costs of the proposed standards for EPSs are shown in Table 1-1. Using a 7-percent discount rate and the SCC value of $22.3/ton in 2010, which was derived using a 3-percent discount rate (see note below Table 1-1), the cost of the standards proposed in today’s rule is $220.0 million per year in increased equipment costs, while the annualized benefits are $274.0 million per year in reduced equipment operating costs, $47.5 million in CO_2 reductions, and $2.7 million in reduced NO_X emissions. In this case, the net benefit amounts to $104.2 million per year. Using a 3-percent discount rate and the SCC value of $22.3/ton in 2010, the cost of the standards proposed in today’s rule is $233.1 million per year in increased equipment costs, while the benefits are $316.5 million per year in reduced operating costs, $47.5 million in CO_2 reductions, and $3.0 million in reduced NO_X emissions. At a 3-percent discount rate, the net benefit amounts to $134.0 million per year.

---

[d] DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value for the time-series of costs and benefits using a discount rate of either three or seven percent. From the present value, DOE then calculated the fixed annual payment over the analysis time period (2013 through 2042) that yielded the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined is a steady stream of payments.

Table 1-1 Annualized Benefits and Costs of Proposed Standards for External Power Supplies Shipped in 2013-2042

	Discount Rate	Primary Estimate*	Low Estimate*	High Estimate*
		Monetized (million 2010$/year)		
Benefits				
Operating Cost Savings	7%	274.0	260.4	287.4
	3%	316.5	299.4	333.8
CO_2 Reduction at $4.9/t**	5%	12.3	12.3	12.3
CO_2 Reduction at $22.3/t**	3%	47.5	47.5	47.5
CO_2 Reduction at $36.5/t**	2.5%	74.7	74.7	74.7
CO_2 Reduction at $67.6/t**	3%	145.1	145.1	145.1
NO_X Reduction at $2,537/t**	7%	2.7	2.7	2.7
	3%	3.0	3.0	3.0
Total†	7% plus CO_2 range	289.0 to 421.8	275.4 to 408.2	302.5 to 435.2
	7%	324.2	310.6	337.7
	3%	367.1	350.0	384.4
	3% plus CO_2 range	331.9 to 464.6	314.8 to 447.6	349.2 to 481.9
Costs				
Incremental Product Costs	7%	220.0	220.0	220.0
	3%	233.1	233.1	233.1
Total Net Benefits				
Total†	7% plus CO_2 range	69.0 to 201.8	55.4 to 188.2	82.4 to 215.2
	7%	104.2	90.6	117.6
	3%	134.0	116.9	151.3
	3% plus CO_2 range	98.8 to 231.6	81.7 to 214.5	116.1 to 248.9

* The results include benefits to consumers which accrue after 2042 from the products purchased from 2013 through 2042. Costs incurred by manufacturers, some of which may be incurred prior to 2013 in preparation for the rule, are indirectly included as part of incremental equipment costs. The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices from the AEO2010 Reference case, Low Estimate, and High Estimate, respectively.** The CO_2 values represent global monetized values (in 2010$) of the social cost of CO_2 emissions in

2010 under several scenarios. The values of $4.9, $22.3, and $36.5 per ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.6 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_X (in 2010$) is the average of the low and high values used in DOE's analysis.

† Total Benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.3/ton in 2010 (in 2010$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

DOE's analyses for battery chargers indicate that the proposed standards would save a significant amount of energy–an estimated 1.53 quads of cumulative energy over 30 years (2013 through 2042). This amount is equivalent to 1.25 times the amount of energy used annually by electronics in U.S. homes. In addition, DOE expects the energy savings from the proposed standards to eliminate the need for approximately 0.83 GW of generating capacity by 2042.

The cumulative NPV of total consumer costs and savings of the proposed standards for products shipped in 2013–2042, in 2010$, ranges from $6.60 billion (at a 7-percent discount rate) to $12.01 billion (at a 3-percent discount rate).[e] This NPV is the estimated total value of future operating-cost savings during the analysis period, minus the estimated increased product costs, discounted to 2011.

In addition, the proposed standards would have significant environmental benefits. The energy savings would result in cumulative greenhouse gas emission reductions of 70.69 Mt of CO_2 in 2013–2042. During this period, the proposed standards would result in emissions reductions of 58.27 kt of NO_X and 0.39 t of Hg.[f] DOE estimates the net present monetary value of the CO_2 emissions reduction is between $0.30 and $4.54 billion, expressed in 2010$ and discounted to 2011. DOE also estimates the net present monetary value of the NO_X emissions reduction, expressed in 2010$ and discounted to 2011, is between $9.20 and $94.52 million at a 7-percent discount rate, and between $16.73 and $172.02 million at a 3-percent discount rate.

The benefits and costs of today's proposed standards can also be expressed in terms of annualized values over the 2013–2042 period. The annualized monetary values are the sum of (1) the annualized national economic value, expressed in 2010$, of the benefits from operating products that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase costs, which is another way of representing consumer NPV), and (2) the monetary value of the benefits of emission reductions,

---

[e] DOE uses discount rates of 7 and 3 percent based on guidance from the Office of Management and Budget (OMB Circular A-4, section E, September 17, 2003). See section IV.G for further information.

[f] DOE calculates emissions reductions relative to the most recent version of the Annual Energy Outlook (AEO) Reference case forecast. As noted in section 15.2.4 of TSD chapter 15, this base case accounts for regulatory emissions reductions through 2008, including the Clean Air Interstate Rule (CAIR, 70 FR 25162 (May 12, 2005)), but not the Clean Air Mercury Rule (CAMR, 70 FR 28606 (May 18, 2005)). Subsequent regulations, including the currently proposed CAIR replacement rule, the Clean Air Transport Rule, do not appear in the base case.

including CO_2 emission reductions.[g] The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The monetary costs and benefits of cumulative emissions reductions are reported in 2010$ to permit comparisons with the other costs and benefits in the same dollar units. The derivation of the SCC values is discussed in further detail in chapter 16 of this TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of battery chargers shipped in 2013 –2042. The SCC values, on the other hand, reflect the present value of all future climate-related impacts resulting from the emission of one ton of carbon dioxide in each year. These impacts continue well beyond 2100.

Using a 7-percent discount rate and the SCC value of $22.3/ton in 2010, which was derived using a 3-percent discount rate (see note below Table 1-2), the cost of the standards proposed in today's rule is -$92.8 million per year in increased equipment costs, while the annualized benefits are $439.0 million per year in reduced equipment operating costs, $75.9 million in CO_2 reductions, and $4.2 million in reduced NO_X emissions. In this case, the net benefit amounts to $611.9 million per year. Using a 3-percent discount rate and the SCC value of $22.3/ton in 2010, the cost of the standards proposed in today's rule is -$98.3 million per year in increased equipment costs, while the benefits are $514.2 million per year in reduced operating costs, $75.9 million in CO_2 reductions, and $4.8 million in reduced NO_X emissions. At a 3-percent discount rate, the net benefit amounts to $693.3 million per year.

---

[g] DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value for the time-series of costs and benefits using a discount rate of either three or seven percent. From the present value, DOE then calculated the fixed annual payment over the analysis time period (2013 through 2042) that yielded the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined is a steady stream of payments.

Table 1-2 Annualized Benefits and Costs of Standards for Battery Chargers Shipped in 2013-2042

	Discount Rate	Primary Estimate*	Low Estimate*	High Estimate*
		Monetized (million 2010$/year)		
Benefits				
Operating Cost Savings	7%	439.0	417.8	460.3
	3%	514.2	487.2	541.9
CO_2 Reduction at $4.9/t**	5%	19.6	19.6	19.6
CO_2 Reduction at $22.3/t**	3%	75.9	75.9	75.9
CO_2 Reduction at $36.5/t**	2.5%	119.3	119.3	119.3
CO_2 Reduction at $67.6/t**	3%	231.6	231.6	231.6
NO_X Reduction at $2,537/t**	7%	4.2	4.2	4.2
	3%	4.8	4.8	4.8
Total †	7% plus CO_2 range	462.9 to 674.8	441.6 to 653.6	484.1 to 696.0
	7%	519.1	497.9	540.3
	3%	594.9	567.9	622.6
	3% plus CO_2 range	538.7 to 750.6	511.7 to 723.6	566.3 to 778.3
Costs				
Incremental Product Costs	7%	(92.8)	(92.8)	(92.8)
	3%	(98.3)	(98.3)	(98.3)
Total Net Benefits				
Total†	7% plus CO_2 range	555.7 to 767.6	534.5 to 746.4	576.9 to 788.8
	7%	611.9	590.7	633.2
	3%	693.3	666.3	720.9
	3% plus CO_2 range	637.0 to 849.0	610.0 to 821.9	664.7 to 876.6

* The results include benefits to consumers which accrue after 2042 from the products purchased from 2013 through 2042. Costs incurred by manufacturers, some of which may be incurred prior to 2013 in preparation for the rule, are indirectly included as part of incremental equipment costs. The Primary, Low Benefits, and High Benefits Estimates utilize forecasts of energy prices from the AEO2010 Reference case, Low Estimate, and High Estimate, respectively
** The CO_2 values represent global monetized values (in 2010$) of the social cost of CO_2 emissions in 2010 under several scenarios. The values of $4.9, $22.3, and $36.5 per ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $67.6 per ton represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_X (in 2010$) is the average of the low and high values used in DOE's analysis.
† Total Benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $22.3/ton in 2010 (in 2010$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2

range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

1.3 OVERVIEW OF ENERGY CONSERVATION STANDARDS FOR BATTERY CHARGERS AND EXTERNAL POWER SUPPLIES

Title III of the Energy Policy and Conservation Act (EPCA) (42 U.S.C. 6291, et seq.) sets forth a variety of provisions designed to improve energy efficiency. Part A of Title III (42 U.S.C. 6291–6309) establishes the "Energy Conservation Program for Consumer Products Other Than Automobiles." The consumer products subject to this program (referred to as "covered products") include battery chargers and EPSs. Section 135 of the Energy Policy Act of 2005 (EPACT 2005), Pub. L. 109-58, amended sections 321 and 325 of EPCA by inserting definitions for battery chargers and EPSs and directing the Secretary of Energy to carry out three activities: (1) establish test procedures, (2) hold a scoping workshop to discuss plans for developing energy conservation standards, and (3) conduct a determination analysis for energy conservation standards for battery chargers and EPSs. (42 U.S.C. 6295(u))

DOE complied with the first of these requirements by publishing the test procedure final rule on December 8, 2006. 71 FR 71340, 71365-75. This rule included definitions and test procedures for battery chargers and EPSs. DOE codified a test procedure for battery chargers in Title 10 of the Code of Federal Regulations (CFR), Part 430, Subpart B, Appendix Y ("Uniform Test Method for Measuring the Energy Consumption of Battery Chargers") and a test procedure for EPSs in 10 CFR Part 430, Subpart B, Appendix Z ("Uniform Test Method for Measuring the Energy Consumption of External Power Supplies").

Complying with the second requirement, DOE then published a NOPM and availability of documentation for public review on December 29, 2006. 71 FR 78389. DOE made two documents available on its website: "Plans for Developing Energy Conservation Standards for Battery Chargers and External Power Supplies" and "The Current and Future Market for Battery Chargers and External Power Supplies." The public meeting, called a "Scoping Workshop," was held at DOE's Forrestal Building in Washington, DC, on January 24, 2007. As EPACT 2005 required, the workshop focused on DOE's plans for developing energy conservation standards for battery chargers and EPSs. Information pertaining to the scoping workshop is available on DOE's website at: www.eere.energy.gov/buildings/appliance_standards/residential/battery_external_det_2006.html.

Regarding the third requirement, the President signed into law the Energy Independence and Security Act of 2007 (EISA 2007), Pub. L. 110-140, on December 19, 2007, amending sections 321, 323, and 325 of EPCA. These amendments required significant changes to the determination analysis DOE had been conducting. Sections 301, 309, and 310 of EISA 2007 made several changes to EPCA related to battery chargers and EPSs.

Section 301 of EISA 2007 amended section 321 of EPCA by modifying definitions concerning EPSs. EPACT 2005 had amended EPCA to define an EPS as “an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product.”[h] (42 U.S.C. 6291(36)(A)) Section 301 of EISA 2007 further amended this definition by creating a subset of EPSs called Class A EPSs. EISA 2007 defined this subset as those EPSs that, in addition to meeting several other requirements common to all EPSs, are “able to convert to only 1 AC or DC output voltage at a time” and have “nameplate output power that is less than or equal to 250 watts.”[i] (42 U.S.C. 6291(36)(C)(i))

Section 301 also amended EPCA to establish minimum standards for Class A EPSs, which became effective on July 1, 2008 (42 U.S.C. 6295(u)(3)(A)), and directed DOE to publish a final rule by July 1, 2011, to determine whether to amend these standards. (42 U.S.C. 6295(u)(3)(D)) Section 301 further directed DOE to issue a final rule that prescribes energy conservation standards for battery chargers or determine that no “standard is technically feasible or economically justified.” (42 U.S.C. 6295(u)(1)(E)(i)(II))

In satisfaction of this requirement, DOE is bundling battery chargers and Class A EPSs together in a single rulemaking proceeding to consider appropriate energy conservation standards for these products. DOE published the “Notice of Public Meeting and Availability of Framework Document for Battery Chargers and External Power Supplies” on June 4, 2009. 74 FR 26816. DOE then held a public meeting to receive comment on the framework document[j] on July 16, 2009 (hereafter referred to as the framework document public meeting). The present preliminary analysis represents the next stage in the rulemaking process.

Section 309 of EISA 2007 further amended section 325(u)(1)(E) of EPCA, instructing DOE to issue no later than two years after EISA 2007's enactment a final rule “that determines whether energy conservation standards shall be issued for external power supplies or classes of external power supplies.” (42 U.S.C. 6295(u)(1)(E)(i)(I)) However, as section 301 of EISA simultaneously set standards for Class A EPSs, DOE interprets sections 301 and 309 jointly as a requirement to determine, no later than December 19, 2009, whether additional energy conservation standards shall be issued for EPSs that are outside the scope of the current Class A standards, *e.g.*, multiple-voltage EPSs. DOE determined that standards are warranted for non-Class A EPSs in a final rule published on May 14, 2010. 75 FR 27170. Standards for non-Class A EPSs are thus being considered within the present rulemaking process.

---

[h] The terms “AC” and “DC” refer to the polarity (*i.e.*, direction) and amplitude of current and voltage associated with electrical power. For example, a household wall socket supplies alternating current (AC), which varies in amplitude and reverses polarity. In contrast, a battery or solar cell supplies direct current (DC), which is constant in both amplitude and polarity.

[i] EISA 2007 defines a Class A EPS as an EPS that converts AC line voltage to only 1 lower AC or DC output, is intended to be used with a separate end-use product, is in a different enclosure from the end-use product, is wired to the end-use product, and has rated output power that is less than 250 watts. (42 U.S.C. 6291(36)(C)(i))

[j] “Energy Conservation Standards Rulemaking for Battery Chargers and External Power Supplies.” May 2009. Available at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/bceps_frameworkdocument.pdf

Finally, section 310 of EISA 2007 amended section 325 of EPCA to establish definitions for active mode, standby mode, and off mode. (42 U.S.C. 6295(gg)(1)(A)) This section also directed DOE to amend its existing test procedures by December 31, 2008, to measure the energy consumed in standby mode and off mode for both battery chargers and EPSs. (42 U.S.C. 6295(gg)(2)(B)(i)) Further, it authorized DOE to amend, by rule, any of the definitions for active, standby, and off mode. (42 U.S.C. 6295(gg)(2)(A)) The Department presented its amendments during a public meeting on September 12, 2008 (hereafter referred to as the standby and off mode test procedure public meeting) and published them in the Test Procedures for Battery Chargers and External Power Supplies (Standby Mode and Off Mode) Final Rule on March 27, 2009. 74 FR 13318.

1.4 PROCESS FOR SETTING ENERGY CONSERVATION STANDARDS

Under EPCA, when DOE studies new or amended standards, it must consider to the greatest extent practicable the following seven factors:

1) the economic impact of the standard on the manufacturers and consumers of the products subject to the standard;

2) the savings in operating costs throughout the estimated average life of the products in the type (or class) compared to any increases in the price, initial charges, or maintenance expense for the products that are likely to result from the imposition of the standard;

3) the total projected amount of energy savings likely to result directly from the imposition of the standard;

4) any lessening of the utility or the performance of the products likely to result from the imposition of the standard;

5) the impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;

6) the need for national energy conservation; and

7) other factors the Secretary considers relevant. (42 U.S.C. 6295(o)(2)(B)(i))

Other statutory requirements are set forth in 42 U.S.C. 6295(o)(1)-(2)(A), (2)(B)(ii)-(iii), and (3)-(4).

DOE considers stakeholder participation to be a very important part of the process for setting energy conservation standards. Through formal public notifications (i.e., Federal Register notices), DOE actively encourages the participation and interaction of all stakeholders during the comment period in each stage of the rulemaking. Beginning with the Framework Document and during subsequent comment periods, interactions among stakeholders provide a balanced discussion of the information that is required for the standards rulemaking.

Before DOE determines whether or not to adopt a proposed energy conservation standard, it must first solicit comments on the proposed standard. (42 U.S.C. 6313(a)(6)(B)(i)) Any new or amended standard must be designed to achieve significant additional conservation of energy and be technologically feasible and economically justified. (42 U.S.C. 6313(a)(6)(A)) To determine whether economic justification exists, DOE must review comments on the proposal and determine that the benefits of the proposed standard exceed its burdens to the greatest extent practicable, weighing the seven factors listed above. (42 U.S.C. 6295 (o)(2)(B)(i))

After the publication of the framework document, the energy conservation standards rulemaking process involves three additional, formal public notices, which DOE publishes in the Federal Register. The first of the rulemaking notices is a NOPM, which is designed to publicly vet the models and tools used in the preliminary rulemaking and to facilitate public participation before the NOPR stage. The second notice is the NOPR, which presents a discussion of comments received in response to the NOPM and the preliminary analyses and analytical tools; analyses of the impacts of potential amended energy conservation standards on consumers, manufacturers, and the Nation; DOE's weighting of these impacts of amended energy conservation standards; and the proposed energy conservation standards for each product. The third notice is the final rule, which presents a discussion of the comments received in response to the NOPR; the revised analyses; DOE's weighting of these impacts; the amended energy conservation standards DOE is adopting for each product; and the effective dates of the amended energy conservation standards.

In June 2009, DOE published a notice of public meeting and availability of the framework document. 74 FR 26816 (June 4, 2009). The framework document, *Energy Conservation Standard Rulemaking Framework for Battery Chargers and External Power Supplies*, describes the procedural and analytical approaches DOE anticipated using to evaluate the establishment of amended energy conservation standards for these products. This document is available at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/bceps_frameworkdocument.pdf

Subsequently, DOE held a public meeting on July 16, 2009, to discuss procedural and analytical approaches to the rulemaking. In addition, DOE used the public meeting to inform and facilitate involvement of interested parties in the rulemaking process. The analytical framework presented at the public meeting described the different analyses, such as the engineering analysis and the consumer economic analyses (i.e., the life-cycle cost (LCC) and payback period (PBB) analyses), the methods proposed for conducting them, and the relationships among the various analyses.

During the July 2009 public meeting, interested parties commented about numerous issues relating to each one of the analyses listed in Table 1-4. Comments from interested parties submitted during the framework document comment period elaborated on the issues raised during the public meeting. DOE attempted to address these issues during its preliminary analyses and summarized the comments and DOE's responses in chapter 2 of the preliminary TSD.

Table 1-3 Analyses Under the Process Rule

Preliminary Analyses	NOPR	Final Rule
Market and technology assessment	Revised preliminary analyses	Revised analyses
Screening analysis	Consumer sub-group analysis	
Engineering analysis	Manufacturer impact analysis	
Energy use analysis	Employment impact analysis	
Markups analysis	Utility impact analysis	
Life-cycle cost and payback period analysis	Emissions Analysis	
Shipments analysis	Monetization of Emission Reductions Benefits	
National impact analysis	Regulatory impact analysis	
Preliminary manufacturer impact analysis		

As part of the information gathering and sharing process, DOE organized and held interviews with manufacturers of the battery chargers and external power supplies considered in this rulemaking as part of the engineering analysis. DOE selected companies that represented production of all types of products, ranging from small to large manufacturers, and included the Association of Home Appliance Manufacturers (AHAM) member companies. DOE had four objectives for these interviews: (1) solicit manufacturer feedback on the draft inputs to the engineering analysis; (2) solicit feedback on topics related to the preliminary manufacturer impact analysis; (3) provide an opportunity, early in the rulemaking process, to express manufacturers' concerns to DOE; and (4) foster cooperation between manufacturers and DOE.

DOE incorporated the information gathered during the engineering interviews with manufacturers into its engineering analysis (Chapter 5) and the preliminary manufacturer impact analysis (Chapter 12). Following the publication of the preliminary analyses and the preliminary public meeting, DOE held additional meetings with manufacturers as part of the consultative process for the manufacturer impact analysis conducted during the NOPR phase of the rulemaking.

DOE developed spreadsheets for the engineering, LCC, PBP, and national impact analyses for each product. DOE developed an LCC spreadsheet that calculates the LCC and PBP at various energy efficiency levels. DOE also developed a national impact analysis spreadsheet that calculates the national energy savings (NES) and national net present values (NPVs) at various energy efficiency levels. All of these spreadsheets are available on the DOE website for battery chargers and external power supplies (http://www1.eere.energy.gov/buildings/appliance_standards/residential/battery_external_std_2008.html).

1.5 STRUCTURE OF THE DOCUMENT

This TSD describes the analytical approaches and data sources used in this rulemaking. The TSD consists of the following chapters, and a number of appendices.

Chapter 1	Introduction: provides an overview of the appliance and equipment standards program and how it applies to the battery chargers and external power supplies, and outlines the structure of the document.
Chapter 2	Analytical Framework: describes the rulemaking process step by step and summarizes the major components of DOE's analysis.
Chapter 3	Market and Technology Assessment: characterizes the battery chargers and external power supplies market and the technologies available for increasing equipment efficiency.
Chapter 4	Screening Analysis: determines which technology options are viable for consideration in the engineering analysis.
Chapter 5	Engineering Analysis: discusses the methods used for developing the relationship between increased manufacturer price and increased efficiency.
Chapter 6	Markups Analysis: discusses the methods used for establishing markups for converting manufacturer prices to customer product prices.
Chapter 7	Energy Use Analysis: discusses the process used for generating energy-use estimates of battery chargers an external power supplies for a variety of product classes, climate locations, and standard levels.
Chapter 8	Life-Cycle Cost and Payback Period Analyses: discusses the economic effects of standards on individual consumers of the products and compares the LCC and PBP of products with and without higher efficiency standards.
Chapter 9	Shipments Analysis: discusses the methods used for forecasting shipments with and without higher efficiency standards.
Chapter 10	National Impact Analysis: discusses the methods used for forecasting national energy consumption and national economic impacts based on annual product shipments and estimates of future product efficiency distributions in the absence and presence of higher efficiency standards.
Chapter 11	Consumer Sub-Group Analysis: discusses the effects of standards on subgroups of battery chargers and external power supplies customers and compares the LCC and PBP of products with and without higher efficiency standards for these customers.

Chapter 12	Manufacturer Impact Analysis: discusses the effects of standards on the finances and profitability of product manufacturers.
Chapter 13	Employment Impact Analysis: discusses the effects of standards on the installed generation capacity of electric utilities.
Chapter 14	Utility Impact Analysis: discusses the effects of standards on National employment.
Chapter 15	Emissions Analysis: discusses the effects of standards on air-borne emissions of electric utilities.
Chapter 16	Monetization of Emission Reductions Benefits: discusses the monetization of reductions in CO_2 and NO_X emissions.
Chapter 17	Regulatory Impact Analysis: discusses the present regulatory actions as well as the impact of non-regulatory alternatives to setting energy efficiency standards.
Appendix 3-A	BCEPS Applications
Appendix 3-A	BCEPS Efficiency Programs
Appendix 3-C	Evaluation Methods Identifying External Power Supplies that can Directly Power an Application
Appendix 3-D	End-Use Application Product Class Assignments
Appendix 5-A	EPS Test data
Appendix 5-B	BC Test data
Appendix 5-C	Bill of Materials
Appendix 7-A	BCEPS Usage Profiles
Appendix 8-A	User Instructions for LCC and PBP Spreadsheets
Appendix 8-B	Supplementary LCC and PBP Results
Appendix 8-C	End-Use Application Inputs for the LCC
Appendix 8-D	Residential Discount Rate Distributions
Appendix 9-A	Shipments Sensitivity Analysis
Appendix 10-A	NES and NPV Under Alternative Scenarios

Appendix 10-B NIA Sensitivity Analysis for Alternative Product Price Trend Scenarios

Appendix 12-A Manufacturer Impact Analysis Interview Guide

Appendix 12-B Industry Net Present Value Results for Price Elastic Shipment Sensitivity Scenario

Appendix 12-C Government Regulatory Impact Model (GRIM) Overview

Appendix 12-D Industry Net Present Value Results for the Alternative California Base Case Sensitivity Scenario

Appendix 16-A Social Cost of Carbon

Appendix 17-A Regulatory Impact Analysis: Supporting Materials

CHAPTER 2. ANALYTICAL FRAMEWORK

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6295(o)(2)(A) of 42 United States Code (U.S.C.) requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that are technologically feasible and economically justified, and would achieve the maximum improvement in energy efficiency. This chapter provides a description of the general analytical framework that DOE uses in developing such standards. The analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost (LCC), economic impact on manufacturers and users, national benefits, impacts, if any, on utility companies, and impacts, if any, from lessening competition among manufacturers.

Figure 2.1.1summarizes the stages and analytical components of the rulemaking process. The focus of this figure is the center column, which lists the analyses that DOE conducts. The figure shows how the analyses fit into the rulemaking process, and how they relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from stakeholders or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Arrows connecting analyses show types of information that feed from one analysis to another.

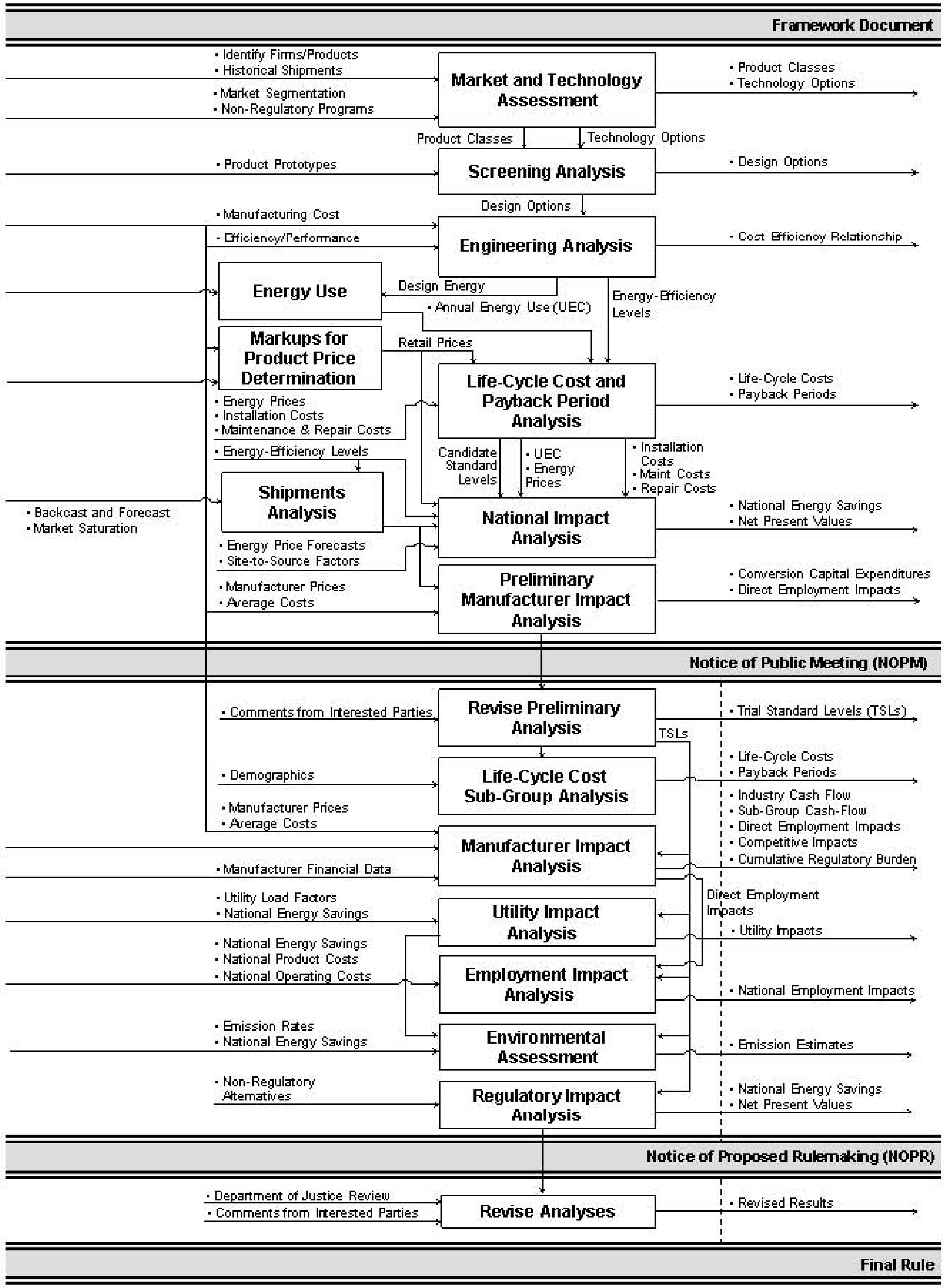


Figure 2.1.1 Flow Diagram of Analyses for the Energy Conservation Standards Rulemaking Analysis Process

The analyses performed prior to the notice of proposed rulemaking (NOPR) stage as part of the preliminary analyses and described in the preliminary technical support document (TSD) are listed below. These analyses were revised for the NOPR based in part on comments received, and are reported in this NOPR TSD. The analyses will be revised once again for the final rule based on any new comments or data received in response to the NOPR.

- A market and technology assessment to characterize the relevant product markets and existing technology options, including prototype designs.
- A screening analysis to review each technology option and determine if it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.
- An engineering analysis to develop cost-efficiency relationships that show the manufacturer's cost of achieving increased efficiency.
- An energy use analysis to determine the annual energy use in the field of the considered products as a function of efficiency level.
- An LCC and payback period (PBP) analysis to calculate, at the consumer level, the relationship between savings in operating costs compared to any increase in the installed cost for products at higher efficiency levels.
- A shipments analysis to forecast product shipments, which then are used to calculate the national impacts of standards and future manufacturer cash flows.
- A national impact analysis (NIA) to assess the impacts at the national level of potential energy conservation standards for each of the considered products, as measured by the net present value (NPV) of total consumer economic impacts and the national energy savings (NES).
- A preliminary manufacturer impact analysis to assess the potential impacts of energy conservation standards on manufacturers, such as impacts on capital conversion expenditures, marketing costs, shipments, and research and development costs.

The additional analyses DOE performed for the NOPR stage of the rulemaking analysis include those listed below. DOE further revises the analyses for the final rule based on comments received in response to the NOPR.

- A consumer subgroup analysis to evaluate impacts of standards on particular consumer sub-populations, such as low-income households.

- A manufacturer impact analysis to estimate the financial impact of standards on manufacturers and to calculate impacts on competition, employment, and manufacturing capacity.

- An employment impact analysis to assess the indirect impacts of energy conservation standards on national employment.

- A utility impact analysis to estimate the effects of energy conservation standards on installed electricity generation capacity and electricity generation.

- An emissions analysis to provide estimates of the effects of energy conservation standards on emissions of carbon dioxide (CO_2), nitrogen oxides (NOx), and mercury (Hg) and to evaluate the monetary benefits likely to result from the reduced emissions of CO_2 and NO_x.

- A regulatory impact analysis to assess alternatives to energy conservation standards that could achieve substantially the same regulatory goal.

2.2 BACKGROUND

DOE developed this analytical framework and documented it in the Energy Conservation Standards Rulemaking Framework Document for Battery Chargers and External Power Supplies (the framework document). DOE presented the analytical approach to interested parties during a public meeting held on July 16, 2009. The framework document is available at http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/bceps_frameworkdocument.pdf. At the meeting and during the related comment period, DOE received many comments that helped it identify and resolve issues involved in this rulemaking.

DOE then gathered additional information and performed preliminary analyses to help develop the potential energy conservation standards for battery chargers (BCs) and external power supplies (EPSs). This process culminated in DOE's announcement of a preliminary analysis public meeting to discuss and receive comments on the following matters: The product classes DOE analyzed; the analytical framework, models, and tools that DOE was using to evaluate standards; the results of the preliminary analyses performed by DOE; and potential standard levels that DOE could consider. 75 FR 56021 (September 15, 2010). DOE also invited written comments on these subjects and announced the availability on its website of a preliminary technical support document (preliminary TSD) it had prepared to inform interested parties and enable them to provide comments. Id. The preliminary TSD is available at http://www1.eere.energy.gov/buildings/appliance_standards/residential/battery_external_preliminaryanalysis_tsd.html.

The preliminary analysis public meeting announced in the September 2010 notice took place on October 13, 2010. At this meeting, DOE presented the methodologies and results of the analyses set forth in the preliminary TSD. DOE also discussed plans for conducting the NOPR analyses. The comments received since publication of the September 2010 notice, including those received at the preliminary analysis public meeting, have contributed to DOE's proposed resolution of the issues in this rulemaking and the analysis conducted in support of the NOPR.

The following sections provide a general description of the different analytical components of the rulemaking analytical plan. DOE has used the most reliable data available at the time of each analysis in this rulemaking. DOE has also considered submissions of additional data from interested parties during the rulemaking process.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the products concerned. This activity assesses the industry and products both quantitatively and qualitatively based on publicly available information and encompasses the following: (1) manufacturer market share and characteristics, (2) existing regulatory and non-regulatory equipment efficiency improvement initiatives, and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

DOE reviewed existing literature and interviewed manufacturers to get an overall picture of the industry serving the United States market. Industry publications and trade journals, government agencies, trade organizations, and product literature provided the bulk of the information, including: (1) manufacturers and their approximate market shares, (2) product characteristics, and (3) industry trends. The appropriate sections of the NOPR describe the analysis and resulting information leading up to the proposed trial standard levels, while supporting documentation is provided in the TSD.

DOE categorizes covered products into separate product classes and formulates a separate energy conservation standard for each product class. The criteria for separation into different classes are type of energy used, capacity, and other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295(q) and 6316(a))

The market and technology assessment also addresses applicable test procedures. DOE initiated a test procedure rulemaking for BCs and EPSs and published a test procedure final rule on June 1, 2011. 76 FR 31750. These test procedures are discussed in chapter 3 of the TSD.

As part of the market and technology assessment, DOE developed a list of technologies for consideration for improving the efficiency of BCs and EPSs. DOE typically uses information about existing and past technology options and prototype designs to determine which technologies manufacturers use to attain higher performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those DOE believes are technologically feasible.

DOE developed its list of technologically feasible design options for BCs and EPSs from trade publications, technical papers, research conducted in support of previous rulemakings concerning these products, and through consultation with manufacturers of components and systems. Since many options for improving product efficiency are available in existing products, product literature and direct examination provided additional information. Chapter 3 of the TSD includes the detailed list of all technology options identified.

2.4 SCREENING ANALYSIS

After DOE identified the technologies that could potentially improve the energy efficiency of BCs and EPSs, DOE conducted the screening analysis. The purpose of the screening analysis is to evaluate these technologies to determine which options to consider further and which options to screen out.

The screening analysis examines whether various technologies (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. In consultation with interested parties, DOE reviews the list to determine if the technologies described in chapter 3 of the TSD are practicable to manufacture, install, and service; would adversely affect product utility or availability; or would have adverse impacts on health and safety. In the engineering analysis, DOE further considers the efficiency enhancement options (i.e., technologies) that it did not screen out in the screening analysis. Chapter 4 of the TSD contains further detail on the criteria that DOE uses.

2.5 ENGINEERING ANALYSIS

The engineering analysis establishes the relationship between the manufacturing production cost and the efficiency of BCs and EPSs. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the Nation. Chapter 5 discusses product classes DOE analyzed, the representative baseline units, the efficiency levels analyzed, the methodology DOE used to develop the manufacturing production costs, and the cost-efficiency curves.

In the engineering analysis, DOE evaluates a range of product efficiency levels and their associated manufacturing costs. The purpose of the analysis is to estimate the incremental manufacturer selling prices (MSPs) for a product that would result from increasing efficiency levels above the level of the baseline model in each product class. The engineering analysis considers technologies not eliminated in the screening analysis. The LCC analysis and NIA use the cost-efficiency relationships developed in the engineering analysis.

DOE typically structures its engineering analysis around one of three methodologies: (1) the design-option approach, which calculates the incremental costs of adding specific design options to a baseline model; (2) the efficiency-level approach, which calculates the relative costs of achieving increases in energy efficiency levels without regard to the particular design options used to achieve such increases; and/or (3) the reverse-engineering or cost-assessment approach, which involves a “bottom-up” manufacturing cost assessment based on a detailed bill of materials derived from teardowns of the product being analyzed.

For the NOPR analysis, DOE primarily used the reverse-engineering or cost-assessment approach to develop its relationships for cost and efficiency for EPSs and BCs. DOE developed a manufacturing cost model for BCs and EPSs based on reverse engineering of purchased products. DOE estimated costs for these efficiency improvements based on the manufacturing cost model, information from component vendors, and information obtained through discussions with manufacturers. Chapter 5 of the TSD describes the methodology that DOE used to perform the efficiency level analysis and derive the cost-efficiency relationship.

2.6 MARKUPS TO DETERMINE PRODUCT PRICE

DOE uses markups to convert the manufacturer selling prices estimated in the engineering analysis to consumer prices, which then were used in the LCC, PBP, national impact, and manufacturer impact analyses. DOE calculates a separate markup for the baseline component of a product’s cost (baseline markup) and for the incremental increase in cost due to standards (incremental markup).

To develop markups, DOE identifies how the products are distributed from the manufacturer to the customer. After establishing appropriate distribution channels, DOE used data from the financial filings of manufacturers and distributors and other sources to determine how prices are marked up as the products pass from the manufacturer to the end consumer. See chapter 6 of the TSD for details on the development of markups.

2.7 ENERGY USE ANALYSIS

The energy use analysis, which assesses the energy savings potential from higher efficiency levels, provides the basis for the energy savings values used in the LCC and subsequent analyses. The goal of the energy use analysis is to generate a range of energy use values that reflects actual product use in American homes. The analysis uses information on use of actual products in the field to estimate the energy that would be used by new products at various efficiency levels. Chapter 7 of the TSD provides more detail about DOE's approach for characterizing energy use of BCs and EPSs.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

New or amended energy conservation standards affect products' operating expenses—usually decreasing them—and consumer prices for the products—usually increasing them. DOE analyzed the net effect of standards on consumers by evaluating the net change in LCC. To evaluate the net change in LCC, DOE used the cost-efficiency relationship derived in the engineering analysis along with the energy costs derived from the energy use analysis. Inputs to the LCC calculation include the installed cost of a product to the consumer (consumer purchase price plus installation cost), operating expenses (energy expenses and maintenance costs), the lifetime of the unit, and a discount rate. These inputs are described in detail in chapter 8 of the TSD.

Because the installed cost of a product typically increases while operating cost typically decreases in response to new standards, there is a time in the life of products having higher-than-baseline efficiency when the operating-cost benefit (in dollars) since the time of purchase is equal to the incremental first cost of purchasing the higher-efficiency product. The length of time required for products to reach this cost-equivalence point is known as the payback period (PBP).

Recognizing that several inputs used to determine consumer LCC and PBP are either variable or uncertain, DOE conducted the LCC and PBP analyses by modeling both the uncertainty and variability in the inputs using Monte Carlo simulation and probability distributions. DOE developed an LCC and PBP spreadsheet model that incorporates both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in program.

For BCs and EPSs, it was necessary to determine the input values for a wide array of end-use applications that are powered by BCs or EPSs. There are typically multiple applications associated with each representative unit and product class that DOE analyzed. As such, DOE considered a wide array of input values for each unit analyzed. The lifetime, markups, maintenance costs, base case market efficiency distribution, and unit energy consumption all vary based on the application. DOE also determined input values that vary across the population of consumers, but not across the specific applications. These include electricity prices, discount rates, and sales tax. Lastly, DOE assumed that installation costs were zero for all BCs and EPSs. Further detail on these inputs and the LCC calculation can be found in chapter 8 of the TSD.

Because BCs and EPSs are used in both residential and commercial settings, DOE used separate discount rates for residential and commercial consumers. For residential consumers, DOE developed discount rates from estimates of the interest rate or “finance cost” to purchase and operate residential products. Following accepted principles of financial theory, the finance cost of raising funds to purchase such products can be interpreted as: (1) the financial cost of any debt incurred to purchase and operate products, principally interest charges on debt; or (2) the opportunity cost of any equity used to purchase products, principally interest earnings on household equity. Household equity is represented by holdings in assets such as stocks and bonds, as well as the return on homeowner equity. DOE obtained much of the data required to determine the cost of debt and equity from the Federal Reserve Board’s triennial *Survey of Consumer Finances*.

For commercial customers, DOE developed discount rates by estimating the cost of capital to companies that purchase BCs or EPSs. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so the cost of capital is the weighted-average cost of equity and debt financing. This corporate finance approach is referred to as the weighted-average cost of capital (WACC).

The LCC and PBP analyses are described in more detail in chapter 8 of the TSD.

2.9 SHIPMENTS ANALYSIS

Forecasts of product shipments are needed to calculate the potential effects of standards on national energy use, NPV, and future manufacturer cash flows. DOE generated both shipments and efficiency forecasts for each product class. The shipments forecast calculates the total number of BCs and EPSs shipped each year over a 30 year period, beginning in 2013 and ending in 2042. To create this forecast, DOE combined current year shipments, discussed in the market assessment (chapter 3), with a compound annual growth rate for BCs and EPSs and generated unit shipment values through the analysis period. The efficiency forecast shows the distribution of shipments of BCs and EPSs by candidate standard level (CSL), which determines the percentage of shipments affected by a standard. To develop its efficiency forecast, DOE first assessed present-day (2009) efficiency and then considered how the efficiency of new units might change by the first year of the analysis period (2013) and throughout the analysis period in the absence of new or amended Federal standards.

Chapter 9 of the TSD provides additional details on the shipments analysis.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis estimates energy savings and assesses the NPV of consumer LCC savings at the national scale. The results can be used to identify the CSL that, for a given product class, yields the greatest energy savings while remaining cost effective from a consumer perspective. DOE estimated both NES and NPV for all candidate standard levels for each BC and EPS product class. To make the analysis more accessible and transparent to all interested parties, it is documented in a Microsoft Excel spreadsheet model that can be downloaded from the EERE website.

The NIA considers total installed cost (which includes manufacturer selling prices, distribution chain markups, sales taxes, and installation costs), operating expenses (energy, repair, and maintenance costs), product lifetime, and discount rate. However, where the LCC considers the savings and costs associated with standards for a set of representative units, the NIA considers the savings and costs associated with all units affected by standards during the entire analysis period. Chapter 10 provides additional details regarding the NIA.

2.10.1 National Energy Savings Analysis

The major inputs for determining the NES for each product analyzed are annual unit energy consumption, shipments, lifetimes, and site-to-source conversion factors. DOE calculated national energy consumption for each year by multiplying unit energy consumption by the number of units in the installed base in that year. NES for a given year, then, is the difference in national energy consumption between the base case (without new efficiency standards) and each standards case. DOE estimated energy consumption and savings first in terms of site energy and then converted the savings into source energy. Cumulative energy savings are the sum of the NES estimates for each year.

2.10.2 Net Present Value Analysis

The inputs for determining net present value (NPV) of consumer benefits are: (1) total annual installed cost; (2) total annual savings in operating costs; (3) a discount factor; (4) present value of costs; and (5) present value of savings. DOE calculated net savings each year as the difference between the base case and each standards case in total savings in operating costs and total increases in installed costs. DOE calculated savings over the life of each product, accounting for differences in yearly electricity rates. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of total installed costs. DOE used a discount factor based on real discount rates of 3% and 7% to discount future costs and savings to present values.

DOE calculated increases in total installed costs as the difference in total installed cost between the base case and standards case (*i.e.*, once the standards take effect). Because the more efficient products bought in the standards case usually cost more than products bought in the base case, cost increases appear as negative values in the NPV.

DOE expressed savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

2.11 CONSUMER SUBGROUP ANALYSIS

The consumer subgroup analysis evaluates economic impacts on selected groups of consumers who might be adversely affected by a change in the national energy conservation standards for the considered products. DOE performed LCC subgroup analyses for low-income consumers, small businesses, top-tier marginal electricity price consumers, and consumers of specific applications. DOE evaluated the potential LCC impacts and PBPs for these consumers using the LCC spreadsheet model. Chapter 11 of the TSD provides more detail.

2.12 MANUFACTURER IMPACT ANALYSIS

DOE performed a manufacturer impact analysis (MIA) to estimate the financial impact of energy conservation standards on manufacturers of BCs and EPSs, and to calculate the impact of such standards on employment and manufacturing capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA relies on the government regulatory impact model (GRIM), an industry-cash-flow model customized for this rulemaking. The GRIM inputs are information regarding the industry cost structure, shipments, and revenues. This includes information from many of the analyses described above, such as manufacturing costs and prices from the engineering analysis and shipments forecasts. The key GRIM output is the industry net present value (INPV). Different sets of assumptions (scenarios) will produce different results. The qualitative part of the MIA addresses factors such as product characteristics, characteristics of particular firms, and market and product trends, and includes assessment of the impacts of standards on subgroups of manufacturers. The complete MIA is described in chapter 12 of the TSD.

DOE conducted each MIA in this rulemaking in three phases. In Phase I, DOE created an industry profile to characterize the industry and identify important issues that require consideration. In Phase II, DOE prepared an industry cash-flow model and an interview questionnaire to guide subsequent discussions. In Phase III, DOE interviewed manufacturers and assessed the impacts of standards both quantitatively and qualitatively. DOE assessed industry and subgroup cash flow and NPV using the GRIM. DOE then assessed impacts on competition, manufacturing capacity, employment, and regulatory burden based on manufacturer interview feedback and discussions.

2.13 EMPLOYMENT IMPACT ANALYSIS

The imposition of standards can affect employment both directly and indirectly. Direct employment impacts are changes, produced by new standards, in the number of employees at plants that produce the covered products. DOE evaluated direct employment impacts in the manufacturer impact analysis. Indirect employment impacts that occur because of the imposition of standards may result from consumers shifting expenditures between goods (the substitution effect) and from changes in income and overall expenditure levels (the income effect). DOE utilizes Pacific Northwest National Laboratory's ImSET model to investigate the combined direct and indirect employment impacts. The ImSET model, which was developed for DOE's Office of Planning, Budget, and Analysis, estimates the employment and income effects energy-saving technologies produced in buildings, industry, and transportation. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments. Further detail is provided in chapter 13 of the TSD.

2.14 UTILITY IMPACT ANALYSIS

The utility impact analysis includes an analysis of selected effects of new energy conservation standards on the electric and the gas utility industries. For this analysis, DOE adapted National Energy Modeling System (NEMS), a large multi-sectoral, partial-equilibrium model of the U.S. energy sector that the EIA developed throughout the past decade primarily for preparing EIA's AEO. In previous rulemakings, a variant of NEMS (currently termed NEMS-BT, BT referring to DOE's Building Technologies Program) was developed to address the specific impacts of an energy conservation standard.

Available in the public domain, NEMS produces a widely recognized baseline energy forecast for the United States through 2030. The typical NEMS outputs include forecasts of electricity sales, prices, and electric generating capacity. DOE conducts the utility impact analysis as a scenario that departs from the latest AEO reference case. In other words, the energy savings impacts from energy conservation standards are modeled using NEMS-BT to generate forecasts that deviate from the AEO reference case.

As part of the utility impact analysis, DOE analyzed the potential impact on electricity prices resulting from standards on BCs and EPSs and the associated benefits for all electricity users in all sectors of the economy. Further detail is provided in chapter 14 of the TSD.

2.15 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), and mercury (Hg) using the NEMS-BT computer model. In the emissions analysis, NEMS-BT is run similarly to the AEO NEMS, except that battery chargers and external power supplies energy use is reduced by the amount of energy saved (by fuel type) due to each considered standard level. The inputs of national energy savings come from the NIA spreadsheet model, while the output is the forecasted physical emissions. The net benefit of each considered standard level is the difference between the forecasted emissions estimated by NEMS-BT at that level and the AEO 2010 Reference Case.

2.15.1 Carbon Dioxide

In the absence of any Federal emissions control regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emission reductions likely to result from a standard will be estimated using NEMS-BT and national energy savings estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* Reference Case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results with broad coverage of all sectors and inclusion of interactive effects.

2.15.2 Sulfur Dioxide

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs, and DOE has preliminarily determined that these programs create uncertainty about the potential standards' impact on SO_2 emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). SO_2 emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR, 70 Fed. Reg. 25162 (May 12, 2005)), which created an allowance-based trading program. Although CAIR has been remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008), it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule. 76 FR 48208 (August 8, 2011). (See http://www.epa.gov/crossstaterule/). On December 30, 2011, however, the D.C. Circuit stayed the new rules while a panel of judges reviews them, and told EPA to continue enforcing CAIR (see *EME Homer City Generation v. EPA*, No. 11-1302, Order at *2 (D.C. Cir. Dec. 30, 2011)).

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-

BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.

2.15.3 Nitrogen Oxides

Under CAIR, there is a cap on NO_X emissions in 28 eastern states and the District of Columbia. All these States and D.C. have elected to reduce their NO_X emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards for battery chargers and external power supplies may have little or no physical effect on these emissions in the 28 eastern states and the D.C. for the same reasons that they may have little or no physical effect on NO_X emissions. DOE is using the NEMS-BT to estimate NO_X emissions reductions from possible standards in the States where emissions are not capped.

2.15.4 Mercury

In the absence of caps, a DOE energy conservation standard could reduce Hg emissions and DOE used NEMS-BT to estimate these emission reductions. Although at present there are no national, Federally binding regulations for mercury from EGUs, on March 16, 2011, EPA proposed national emissions standards for hazardous air pollutants (NESHAPs) for mercury and certain other pollutants emitted from coal and oil-fired EGUs. (http://epa.gov/mats/pdfs/20111216MATSfinal.pdf)The NESHAPs do not include a trading program and, as such, DOE's energy conservation standards would likely reduce Hg emissions. For the emissions analysis for this rulemaking, DOE estimated mercury emissions reductions using NEMS-BT based on *AEO2010*, which does not incorporate the NESHAPs. DOE expects that future versions of the NEMS-BT model will reflect the implementation of the NESHAPs.

2.15.5 Particulate Matter

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_X. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_X, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the standards would impact either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described previously, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2, which are now largely regulated by cap and trade systems.

2.16 MONETIZATION OF EMISSIONS REDUCTIONS

DOE plans to consider the estimated monetary benefits likely to result from the reduced emissions of CO_2 and NO_X that are expected to result from each of the standard levels considered.

In order to estimate the monetary value of benefits resulting from reduced emissions of CO_2 emissions, DOE used in its analysis the most current Social Cost of Carbon (SCC) values developed and/or agreed to by interagency reviews. The SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But with full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

At the time of this notice, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010 were \$4.7, \$21.4, \$35.1, and \$64.9 per metric ton in 2007 dollars. These values are then adjusted to 2010\$ using the appropriate standard GDP deflator values. For emissions reductions that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE will give preference to consideration of the global benefits of reducing CO_2 emissions. See appendix 16A of this TSD for the full range of annual SCC estimates from 2010 to 2050. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHG to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also estimates the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. For NO_X emissions, available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from \$370 per ton to \$3,800 per ton of NO_X from stationary sources, measured in 2001\$ (equivalent to a range of \$450 to \$4,623 per ton in 2010$).[a] In accordance with U.S. Office of Management and Budget (OMB) guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[b]

DOE did not monetize estimates of Hg reduction in this rulemaking. DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings. Further detail is provided in chapter16 of the TSD.

2.17 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE prepared a regulatory impact analysis (RIA) pursuant to Executive Order 12866, Regulatory Planning and Review, 58 FR 51735, October 4, 1993, which is subject to review by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA addresses the potential for non-regulatory approaches to supplant or augment energy conservation standards in order to improve the energy efficiency or reduce the energy consumption of the products covered under this rulemaking.

DOE recognizes that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE bases its assessment on the actual impacts of any such initiatives to date, but also considers information presented by interested parties regarding the impacts existing initiatives might have in the future. Further detail is provided in chapter 17 of the TSD.

---

[a] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, 2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities, Washington, DC.

[b] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 DEFINITIONS

All battery chargers and external power supplies, as defined below, are covered products and are within the scope of DOE's rulemaking activities.

3.1.1 Current Definitions

The definitions in this section were created by public laws passed by Congress and can be found in the United States Code.

The term "**battery charger"** means a device that charges batteries for consumer products, including battery chargers embedded in other consumer products. (42 U.S.C. 6291(32))

The term "**external power supply"** means an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product. (42 U.S.C. 6291(36)(A))

In general.– The term **"class A external power supply"** means a device that–

I. is designed to convert line voltage AC input into lower voltage AC or DC output;
II. is able to convert to only 1 AC or DC output voltage at a time;
III. is sold with, or intended to be used with, a separate end-use product that constitutes the primary load;
IV. is contained in a separate physical enclosure from the end-use product;
V. is connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring; and
VI. has nameplate output power that is less than or equal to 250 watts.

Exclusions.– The term "class A external power supply" does not include any device that–

I. requires Federal Food and Drug Administration listing and approval as a medical device in accordance with section 360c of title 21; or
II. powers the charger of a detachable battery pack or charges the battery of a product that is fully or primarily motor operated. (42 U.S.C. 6291(36)(C))

The term "**detachable battery"** means a battery that is–

A. contained in a separate enclosure from the product; and
B. intended to be removed or disconnected from the product for recharging. (42 U.S.C. 6291(52))

The term "**consumer product"** means any article (other than an automobile, as defined in section 32901 (a)(3) of title 49) of a type–

A. which in operation consumes, or is designed to consume, energy or water with respect to showerheads, faucets, water closets, and urinals; and

B. which, to any significant extent, is distributed in commerce for personal use or consumption by individuals;

without regard to whether such article of such type is in fact distributed in commerce for personal use or consumption by an individual, except that such term includes fluorescent lamp ballasts, general service fluorescent lamps, incandescent reflector lamps, showerheads, faucets, water closets, and urinals distributed in commerce for personal or commercial use or consumption. (42 U.S.C. 6291(1))

Except as provided in 49 U.S.C. 32908, "**automobile"** means a 4-wheeled vehicle that is propelled by fuel, or by alternative fuel[a], manufactured primarily for use on public streets, roads, and highways and rated at less than 10,000 pounds gross vehicle weight, except–

A. a vehicle operated only on a rail line;
B. a vehicle manufactured in different stages by 2 or more manufacturers, if no intermediate or final-stage manufacturer of that vehicle manufactures more than 10,000 multi-stage vehicles per year; or
C. a work truck. (49 U.S.C. 32901(a)(3))

3.1.2 Proposed Definitions

DOE proposes to add the definitions in this section to section 430.2 of Title 10 of the Code of Federal Regulations.

"AC-AC external power supply" means an external power supply that is used to convert household electric current into a single lower-voltage AC current.

"AC-DC external power supply" means an external power supply that is used to convert household electric current into a single DC current.

"**Basic voltage external power supply"** means an external power supply that is not a low voltage power supply.

"**Direct operation external power supply"** means an external power supply that can operate a consumer product that is not a battery charger without the assistance of a battery.

"**Indirect operation external power supply"** means an external power supply that is not a direct operation external power supply.

"**Low voltage external power supply"** means an external power supply with a nameplate output voltage is less than 6 volts and nameplate output current greater than or equal to 550 milliamps.

"**Multiple voltage external power supply"** means an external power supply that is used to convert household electric current into multiple simultaneous output currents.

---

[a] The term “alternative fuel” includes electricity. (49 U.S.C. 32901(a)(1)(J))

3.2 MARKET ASSESSMENT

3.2.1 Applications that Use BCs and EPSs

To characterize the market for BCs and EPSs, DOE gathered information on the products that use them. DOE refers to these products as end-use consumer products or BC and EPS "applications." This method was chosen for two reasons. First, the demand for applications drives the demand for BCs and EPSs because BCs and EPSs are nearly always integrated into, bundled with, or otherwise intended to be used with a given application. Second, because most BCs and EPSs are not stand-alone products, their usage profiles, energy consumption, and power requirements are all determined by the associated application. Therefore, to develop reliable estimates of the real-world unit energy consumption of a BC or EPS, it is necessary to examine the application.

To best characterize the markets for BCs and EPSs, DOE analyzed online and brick-and-mortar retail outlets to determine which applications use BCs and EPSs and which BC and EPS technologies are most prevalent. DOE focused its search on those applications likely to have the greatest significance in the standards analyses (based on shipments, lifetimes, and energy use). The survey consisted of the following steps:

1. Identified all applications that use BCs and Class A EPSs
2. Visited websites and retail outlets to identify popular models and document BC and EPS characteristics.
3. Estimated annual shipments, lifetimes, and energy consumption for those applications.

DOE then used this survey to select representative units and common BCs and EPSs to be tested. This process is described in chapter 5. The results of this product survey are presented in the Excel file BCEPS_Master_Survey.xls.

DOE has identified four major trends that can affect shipments of BCs and EPSs over time. These trends are all related to the consumer products powered by BCs and EPSs.

- *Demand for Consumer Product Applications* refers to the changes in preferences, level of affluence, and population size that affect the demand for existing consumer product applications that use BCs or EPSs.

- *Convergence* means the application that uses an EPS is made redundant by another application. For example, mobile telephones increasingly incorporate the features of personal digital assistants (PDAs), digital cameras, portable media players, and portable navigation devices. As a result of convergence, some consumers may now have fewer devices than in the past, thus reducing the demand for BCs or EPSs.

- *Emergence* refers to the creation of new consumer product application categories—a critical factor, given the rapid pace of change in the consumer electronics market.

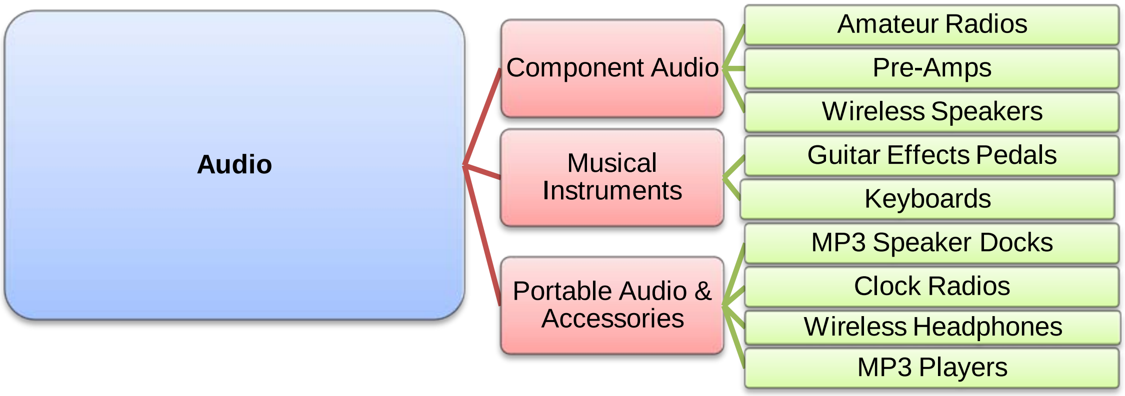
- *Substitution* means a shift between methods for supplying power to consumer products—internal power supplies, external power supplies, primary batteries, rechargeable batteries, Universal Serial Bus (USB) systems, and others.

DOE identified approximately eighty applications that use BCs and EPSs. Although there are certainly some BC and EPS applications that DOE did not consider, DOE believes it has captured the majority of BC and EPS shipments for use with consumer products. Because DOE's scope does not include BCs and EPSs used only in a commercial setting, DOE did not estimate shipments of BCs and EPSs used exclusively with commercial products. DOE did, however, estimate the percentage of shipments of certain consumer products that are used in a commercial setting. For example, notebook computers are frequently purchased by consumers for use in the home, but they are also widely used in office buildings and other commercial environments. In the following sections, the base year (2009) commercial and residential shipments of all applications analyzed are presented.

For ease of exposition, DOE grouped applications into nine categories. A categorized list of applications is shown in Appendix 3A. For each category, the market assessment examines major applications, shipments, lifetimes, and BC and EPS technical characteristics. Trends and factors that may affect future shipments of BCs and EPSs are also discussed. Generally, characteristics about the batteries, BCs, and EPSs used with each application were derived from an extensive survey of products available at online retailers and in stores. DOE surveyed nearly 1,000 products to gather specific BC and EPS data (such as output voltage). The details of the survey can be found in the Excel file BCEPS_Master_Survey.xls.

3.2.1.1 Audio

The audio equipment category includes both niche applications, such as guitar effects pedals, and very common applications such as MP3 players. This category does not include computer speakers. DOE estimates total shipments were 69 million in 2009. The most numerous units include MP3 players, MP3 speaker docks, and clock radios, with shipments of approximately 65 million units in 2009.[1] DOE estimates that 21 percent of these units use an EPS and 65 percent use a BC. The prevalence of BC- or EPS-powered musical instruments and component audio equipment is low; DOE did not find any guitar effects pedals or electric keyboards that ship with BCs, and it estimated EPS shipments to be approximately 1.6 million. DOE examined amateur radios as part of its determination for non-Class A EPSs. DOE estimated annual shipments of 3,000 high power EPSs for amateur radios. These EPSs typically have nameplate output powers of 345 watts. 74 FR 56928.



MP3 Players

Portable media players such as MP3 players constitute the majority of shipments in the audio category; 40.1 million units were shipped in 2009, all of which employed a BC. While shipments are high, CEA noted a 16.5 percent drop in shipments between 2007 and 2009. They attribute this decline to convergence with smart phones. In contrast, trends to add additional features to portable media players, such as video, could increase demand for these devices. The Pacific Gas and Electric Company and others commented that lifetimes are estimated to be four years. (PG&E et al., No. 20 at p. 10) All portable media players analyzed by DOE were powered by 3.7 volt batteries. Apple is the market leader for portable media players; as of 2007, Apple's market share was over 70 percent.[2] [b] Battery energy for Apple products ranges from 0.9 to 3.3 watt-hours. Overall, portable media players with color display screens tend to use similar batteries as mobile phones. Nearly all portable media players are recharged via USB connections, although many manufacturers offer EPSs that output voltage at USB levels (five volts) as an optional accessory. DOE assumes that ten percent users that purchase an MP3 player also purchase an aftermarket EPS.

MP3 Speaker Docks and Clock Radios

From researching common units for sale, DOE found that the majority of MP3 speaker docks employ EPSs, while most traditional clock radios run directly from mains power. However, convergence between these devices is increasing. In 2009, a total of 24.5 million clock radios and MP3 speaker docks were shipped, and DOE estimates approximately 38 percent of those units had EPSs.[1] Of the models DOE examined, most used EPSs with nameplate output power between 13 and 18 watts. DOE found a few models with EPSs as high as 60 watts of output power. EPS output voltage clustered around 10, 12, and 15 volts.[c] DOE estimated that 15 percent of MP3 speaker docks contain integral rechargeable batteries and have BCs for those batteries. DOE found battery information for only one such MP3 speaker dock. That model used a 3.7 volt battery rated at 8 watt hours. Since most MP3 speaker docks can also charge the media player, there is some question as to whether these docks contain BCs for this purpose. At present, DOE believes that charge control lies within the media player while the MP3 speaker dock acts simply as a power supply. DOE welcomes stakeholder comment on this issue. DOE assumes lifetimes for MP3 speaker docks and clock radios to be 4 years.

---

[b] According to the NPD Group, the iPod's market share was at 72.7 percent in January, 72.3 percent in February, and 68.9 percent in March of 2007.

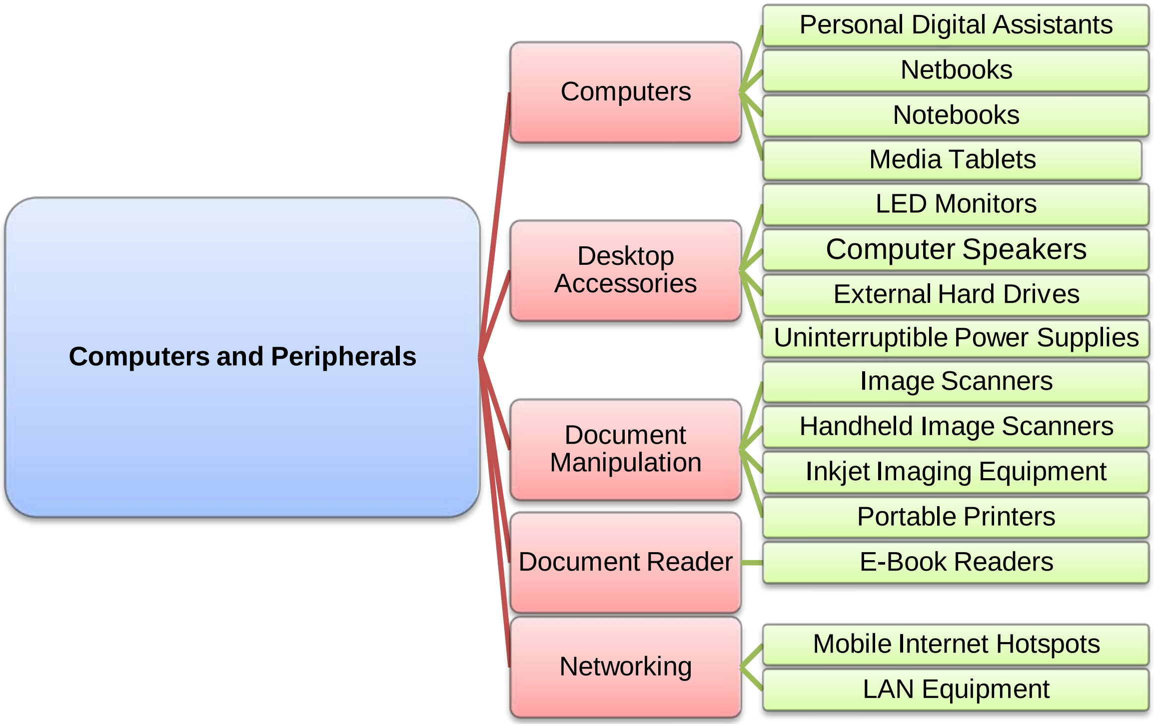
[c] Based on wall adapter information from 20 MP3 speaker docks and clock radios.

Wireless Speakers

DOE estimates shipments of wireless speakers to be 760,000 units in 2009. This application will likely experience strong growth as wireless technology improves and demand increases. Wireless speakers require no cable to transmit audio output from the audio source, but the wireless transmitter is powered by an EPS. Power to the speaker or speakers is provided by one or two EPSs and DOE estimates that approximately 1.5 million EPSs were shipped with wireless speakers in 2008. DOE is aware of one wireless speaker model that is powered by a wall adapter and can charge and operate on standard-sized C-cell rechargeable batteries.[3]

3.2.1.2 Computers and Peripherals

This category includes all computers and related equipment. As this is a broad category, applications have been separated into five subcategories: computers, desktop accessories, document manipulation, document readers, and networking. These applications have lifetimes of between 3 and 5 years. (PG&E et al., No. 20 at p. 10)[4] Shipments totaled 124.0 million units in 2009 for the category as a whole. DOE estimated that 58.4 million BCs and 70.1 million EPSs were shipped with these end-use products. DOE estimated that nearly half of the products in this category were used in the commercial sector, predominantly in office buildings but also in other public commercial spaces.



DOE estimated external hard drive shipments at over 770,000 units in 2009. Document manipulation devices shipped 26.3 million units. Shipments of electronic book readers increased significantly from 580,000 units in 2008 to 2.2 million units in 2009; however, the introduction of media tablets will likely lead to a significant reduction in e-book shipments in the near future.[1]

Computers

Computer products, which comprise personal digital assistants (PDAs), netbooks, notebooks, and media tablets, represent the largest subcategory.d In 2009, 45.8 million units shipped, 47 percent of which DOE estimated were used in the commercial sector. Applications covered in the computers subcategory are built for portability and, as a result, use BCs and EPSs. PDAs have seen significant convergence with smart phones. In 2005, more than 4.7 million units were shipped, but by 2009 shipments had decreased to 1.75 million units.1 The broader functionality of smart phones reduces the need for two devices and, by extension, the need for multiple BCs. See Table 3-1for an illustration of this convergence. DOE includes smart phones in its analysis of mobile phones under the telephony category.

Table 3-1 Shipments by Application, thousands

	2006	2007	2008	2009	CAGR (%)
PDAs	3,850	2,175	1,977	1,750	-18
Smart-phones	11,282	19,500	28,555	41,163	38

Although PDA shipments are in decline, netbook shipments have grown significantly owing to their greater portability and lower prices compared to full-sized notebooks. DOE estimated that netbooks shipments increased from approximately 3.7 million units in 2008 to 8.7 million units in 2009. However, Apple's introduction of the iPad in 2010 could significantly impact the dynamics of the computer market. 17.1 million media tablets shipped globally in 2010, and iSuppli expects global shipments to increase to 57.6 million units in 2011.[5] For purposes of the analysis, DOE extrapolated base year shipments for media tablets in the United States to be 7.4 million units.

Based on its survey of the market, DOE found that all EPSs powering notebook and netbook computers are similar in voltage (~20 V), but vary in output power due to differences in intended functionality. Netbooks require wall adapter output powers of approximately 30-65 W, while notebooks require 60-120 W. Both types typically use 11.1 V batteries. Battery energy is similar between netbooks and notebooks, typically ranging from 40 to 60 watt hours. PDAs and media tablets both use 3.7 V batteries and 5 V output wall adapters; however, media tablet batteries have higher capacities than PDA batteries, with rated battery energies of 25 Wh versus 4.4 Wh, respectively.

Desktop Accessories

Desktop accessories are applications designed for at-home use with personal computers. Total shipments in 2009 were 28.8 million units and include computer speakers, external hard drives, and uninterruptible power supplies. Without data on computer speaker shipments, DOE assumed that speaker sales would be equivalent to sales of desktop computers, at 10.3 million units in 2009.[1] Based on its survey of products, DOE estimates that 38 percent of computer speakers are powered by EPSs. Output power for these EPSs varied between 6 and 68 W. DOE

---

[d] For the purposes of this analysis, DOE defines media tablets to be portable devices larger than smartphones with complete mobile computer functionality and touch-screens.

estimates that 58 percent of external hard drives, approximately 448,000 units, used EPSs.[6, 7, e] Most units used 12 V EPSs with output power that varied between 12 and 57 W.

Uninterruptable power supplies (UPSs) contain BCs but do not use EPSs. UPSs act as power strips with built-in batteries that remain charged in order to provide battery power to attached devices in the event of a power surge or power interruption. DOE relied upon an EPA estimate of 8 million units for 2009 shipments of consumer UPSs.[8] Most consumer UPSs contain built-in 12 V batteries with energies ranging from 84 to 168 watt hours. Built-in BCs are able to fully charge these batteries in 3 to 24 hours, though most can do so in between 4.5 and 16 hours.

In product surveys, DOE also identified a number of LED and LCD monitors that use EPSs, the majority of which were Dell brand. Therefore DOE used Dell's market share to estimate 1.9 million shipments of EPS for LED monitors, or 20% of CEA's 2009 estimate for computer monitors. The typical output power of products found during the updated product survey was lower, at 72 watts.

Document Manipulation

Document manipulation is another subcategory containing applications that are experiencing significant convergence. Printers often have additional scanning, copying and faxing capabilities. Therefore, DOE analyzed three types of applications: stand-alone image scanners, portable printers, and inkjet imaging equipment, which includes these multi-function devices. DOE estimates total shipments in this subcategory to be 26.3 million units.

Inkjet imaging equipment made up 83% of total U.S. printer shipments, at 17.2 million units in 2009.[9] In its product surveys, DOE found that fewer inkjet printers and multi-function devices require EPSs than was estimated during the preliminary analysis. DOE estimates approximately 4.1 million EPS shipments for these products, with output power varying significantly within the range of 15-108 W and output voltage remaining at 30-32 V. Similarly, about 40% of image scanners shipped with EPS, equal to 3.1 million shipments in 2009. All portable printers on the market—about 1.2 million in 2009 according to DOE estimates—use EPSs, while 75% use BCs. Battery voltage for portable printers ranges from 7.4-11.1 V and battery energy ranges from 3.3 to 25.2 watt hours.

Document Readers

Electronic document readers, also known as e-book readers, are a quickly growing subcategory. CEA estimated that shipments almost quadrupled between 2008 and 2009 to 2.2 million units.[1] These portable rechargeable devices enable users to download and display electronic books. DOE surveyed five of these devices, four of which were conclusively found to use wall adapters (with outputs of 4.2-10.4 W) to power their BCs. The Amazon Kindle, the original e-book reader, uses a 3.7 V battery with 5.7 watt hours of energy.

---

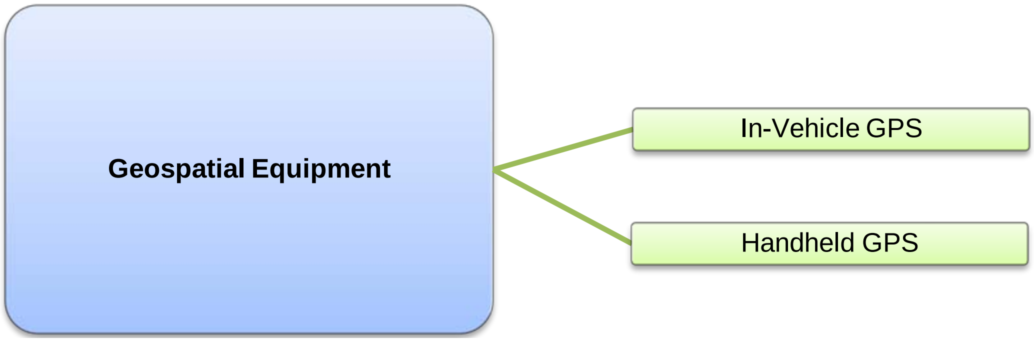
[e] Worldwide shipments for external hard drives were 2.6 million in 2008. Based on the Darnell Group's estimated distribution of computer shipments, North America makes up 29 percent of worldwide computer shipments. U.S. GDP is 85 percent of North American GDP, yielding U.S. external hard drive shipments of 644,215. Finally, iSuppli forecast a 20% growth in U.S. shipments in 2009, resulting in DOE's estimate of 773,058 shipments.

Networking

As wireless technologies gain market share over traditional modems, market saturation of networking equipment will continue to increase. DOE combined devices such as LAN equipment, broadband modems, routers, and Wi-Fi access points under the general application 'LAN Equipment'. CEA estimates 19.4 million units shipped in 2009, of which 96 percent use an EPS that provides output voltage between 5 V and 12 V.[1] Recently, Comcast began offering a broadband modem with a rechargeable back-up battery to new digital voice subscribers. Based on data published by Comcast, DOE estimates that approximately 1.3 million units shipped with BCs in 2009.[10, 11] DOE also identified mobile internet hotpots as a new application in this subcategory. These products connect to the internet via a cellular connection and output a Wi-Fi signal. They use 3.7 V batteries and EPS with 5 V output.

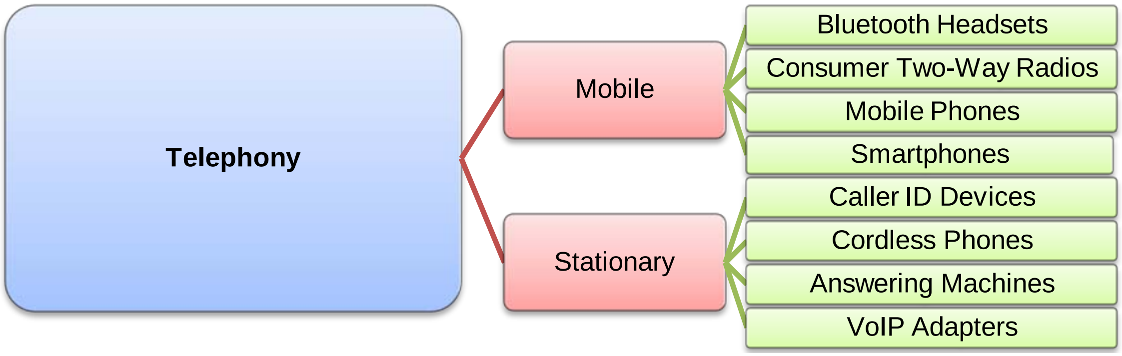
3.2.1.3 Geospatial Equipment

The geospatial equipment category is comprised of rechargeable global positioning system (GPS) devices, which include handheld and in-vehicle GPS devices. After experiencing rapid year-over-year growth, shipments of in-vehicle GPS declined from 15.3 million units in 2008 to 12.6 million units in 2009.[1] GPS functionality in smartphones has likely contributed to lower sales of these products. Since the majority of handheld GPS devices are powered by primary batteries, DOE assumes that just 15 percent of the handheld devices sold are rechargeable. A wall adapter for charging purposes is either included with the product or sold separately. Shipment data is not readily available on handheld GPS units, but DOE estimates that 150,000 units shipped in 2009 use an EPS and BC. DOE assumes lifetimes for handheld and in-car GPS units to be 5 years. In-vehicle GPS units are primarily charged by a DC car charger. Many can also be charged with an AC-DC wall adapter, but these are normally sold as separate accessories. DOE assumes battery voltage for in-vehicle GPS units is 3.7 V with energy between 4 and 8 watt hours.



3.2.1.4 Telephony

DOE has separated telephony into two sub-categories with very different power supply and usage characteristics. These categories are mobile telephony (including two-way radios, mobile/cellular telephones, and accessories for these devices) and stationary telephony (including cordless telephones and satellite charging bases, caller ID devices, and voice over internet protocol – or VoIP – adapters).



Shipments in this category vary widely, from standalone caller ID devices, of which 345,000 units shipped in 2009, to mobile phones, with shipments of 94.2 million units. Total unit shipments for applications in this category were 196.6 million units. [1, 12]

Mobile Telephony

Applications in the mobile telephony category are small, portable devices designed for mobile communication. With the exception of those consumer two-way radios that are powered by primary batteries, products in this subcategory use BCs. Mobile phones typically employ EPSs, although substitution is a factor as some can also obtain power from USB ports. Bluetooth headsets are typically charged with USB connectors or wall adapters.

DOE analyzed mobile phones and smartphones as distinct applications. Smartphones incorporate the utility of handheld computers into mobile telephones, reducing the need for two separate devices. Smartphone shipments increased by 44% over 2008 to 41.2 million units in 2009, while CEA estimates mobile phone shipments of 94.2 million units, 8.5 million less than in 2008. CEA predicts that smartphones also have the potential to adversely affect sales of MP3 players, digital cameras, camcorders, handheld PCs, portable videogames, and GPS devices, just as they have nearly eradicated the PDA market.[1] For example, it was predicted that global sales of GPS-enabled phones would reach 240 million in 2009[13], while 500 million of the smartphones and mobile phones shipped globally in 2007 were capable of playing digital music[14]. Reduced demand for these other applications will lead to lower shipments of their associated BCs and EPSs.

For those mobile phones surveyed, DOE found all to use EPSs, while some have the ability to be charged by USB or 12 V DC car chargers. EPS power output is low (2.5-5 W) and nearly all are five volt output. Mobile phones use 3.7 V batteries with capacities that range from 3 to 5.6 watt hours.

Mobile phones have average lifetimes of 2 years. While the mobile phone itself is designed to last longer than this, the mobile phone industry is driven by technological innovation and trends, two factors that lead consumers to replace phones on a regular basis. Furthermore, cell phone service contracts average two years in length; after this point, consumers are frequently given the option of purchasing a replacement phone at a significant discount.

Therefore, in the past DOE considered mobile phone lifetimes to be two years and EPS lifetimes to also be two years. However, the “GSMA Universal Charging Solution”, described below, will increase the lifetime of the EPS.

GSMA Universal Charging Solution

In early 2009, 21 mobile phone operators and manufacturers agreed to work together to implement a universal battery charging standard for mobile telephones by 2012[15]. Historically, each mobile phone has been manufactured and sold with a unique EPS built specifically for that phone and its internal battery. As a result, EPS unit shipments have mirrored mobile phone shipments. This standard will eliminate the need for consumers to purchase a new EPS each time a new mobile phone is purchased and, as a result, will reduce mobile phone EPS shipments.

The Environmental Protection Agency (EPA) estimates that 125 million mobile phones (and, by extension, nearly that many EPSs) are discarded annually in the United States[16]. The universal charging agreement will use a micro USB interface and common output voltage so that new chargers can work with multiple phones. This will result in a significant reduction in annual EPS shipments after 2012, as the need to replace old EPSs when a new phone is purchased will be eliminated. DOE forecasts that the number of battery chargers manufactured and sold in the global market place (and, by extension, the United States) will be reduced by 50 percent.

The reduction in EPS shipments will be matched by a corresponding increase in product lifetime for EPSs, which DOE estimates will be 4 years. The agreement also includes a no-load mode power ceiling of 0.15 W.[17] This no-load limit may reduce the energy consumption of mobile phone EPSs. These potential impacts are discussed in section 3.2.3

Stationary Telephony

The stationary telephony subcategory includes cordless phones/answering machines, VoIP adapters, and caller ID devices. All use wall adapters.

Cordless phones and answering devices are often packaged with multiple handsets (each with a BC). A typical cordless phone set consists of a charging base with built-in answering machine, a handset, and one or more satellite charging bases, each with its own handset. Each charging base plugs into a wall outlet via a wall adapter to charge the batteries of the corresponding handset. Hence, a cordless phone set will include between one and five wall adapters and charging cradles. DOE estimates total EPS shipments for cordless phones and answering devices was 30.1 million units in 2009.[1] Most cordless phone EPSs have output power between 1.2 and 7.7 W and voltage between six and nine volts. DOE found cordless phone batteries were either 2.4 or 3.6 volts and between 2.6 and 5.3 watt hours. Cordless phone/answering machines have an average lifetime of 5.3 years.[f]

Voice over internet protocol, or VoIP, adapters are powered by EPSs, and 9.9 million units in were shipped in 2009.[1] VoIP adapters provide telephone service via an internet connection. VoIP adapters typically have five or 12 V EPSs with power outputs of 10-14 W.

---

[f] Based on the average values of three sources: PG&E et. al. (5 years) (PG&E et al., No. 20 at p. 10); Appliance Magazine (5 years); and FY2005 Preliminary Priority-Setting Summary Report and Actions Proposed (6 years).

DOE assumes that stand-alone caller ID devices use EPSs similar to those used for cordless phones. Only 345,000 units shipped in 2008.[1] The low and decreasing shipments of standalone caller ID devices can be explained by convergence with stationary telephones, as many now incorporate caller ID technology.

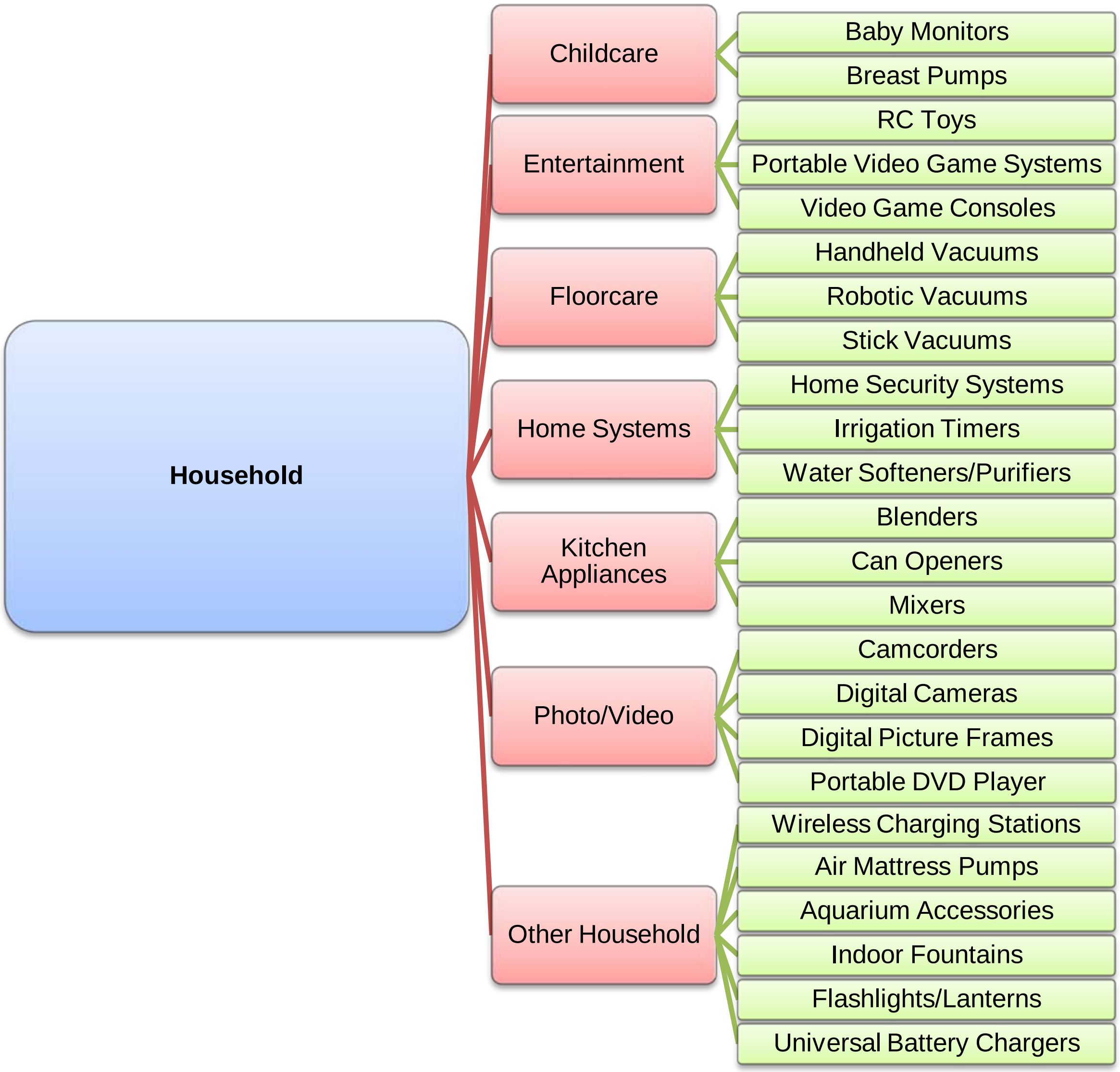
One trend that negatively affects the stationary telephony market, including cordless phones/answering machines and caller ID devices, is the decline in homes with landline telephone service. With the increase in cellular telephone service indicated by increasing mobile phone shipments, many households have opted out of landline telephone service. CEA's data show that answering devices and cordless phone unit shipments have decreased by an average 19 percent annually since 2006. Strong growth in mobile phone unit sales has offset declines in cordless phone unit sales, leading DOE to conclude that, despite these fluctuations, the market for BCs and EPSs has remained largely unchanged in this subcategory[g].

3.2.1.5 Household

This category encompasses a wide array of applications, ranging from water softeners to digital cameras, and DOE estimates that 132.7 million of these applications that often use BCs or EPSs shipped in 2009.

---

[g] As cordless phone sales declined, manufacturers began to bundle multiple receivers and satellite bases in a package. As a result, BC and wall adapter sales for this application are higher than cordless phone package sales.



Household applications are grouped into seven subcategories based on intended use. These subcategories differ significantly from one another in market and technology characteristics and are, therefore, discussed individually below.

Photo/Video

The photo/video subcategory is comprised of consumer products primarily designed for photography, video, and viewing pictures and movies. Applications included in this subcategory are digital cameras (33 million units in 2009), consumer camcorders (6.3 million), portable DVD players (3.7 million), and digital photo frames (9.3 million).[h] Digital cameras and camcorders

---

[h] 2009 US shipments estimates for digital cameras, camcorders, and digital photo frames are taken from Consumer Electronics Association. DOE estimates portable DVD shipments based on global shipments in 2006, with shipments growing annually at the rate of US population growth.

have lifetimes averaging six years and five years respectively, while DOE assumes that portable DVD players have lifetimes of four years.

Growth in this category is driven primarily by growth in digital picture frame shipments, which have increased from 1.5 million units in 2006 to 9.3 million units in 2009.[1] Based on inspection of 20 top-selling models, DOE estimates that close to 100 percent of digital picture frames ship with EPSs. In the same time period, camcorder shipments increased from 5.3 million units to 6.3 million units. [1] CEA predicts that low-cost camcorders with solid state drives have the potential to boost future sales of this application. Furthermore, these units tend to use BCs with USB (five volt) input. The popular Flip Video solid state camcorder, made by Cisco, controls 17% of the camcorder market with its inexpensive line of camcorders that use USB input to recharge their batteries. [18] DOE assumes 25% of camcorder shipments use five volt input BCs. Shipments of digital cameras have held steady between 32.9 million and 33.2 million units over the past 4 years.[1] CEA attributes this stagnated growth to a combination of market saturation and an encroachment on sales due to convergence with other devices such as mobile phones.

Based on product surveys, DOE estimates that 80 percent of digital cameras ship with BCs. Camcorder and digital camera BC shipments have remained constant, while digital picture frames, which are relatively new to the market, are rapidly gaining market share, resulting in a net increase of BC/EPS shipments in the photo/video category.

Digital camera BCs typically provide output power at 4.2-8.4 V. They are used to recharge batteries that typically have 3.2 to 11.1 watt hours of energy. The majority of digital cameras and camcorders DOE surveyed used cradle chargers. DOE found that very few digital cameras use wall adapters; of the digital cameras DOE surveyed, only about half of the digital single-lens reflex (DSLR) cameras, which make up about 30 percent of the market, used one.[19] Therefore, DOE estimates approximately 4.9 million shipments of EPS for digital cameras, of which half operate the application indirectly. DOE also noted a strong trend towards USB power for camcorders; the best selling model in 2008 was rechargeable by this method[18]. DOE found EPSs for digital picture frames to range between 7.5 and 24 W of output power. Portable DVD players use wall adapters with output powers between 9 and 24 W to charge batteries with rated energy between 16 and 32 watt hours.

It is important to note that many mobile phones and PDAs now include digital camera and digital video recording technologies. While DOE expects that this has had a negative effect on the subcategory’s shipments, this effect has most likely been small, a result of the relatively poor quality of most mobile phone camera lenses and sensors. As mobile phones are equipped with higher quality cameras with greater functionality, it is possible that the convergence will increase. Portable DVD players may also face the pressures of convergence with other applications. As streaming videos become more common and mobile devices (such as mobile phones and portable music players) are able to store and play full-length digital movies, the market for portable DVD players may decline. If these applications continue to converge, the demand for multiple devices will be reduced, thus reducing the demand for BCs.

Another instance of convergence within this subcategory is the ability of many digital cameras to record good-quality videos. Many compact, “point and shoot” digital cameras can shoot videos, while a few recent entrants into the DSLR camera market can shoot high-definition videos. DOE expects that this convergence has reduced the need for consumers to own separate digital cameras and camcorders and, as a result, has reduced the need for the BCs and EPSs powering these devices.

Floor Care

This subcategory contains three applications: hand vacuums, stick vacuums, and robotic vacuums. All three applications include models that utilize battery chargers and wall adapters and include models with charging cradles.

DOE estimated 2009 unit shipments to be 4.0 million for rechargeable handheld vacuums and 4.2 million for stick vacuums.[20] DOE estimates that 63 percent of stick vacuums (2.6 million) are rechargeable. One million robotic models shipped, all of which were cordless and rechargeable.[21] Thus, DOE estimates total BC shipments for floor care were 7.6 million units in 2009.

All of the handheld rechargeable vacuums surveyed are charged via charging cradles coupled with wall adapters. BC and wall adapter specifications for handheld vacuums were not readily available; however battery voltage ranged widely from 4.7 to 40 V, with most batteries between 9.6 V and 20 V. DOE assumes typical hand vacuums have battery energy of 19 watt hours.

Stick vacuums are designed for cleaning larger floor areas and have higher capacity batteries than do handheld vacuums. Approximately 50-60 percent of the rechargeable units surveyed were charged via a charging cradle, with the remainder utilizing wall adapters instead. DOE expects that, like handheld vacuums, stick vacuums with charging cradles are designed for the charger to be plugged into mains all the time. Charging times ranged from 3 to 24 hours, while battery voltage ranged between 6 and 24 V.

The majority of popular robotic vacuums can be charged via a wall adapter and charging “base.” The base is similar to a cradle in that the product spends the majority of its time plugged in. Battery energy is higher for robotic models than for stick or handheld models, as the battery must power the vacuum, sensors, and drive wheels. DOE inspected two additional robotic products manufactured by iRobot, the largest manufacturer of robotic vacuums: a robotic floor washer and a robotic gutter cleaner. Both use batteries of similar size and chemistry to the company’s floor vacuum. Charging time for robotic vacuums was between 3 and 15 hours. Where data were available, DOE found BC output voltages of 17-22 V and energy between 36 and 43 watt hours.

Kitchen Appliances

Very few kitchen appliances use BCs or EPSs. DOE estimates that only about 400,000 shipments included BCs and just 20,000 had EPSs. Overall shipments of kitchen appliances are significant, however. The September 2009 issue of *Appliance Magazine* listed 2008 shipments for all electric blenders, can openers, and mixers as 1.2, 5.7, and 5.8 million, respectively, and showed that shipments have remained steady since 2005.[22] Conversations with the Association of Home Appliance Manufacturers (AHAM) have supported DOE's assumption that rechargeable units make up a small fractions of the unit shipments for these applications.

Childcare

Baby monitors use BCs and wall adapters, while breast pumps use EPSs but not BCs. Other applications considered elsewhere in the analysis are toys and entertainment devices. Based on the number of first-births to US families in 2007, DOE estimates that shipments of rechargeable baby monitors were 1.7 million in 2009. Most baby monitors use at least two BCs and wall adapters, one for the nursery unit and one for the receiving unit. DOE assumes that the average baby monitor is used intermittently over a period of 4 years. DOE does not have shipment data for breast pumps, but estimates shipments 550,000 units annually based on first-births and breastfeeding rates. Breast pumps are powered by EPSs.

Entertainment

The home entertainment subcategory includes video game systems (consoles and portable handheld systems) and radio controlled toys. The ride-on toy application is included in the transport category due to similarities between BCs for ride-on toys and BCs for other applications in that category. Other applications not analyzed in this category include musical instruments, computers, and recreational transport (such as motorized bicycles).

DOE estimates total unit shipments for video game consoles to be 23.7 million[i] and shipments of portable video game systems to be 10.4 million.[j] DOE estimates lifetimes of 3 years based on the rate at which manufacturers typically develop new systems. The Nintendo Wii, which made up about 49 percent of the market in 2009, uses a 12 V, 44.4 W output EPS. The Microsoft Xbox 360, which made up 32 percent of the market, uses a 198 watt EPS that has multiple simultaneous output voltages. The Sony Playstation3, which accounted for the remaining 19 percent of the market, does not use an EPS, but each unit ships with one rechargeable controller that contains a BC. EPSs used with handheld game systems are 5 V and have output powers of 2.5 to 7.5 watts. They are powered by 3.7 V batteries with 1.8 to 4.4 watt hours of energy.

This category has experienced a form of convergence that may lead to an increase, rather than a decrease, in EPS shipments. Most new videogame consoles have the ability to play DVD and Blu-ray discs. Stationary DVD and Blu-ray players are not powered by EPSs. This additional functionality in video game consoles may cause some consumers who may otherwise have purchased a stationary DVD or Blu-ray player to purchase a console instead, resulting in accelerated console sales growth and more EPS shipments.

DOE lacks shipments data for radio-controlled (RC) toys but assumes shipments to be 7 million per year (similar to toy ride-on vehicles), of which 30 percent are rechargeable. DOE

---

[i] DOE estimate is based on annual sales dollars reported by CEA and the market-share weighted average sales price of the three major consoles on the market in 2009: Nintendo Wii, Microsoft Xbox 360, and Sony Playstation 3.

[j] According to Comcast (citing iSuppli), there were 38.9 million portable video game systems shipped globally in 2009. DOE assumes shipments to the US are proportional to the US share of global GDP (26%).

estimates total shipments with BCs to be 2.2 million units annually. Growth in BC shipments may result if there is an increase in the ratio of rechargeable RC toys to those powered by primary batteries. Both types of RC vehicles use cradle BCs and often use 7.2 or 9.6 volt batteries with energy between 7.7 and 10.8 watt hours.

Home Systems

Applications considered under the "home systems" category are designed to be continually plugged into household power outlets. These applications operate as background systems, adding comfort, security, or safety to homes. Home security systems, electronic pest repellents, irrigation timers, and water softeners/purifiers are all included in this category. Many use EPSs, and home security systems contain battery chargers. Water softeners/purifiers shipped 1.2 million units in 2008.[22] Shipments data were not readily available for irrigation timers, but DOE estimates modest shipments of 500,000 units in 2009.

PG&E estimates lifetimes for emergency systems, which include home security systems, to be 7.3 years. (PG&E et al., No. 20 at p. 10) Given the similarities among applications in this category, DOE extended this estimate to the other applications in this category as well. Given that 28 percent of homes contain security systems and assuming the lifetime provided by PG&E, DOE estimates annual shipments of home security systems to be 4.2 million units. Home security systems are comprised of various components that use combinations of rechargeable batteries (with integrated chargers) and EPSs as power sources. While there are a few basic configurations and do-it-yourself installation kits available, security systems are component-based and highly customizable. As a result, the number of BCs and EPSs varies from system to system. Security system EPSs tend to be AC-AC transformers, though some components are powered by AC-DC converters. In the most basic home security systems, a simple, non-rechargeable battery-powered circuit is attached to a door, window, or other point of entry into a home. Alarm control boxes that monitor these circuits are often powered by an EPS. An integrated AC-DC converter that functions as a BC provides a continual source of power to a backup battery so, in the event of a power outage, the security system remains functional. Wireless systems can be completely battery powered (with optional after-market wall adapters) and may include one or more BCs. As a simplification, DOE assumed one BC and EPS are included with each security system.

Typical output powers for home security system EPSs (the majority of which are AC-AC EPSs) are 16 or 24 V. DOE found that most home security system BCs convert AC power to DC power in order to charge a security system's backup batteries. Many of these BCs convert AC current to 6, 12, and/or 24 volt DC current to recharge the batteries.[k] Standard batteries are 12 V sealed lead-acid with 14–84 watt hours of energy. Some battery packs feature other battery chemistries, 3.6–7.2 V output, and battery capacities of 1.3–13 Ah.

Water softeners surveyed used AC-AC EPSs rated at 24-volts and 9.6-18 watts nameplate output. DOE found information on one irrigation timer that also had a 24 volt AC/AC EPS rated at 18 watts.[l]

---

[k] Based on examination of retailer and distributor Web sites, including www.bassburglaralarms.com and www.homesecuritystore.com.

[l] The line of Toro ECXTR Sprinkler Timers uses a 24V, 18 watt AC/AC EPS.

Other Household

This subcategory is comprised of consumer applications designed for home use that do not readily fall under the other subcategories. BC applications include air mattress pumps, rechargeable flashlights, and universal battery chargers. Many of these applications also use wall adapters, as do wireless charging stations, aquarium accessories (air and water pumps) and indoor fountain pumps.

PG&E estimated annual shipments of universal battery chargers to be 300,000 units and lifetimes to be eight years. (PG&E et al., No. 20 at p. 11) BCC research predicts that sales of universal battery chargers will continue to increase, driven primarily by an increase in rechargeable battery sales.[23] BC data vary significantly based on the model of universal battery charger and the batteries it is intended to charge. Simple models can accommodate only two or four AA batteries, while others can charge most standard-size rechargeable primary batteries in various combinations and quantities. A typical user may frequently charge four AA batteries; therefore these BCs would typically charge batteries of ten watt hours.

PG&E estimates that 100,000 rechargeable flashlights are sold annually, a small fraction of all the flashlights shipped annually. Rechargeable flashlights have expected lifetimes of ten years. (PG&E et al., No. 20 at p. 11)

Aquarium and fountain pumps use AC/AC EPSs. DOE examined the ENERGY STAR product list of AC/AC EPSs and found aquarium pump EPSs rated at 9 V and 1.8 watts of output power. The American Pet Products Manufacturers' Association estimates that 15 percent of households have fish as pets.[24] Assuming each fish owner has an aquarium with a pump and given an estimated lifetime of five years, DOE estimates shipments of aquarium pumps to be 3.5 million units annually. DOE also assumes that about 20 percent of these aquarium accessories are used in the commercial sector—in restaurants and hotels, for example—based on the ratio of commercial to residential floor space in the US. DOE lacks a source for shipments data on indoor fountain pumps but assumed annual shipments of one million units. DOE assumes indoor fountain pumps use EPSs that are similar to aquarium pumps. DOE expects lifetimes for indoor fountains and air mattress pumps to be approximately five years.[m, 25, 26]

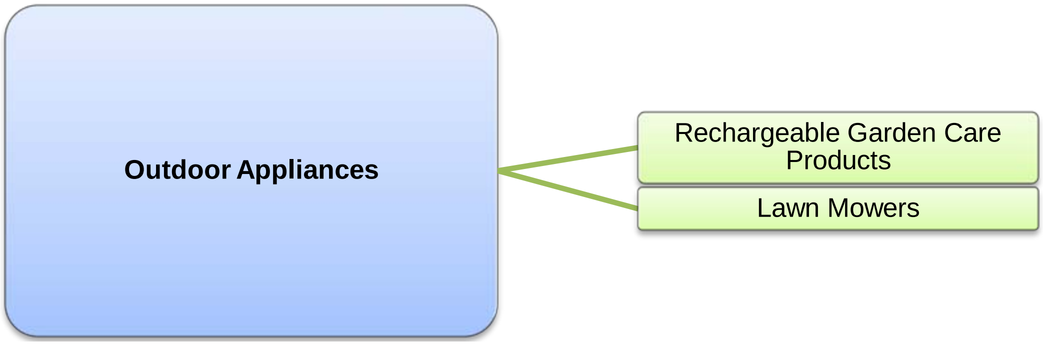
Wireless charging stations are emerging as popular alternatives to wall adapter battery chargers for portable consumer electronics. These products consist of a charging base and a receiver or "skin" that attaches to a handheld device, such as a mobile phone or MP3 player. When the handheld device is placed on the charging base, it transfers power wirelessly to the device, either conductively or through electromagnetic induction. Some products on the market are capable of charging multiple handheld devices simultaneously, reducing the need for multiple wall adapters. According to iSuppli, 3.6 million wireless charging stations are expected to ship globally in 2010, and shipments will increase dramatically to 235 million by 2014.[27] These wireless charging stations generally require EPSs with 18 V and 15 W.

---

[m] Estimate for air mattress pumps and aquarium accessories are based on the lifetime estimate of 5 years for indoor fountains. The EPS for indoor fountains primarily powers the fountain's pump; the same holds true for the EPSs of the other two applications. As a result, DOE assumes all three pump applications to have similar operational lifetimes. Indoor fountain lifetimes estimates based on an average of the lifetimes quoted on retailer websites.

3.2.1.6 Outdoor Appliances

The market for battery powered, rechargeable outdoor appliances is small compared to its gasoline-powered counterparts. DOE has identified three battery-powered outdoor appliance applications: weed trimmers, hedge trimmers, and lawn mowers.



DOE lacks a source of shipments data for cordless weed trimmers and hedge trimmers but estimates annual shipments to be 150,000 units. Although *Appliance Magazine* estimates annual shipments of 300,000 electric lawn mowers, many of these units are corded.[20] DOE believes the prevalence of cordless mowers will increase. In fact, an examination of products available at major home improvement stores showed the availability of 17 cordless lawn mowers compared to just 11 corded mowers.[n] Based on this model count, DOE assumes 61 percent of all outdoor appliances use BCs. DOE estimates that, as technologies improve and battery capacity increases (allowing the product to be used for longer periods of time), battery powered outdoor appliances could experience significant growth.

Cordless lawn mowers require significant power and long discharge times. Most utilize sealed lead-acid batteries and battery energy ranges from 240 to 840 watt hours, with a median of 410 watt hours. Battery voltage was significantly higher than other outdoor appliances: most electric lawn mowers use 24 V batteries, with some as high as 60 V. Most electric lawn mowers have charging times of 12-24 hours.

Short discharge and long recharge times are limitations of cordless lawn mowers. Thus, battery powered mowers are impractical for consumers with larger lawns. DOE expects the market share for rechargeable units to increase as technologies improve discharge times and charging rates.

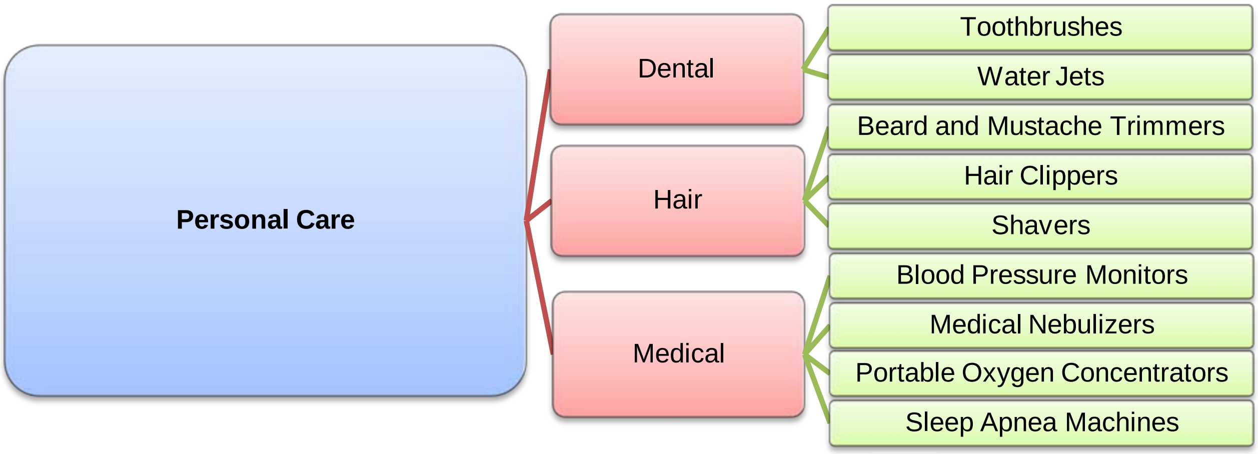
By contrast batteries and battery chargers for cordless weed trimmers and cordless hedge trimmers are much smaller. Both products have similar batteries with outputs between 12 V and 18 V and rated energy of 14 to 31 watt hours. Charging times for these products are relatively short: between 1-3 hours.

---

[n] Models of corded and cordless lawn mowers available on the websites of The Home Depot, Lowes, and Sears were counted. Sites examined September 29, 2009.

3.2.1.7 Personal Care

The personal care products category includes three subcategories. The hair subcategory includes beard and mustache trimmers, hair clippers, and electric shavers. The dental subcategory includes rechargeable toothbrushes and rechargeable water jets (also known as oral irrigators). These products tend to have shallow depths of discharge and smaller capacity rechargeable batteries. DOE believes battery energy for most dental and hair products to be approximately 1 watt hour. The medical subcategory includes blood pressure monitors, medical nebulizers, portable oxygen concentrators, and sleep apnea machines. These applications use non-class A EPSs.



Unit shipments for applications in the hair subcategory were 24.1 million, divided between trimmers (9.4 million), clippers (6.1 million), and shavers (8.7 million).[28] DOE believes the markets for these products to be at or near saturation. As a result, demand is expected to remain constant.

Market surveys showed that the majority of trimmers and clippers are either corded or use primary batteries. Therefore, DOE assumed that only 75% of these products use an EPS and 25% use a BC. On the other hand, DOE found that almost all electric shavers on the market employ both EPSs and BCs. A majority of beard and moustache trimmers are designed for cord/cordless operation, as opposed to a majority of shavers and clippers, which cannot be operated while the battery is charging. In the latter case, DOE assumed the EPS did not directly operate the consumer product. DOE assigned 25% of trimmer EPS shipments to product class N and 75% of shaver and clipper EPS shipments to product class N. DOE observed that typical battery energy is between one and four watt hours and EPS output ranging from 3 V to 15 V and 0.3 W to 6.3 W.

DOE received a comment from Philips following the preliminary analysis that approximately 15 million rechargeable toothbrushes shipped in 2009. (Philips, No. 41 at p. 2) This is an increase over 2000, when 10 million electric toothbrushes were sold.[29] Rechargeable oral care products are inductively charged and use cradles with wall adapters. Rechargeable toothbrushes use inductively charged batteries. Their batteries are typically 1.2 volts and approximately 0.8 watt hours.

DOE also examined medical devices designed for in-home use that employ EPSs and BCs. These applications, including blood pressure monitors, nebulizers, portable oxygen concentrators, and sleep apnea machines.

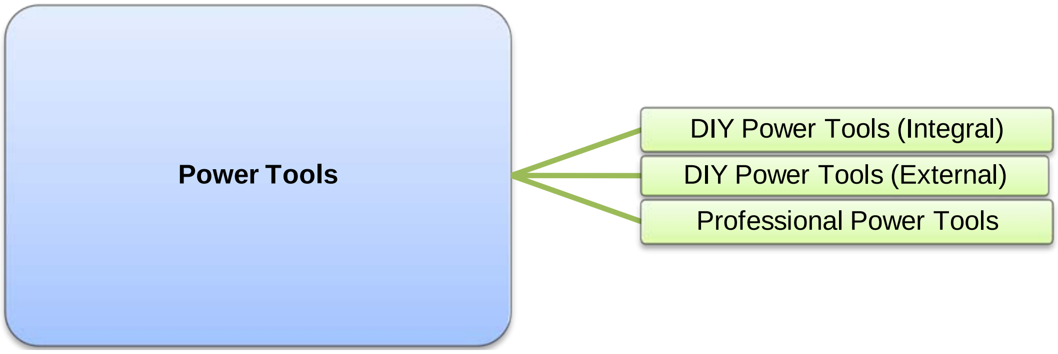
Blood pressure monitors are used by those who must take frequent readings of their blood pressure. Most digital units operate with primary batteries, but some are sold with an EPS or offer an optional EPS. DOE estimates 100,000 EPS for blood pressure monitors shipped in 2009. DOE estimates typical nameplate output power to be around 3 watts. Nebulizers administer liquid medication as a mist that can be inhaled into the lungs. They are commonly used to treat asthma and chronic obstructive pulmonary disease (COPD). The EPSs that provide power to nebulizers tend to have nameplate output power in the range of 10 to 20 watts. Nebulizers occasionally use rechargeable 12 V batteries; DOE estimates shipments of 400,000 nebulizers with BCs.

Sleep therapy devices include continuous positive airway pressure (CPAP), bi-level positive airway pressure (biPAP), automatic positive airway pressure (autoPAP), and similar machines used to treat obstructive sleep apnea. Some sleep therapy devices are battery powered, some plug directly into mains, and others are powered by EPSs, which typically have nameplate output power of approximately 28 to 50 watts. DOE found sleep apnea machines that employ 12 volt batteries with battery energy of 79.2 watt hours. DOE estimates one million EPS shipments and half that number of BC shipments.

Portable oxygen concentrators absorb nitrogen from the air to provide oxygen to the user at higher concentrations, eliminating the need for oxygen tanks. These devices typically use EPSs ranging from 90 to 200 watts. Portable oxygen concentrators include batteries and are typically sold with BCs for both at-home and in-vehicle use. DOE estimates that approximately 9,000 portable oxygen concentrators were sold in 2009. DOE found an example with a 195 watt hour battery.

3.2.1.8 Power Tools

The cordless power tool market is large, with 23.4 million units shipped in 2009.[30] DOE divides power tools into two categories: Do-It-Yourself (DIY) and professional tools. DIY tools are aimed at casual users and have batteries of less than 18 volts while professional tools have batteries of 18 volts or more. Both types of tools are frequently purchased by consumers.



DOE estimates that 50 percent of power tools shipped are DIY tools. These can be divided into those with detachable batteries and those with integral batteries. DOE assumed that the former account for 30 percent and the latter 20 percent of the total market. Based on data provided by the Power Tool Institute, DOE estimated that 5 percent of DIY tools with detachable batteries and 100 percent of DIY tools with integral batteries use EPSs. Professional power tools use detachable battery packs and the battery charging system does not use a wall adapter. Based on manufacturer interviews and data from PG&E, DOE estimates average power tool lifetime at 5.9 years for DIY tools and 3 years for professional tools. (PG&E et al., No. 20 at p. 11)

According to forecasts from the Darnell Group, the market for cordless rechargeable power tools will continue to grow at an average annual rate of 10.6 percent until 2013. This growth is attributed to a falling cost for increasingly powerful and flexible tools. DOE believes that short-term growth will be tempered by the slowdown in the construction and remodeling industries.

Batteries for DIY tools are quite varied. Smaller tools, such as cordless screw drivers, may have batteries in the 3.7 to 4.8 volt range, while larger tools such as drills have batteries clustered around 7.2, 12, and 14.4 volts. Based on limited information, DOE estimates that battery energy for DIY tool batteries fewer than 12 volts is typically less than 15 watt hours.[o] DIY tools between 12 and 18 volts tend to have battery ratings around between 14 and 55 watt hours.[p] Most professional power tools use 18 volt batteries. DOE's research found median battery energy among professional tools to be 54 watt hours.[q]

DOE assumes that some power tools with rechargeable batteries are used in commercial buildings or otherwise at commercial electricity rates. Professional contractors working on commercial sites and office building maintenance staff are most likely to use professional-grade tools, but they would also use tools with lower battery voltages for certain jobs; therefore, DOE assumed a larger share of commercial sector shipments for professional power tools (35%) and smaller shares for DIY integral (5%) and DIY external (15%).

3.2.1.9 Transport

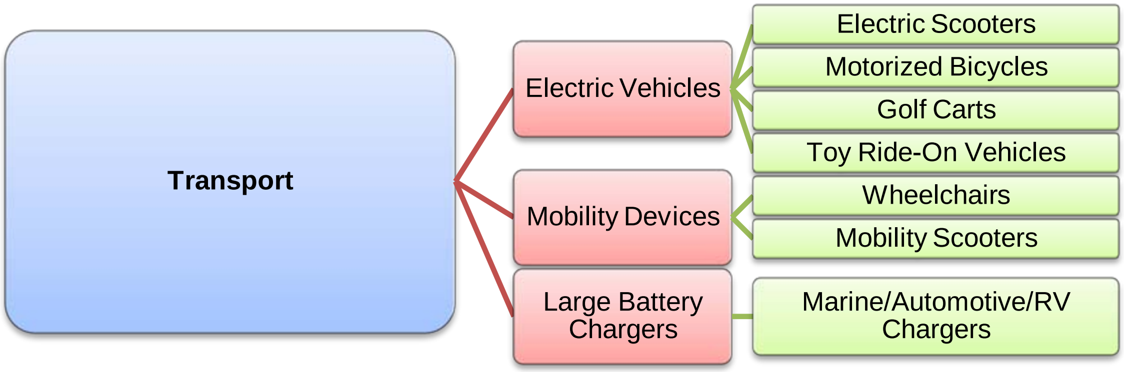
The transport category includes an assortment of applications powered by BCs, including toy ride-on vehicles, golf cars, mobility scooters, and others. While many electric vehicles are included in this category, automobiles, as defined by the U.S. Department of Transportation, are not. See Section 3.1.1 for definitions of "consumer products" and "automobiles."

---

[o] Based on a sample of five DIY tools.

[p] Based on a sample of five DIY tools.

[q] Based on a sample of 13 professional tools.



DOE estimates that 9.6 million BCs for transport applications are shipped annually. Of these, 8.1 million are for toy ride-on vehicles.[31] While DOE assumes lifetimes for toy ride-on vehicles to be about 4 years, other transport applications have lifetimes of approximately 10 years. (PG&E et al., No. 20 at p. 11) While 6-, 12-, and 24-volt batteries are common among these applications, battery energy varies dramatically from 27 to over 9,000 watt-hours. The output powers of the BCs and EPSs that power these batteries also vary considerably.

Electric Vehicles

The electric vehicles subcategory includes BCs for golf cars, chargers for marine and recreational vehicle (RV) batteries, toy ride-on vehicles, motorized bicycles, and electric scooters.

The golf car market includes a wide range of vehicle types, from standard golf carts to heavy duty “utility vehicles”, which are designed to carry loads over difficult terrain. The research firm International Market Solutions (IMS) calls this broad category of products, “small task-oriented vehicles” and each vehicle type may be purchased by consumers. These vehicles are steadily moving towards battery power. IMS estimates that the market share of electric small task-oriented vehicles has increased from 56 percent in 2000 to 64 percent in 2006 and they estimate the electric share will increase to 70 percent by 2012.[32] The same golf car models are often sold to both the golf course fleet market and to private consumers. Furthermore, many fleet golf cars are later sold in the consumer market as used vehicles. IMS estimates that over 210,000 electric small task-oriented vehicles were shipped in 2009, most of which (89%) were shipped to the commercial sector. Shipments are expected to grow at a CAGR of 4.2 percent from 2006 to 2012. As mentioned above, DOE excludes golf cars manufactured for on-road use. These vehicles are automobiles and fall outside DOE’s scope. Based on DOE’s analysis of currently available products, most golf cars employ several 6 or 12 volt batteries and energy greater than 3,000 watt hours. Common golf car BCs have output voltages of 36 or 48 volts.

DOE is also considering large universal battery chargers in its scope, such as those used to charge batteries for marine trolling motors. DOE has found that these battery chargers are functionally equivalent to those used to charge batteries for recreational vehicle (RV) accessories, automotive and motorcycle starter batteries, and other applications. Marine and RV applications use one or more 12 volt deep cycle batteries, depending on the requirements of the accessories being operated. PG&E estimates 2009 shipments of large universal BCs to be 500,000 units and have lifetimes of ten years. (PG&E et al., No. 20 at p. 10) Large universal BCs typically have output powers of 12 volts, although 24-volt universal BCs are not uncommon.

These BCs are used when more than one battery is being charged, as may be the case in some marine and RV applications. Deep cycle marine batteries store approximately 830 watt hours of energy.[r]

Toy ride-on vehicles account for the great majority of BC shipments in the transport category. The Toy Industry Association reported that 2008 retail sales in the U.S. were $1.8 billion.[33] Based on an estimated average retail price of $222.50, DOE estimated shipments to be 8.1 million units per year.[s] These vehicles have BCs with output voltages of 6, 12 and 24 volts and energy between 27 and 144 watt hours. Based on the recommended age levels for these products, DOE estimates toy ride-on vehicles to have a service life of four years.[t] Since the market for these applications is mature, and because the population of children age one to six is projected to grow at a compound annual growth rate of only 0.65 percent during the analysis period, DOE does not expect significant growth in this market.[33]

Electric scooters and motorized bicycles are the remaining applications DOE analyzed. Based on recalls of toy scooters, DOE estimates that annual sales of electric scooters are at least 250,000 units per year.[u] DOE estimates annual shipments of electric bicycles to be 150,000 units in 2009.[34] The scooters and motorized bicycles DOE analyzed used batteries ranging from 24 to 48 volts. Batteries had rated energy between 108 and 456 watt hours. The Segway brand scooter is unique in that it uses two 73.6 volt batteries (each at 427 watt hours of energy). DOE found little information on wall adapters for these applications.

Mobility Devices

Battery-powered wheelchairs and mobility scooters are common BC applications used by individuals with mobility-limiting disabilities, obesity, arthritis and other medical conditions. In 2006, the market research firm Marketstrat, Inc. forecasted that 166,000 powered wheelchairs and 192,000 mobility scooters would ship in 2008.[35] DOE was unable to find recent market information on shipments of mobility devices and thus assumed shipments would remain constant in 2009.

Powered wheelchairs and mobility scooters use similar batteries and chargers. All of the mobility devices examined by DOE were powered by two 12 volt batteries wired in series for a total output of 24 volts. Battery energy for a single battery ranged from 144 to 900 watt hours and with common devices employing pairs of either 144 watt hour batteries or batteries in the range around 400 watt hours.

---

[r] Based on test unit.

[s] DOE examined the retail prices of best-selling toy ride-on vehicles available from Wal-Mart, Toys R Us, and Amazon.com. Web sites examined in November 2010.

[t] According to surveys of retailer websites, typical age categories are one to two years of age for low-powered vehicles and two to six years of age for more powerful vehicles.

[u] Based on recall data from the Consumer Product Safety Commission. Data show that recalls of individual models account for significant shipments. For example see: U.S. Consumer Product Safety Commission. “CPSC, Razor USA Announce Recall of Electric Scooters.” June 14, 2005. (Last accessed September 13, 2010.) <http://www.cpsc.gov/CPSCPUB/PREREL/prhtml05/05193.html> The September 13, 2010 material from this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

3.2.2 Shipments, Lifetimes, and Energy Performance

Awareness of the market for BCs and EPSs is an important aspect of the development of the standards rulemaking. Specifically, by understanding the number of units that ship every year, the energy performance of those units, and how long the products will remain in use, DOE can develop an inventory model for BCs and EPSs in the United States to use in its downstream analyses. DOE used the base-year shipments, lifetimes, and market efficiency distributions presented below to calculate life-cycle costs for each application at each CSL, as well as national energy savings and net present value of consumer benefits from potential standards. See chapter 8 (life-cycle cost analysis), chapter 9 (shipments analysis), and chapter 10 (national impact analysis) of the NOPR TSD for complete discussions of the methodologies of those analyses.

DOE relied on data from public sources, interested parties, industry reports, and its own estimates to determine shipments, lifetimes and efficiency distributions. Where efficiency distribution data were not provided, DOE relied upon product testing and other market research to estimate base-case efficiency distributions. For BCs and EPSs, DOE compared each test result to the proposed compliance curves for each CSL. DOE then divided the number of tested units at a given CSL by the total number of tested units to get the estimated percentage of units in the market at that level. When there was a large enough sample of tested units for a particular application, DOE derived an application-specific efficiency distribution. For EPSs, DOE also calculated the distribution of tested units within the ranges of nameplate output power corresponding to the representative units of analysis. For applications that DOE did not test, DOE relied on product class (for BCs) or representative unit (for EPSs) distributions for use in the energy use analysis and LCC analysis. DOE calculated a shipment-weighted average efficiency distribution for each product class for use in the national impact analysis

3.2.2.1 External Power Supply Shipments, Lifetimes and Energy Performance

DOE estimates that a total of 345 million EPSs shipped in 2009. Table 3-2 shows the average lifetime and an estimate of the number of units shipped in 2009 for all seven of the EPS product classes that DOE identified, as well as the four segments of product class B. See section 3.3.1 for a complete discussion of EPS product classes.

Table 3-2 External Power Supply Lifetimes and Shipments by Product Class

ID	Product Class Description		Average Lifetime	EPS Shipments in 2009 (Thousand Units)
B	**DC Output, Basic Voltage**	0-10.25 W	4.7	68,473
		10.25-39 W	4.6	70,257
		39-90 W	4.1	47,559
		91-250 W	3.7	7,021
C	**DC Output, Low Voltage**		4.2	58,845
D	**AC Output, Basic Voltage**		8.6	7,994
E	**AC Output, Low Voltage**		4.9	2,250
X	**Multiple Voltage**		5.0	7,677
H	**High Power**		10.0	3
N	**Indirect Operation**		5.1	74,782

The following 10 tables show EPS shipment estimates and lifetimes for the top applications in each product class. Product class B is subdivided into four segments by nameplate output power.

Table 3-3 EPS Product Class B, 0-10.25 W: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Answering Machines (Res.)	14,043	5.3
2.	Cordless Phones (Res.)	10,980	5.3
3.	Mobile Phones (Res.)	8,482	4.0
4.	Portable Video Game Systems (Res.)	6,482	3.0
5.	Beard and Moustache Trimmers (Res.)	5,288	4.5
	Other	20,196	-
	Total	**68,473**	**4.7**

Table 3-4 EPS Product Class B, 10.25-39 W: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	LAN Equipment (Res.)	15,464	4.0
2.	Digital Picture Frames (Res.)	9,133	5.0
3.	MP3 Speaker Docks (Res.)	7,853	4.0
4.	Media Tablets (Res.)	6,302	4.0
5.	VoIP Adapters (Res.)	5,919	5.0
	Other	25,586	-
	Total	**70,257**	**4.6**

Table 3-5 EPS Product Class B, 39-90 W: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Notebook Computers (Comm.)	11,569	3.7
2.	Video Game Consoles (Res.)	11,515	5.0
3.	Notebook Computers (Res.)	9,466	3.7
4.	Netbook Computers (Comm.)	4,772	3.7
5.	Netbook Computers (Res.)	3,904	3.7
	Other	6,334	-
	Total	**47,559**	**4.1**

Table 3-6 EPS Product Class B, 91-250 W: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Notebook Computers (Comm.)	3,856	3.7
2.	Notebook Computers (Res.)	3,155	3.7
3.	Portable O2 Concentrators (Res.)	9	11.0
	Total	**7,021**	**3.7**

Table 3-7 EPS Product Class C: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Mobile Phones (Res.)	29,685	4.0
2.	Smartphone (Res.)	8,747	4.0
3.	Mobile Phone (Comm.)	3,298	4.0
4.	Consumer Two-Way Radios (Comm.)	2,959	5.0
5.	Digital Cameras (Res.)	2,346	6.0
	Other	11,809	-
	Total	**58,845**	**4.2**

Table 3-8 EPS Product Class D: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)

1.	Home Security Systems (Res.)	4,219	10.0
2.	Aquarium Accessories (Res.)	1,348	5.0
3.	Water Softeners and Purifiers (Res.)	1,150	10.0
4.	Indoor Fountains (Res.)	500	4.7
5.	Aquarium Accessories (Comm.)	403	5.0
6.	Irrigation Timers (Res.)	375	10.0
	Total	**7,994**	**8.6**

Table 3-9 EPS Product Class E: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Aquarium Accessories (Res.)	1,347,500	5.0
2.	Indoor Fountains (Res.)	500	4.7
3.	Aquarium Accessories (Comm.)	403	5.0
	Total	**2,225**	4.9

Table 3-10 EPS Product Class X: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Video Game Consoles	7,678	5.0
	Total	**7,678**	**5.0**

Table 3-11 EPS Product Class H: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Amateur Radios	3	10.0
	Total	**3**	**10.0**

Table 3-12 EPS Product Class N: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	EPS Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Rechargeable Toothbrushes (Res.)	15,000	5.0
2.	Bluetooth Headsets (Res.)	11,815	5.0
3.	Shavers (Res.)	6,492	4.1
4.	Smartphones (Res.)	5,248	4.0
5.	DIY Power Tools (Integral) (Res.)	4,441	5.9
	Other	31,786	
	Total	**74,782**	5.4

Table 3-13 shows the distribution of EPS shipments by efficiency level in 2009. These efficiency distributions are shipment-weighted averages of the efficiency profiles assigned to each application within the product class or representative unit of analysis. DOE tested 116 EPSs with output power ranging from 1.2 W to 135 W. DOE had sufficient test data to develop application-specific EPS efficiency distributions for the following applications: notebook computers, external hard drives, ink jet imaging equipment, LAN equipments, mobile phones, digital picture frames, and portable DVD players. DOE developed market efficiency distributions for amateur radios and video game consoles based on manufacturer interviews. For the remaining applications, DOE assumed efficiency distributions at the representative unit level. See BCEPS_Market_NOPR.xlsx for a complete presentation of DOE's efficiency distribution calculations.

Table 3-13 Energy Performance of New External Power Supplies in 2009

ID	**Product Class Description**		**Percent of Market at Each CSL**				
			CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
B	**DC Output, Basic Voltage**	**0-10.25 W**	84%	7%	6%	3%	0%
		10.25-39 W	39%	33%	18%	10%	0%
		39-90 W	37%	46%	17%	1%	0%
		91-250 W	51%	27%	18%	3%	0%
C	**DC Output, Low Voltage**		85%	10%	2%	3%	0%
D	**AC Output, Basic Voltage**		48%	31%	17%	4%	0%
E	**AC Output, Low Voltage**		61%	22%	13%	4%	0%
X	**Multiple Voltage**		5%	95%	0%	0%	-
H	**High Power**		50%	50%	0%	0%	-
N	**Indirect Operation**		-	-	-	-	-

3.2.2.2 Battery Charger Shipments, Lifetimes and Energy Performance

DOE estimates that 437 million BCs shipped in 2009. See section 3.3.2 for a complete discussion on BC product classes.

Table 3-14 shows the average lifetime and an estimate of the number of units shipped in 2009 for each of the ten BC product classes DOE defined. See section 3.3.2 for a complete discussion on BC product classes.

Table 3-14 Battery Charger Lifetimes and Shipments by Product Class

Class ID		Battery Energy	Battery Voltage	Average Lifetime	BC Shipments in 2009 (Thousand Units)
1	AC-DC	<100 Wh	Inductive Connection	5.0	15,100
2			<4 V	3.6	249,018
3			4<10 V	4.6	23,060
4			≥10 V	3.8	60,926
5		100–3000 Wh	<20 V	5.0	4,866
6			≥20 V	8.6	624
7		>3000 Wh		3.8	211
8	DC-DC		<9 V Input	3.6	65,210
9			≥9 V Input	5.0	9,583
10	AC-AC		AC Output from Battery	7.3	8,000

The following ten tables show BC shipment estimates and lifetimes for the top applications in each product class.

Table 3-15 BC Product Class 1: Top Applications, Shipments, and Lifetimes

	Top Applications by BC Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Rechargeable Toothbrushes (Res.)	15,000	5.0
2.	Rechargeable Water Jets (Res.)	100	5.0
	Total	**15,100**	**5.0**

Table 3-16 BC Product Class 2: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Mobile Phones (Res.)	67,852	2.0
2.	Smartphones (Res.)	34,989	2.0
3.	Digital Cameras (Res.)	20,023	6.0
4.	Answering Machines (Res.)	14,043	5.3
5.	Cordless Phones (Res.)	10,980	5.3
	Other	101,132	-
	Total	**249,018**	**3.6**

Table 3-17 BC Product Class 3: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Camcorders (Res.)	4,700	4.9
2.	Toy Ride-On Vehicles (Res.)	4,045	4.0
3.	Portable DVD Players (Res.)	3,703	4.0
4.	DIY Power Tools (Integral) (Res.)	2,221	5.9
5.	RC Toys (Res.)	2,100	2.0
	Other	6,292	-
	Total	**23,060**	**4.6**

Table 3-18 BC Product Class 4: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Notebook Computers (Comm.)	15,425	3.7
2.	Notebook Computers (Res.)	12,621	3.7
3.	Professional Power Tools (Res.)	7,597	3.0
4.	Netbook Computers (Comm.)	4,772	3.7
5.	DIY Power Tools (External) (Res.)	4,470	5.9
	Other	16,041	-
	Total	**60,926**	**3.8**

Table 3-19 BC Product Class 5: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Toy Ride-On Vehicles (Res.)	4,045	4.0
2.	Auto/Marine/RV Chargers (Res.)	500	10.0
3.	Mobility Scooters (Res.)	192	9.7
4.	Wheelchairs (Res.)	125	9.7
5.	Portable Oxygen Concentrators	5	11.0
	Total	**4,866**	**5.0**

Table 3-20 BC Product Class 6: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Electric Scooters (Res.)	250	9.7
2.	Lawn Mowers (Res.)	182	6.0
3.	Motorized Bicycles (Res.)	150	9.7
4.	Wheelchairs (Res.)	42	9.7
	Total	**624**	**8.6**

Table 3-21 BC Product Class 7: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Golf Carts (Comm.)	188	3.5
2.	Golf Carts (Res.)	22	6.5
	Total	**211**	**3.8**

Table 3-22 BC Product Class 8: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	MP3 Players (Res.)	36,091	4.0
2.	Mobile Phones (Res.)	16,963	2.0
3.	Digital Cameras (Res.)	5,006	6.0
4.	Mobile Phones (Comm.)	1,885	2.0
5.	Camcorders (Res.)	1,567	4.9
	Other	3,699	-
	Total	**65,210**	**3.6**

Table 3-23 BC Product Class 9: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	In Vehicle GPS (Res.)	9,484	4.9
2.	Flashlights/Lanterns (Res.)	50	10.0
3.	Medical Nebulizers (Res.)	45	11.0
4.	Portable O2 Concentrators (Res.)	5	11.0
	Total	**9,583**	**5.0**

Table 3-24 BC Product Class 10: Top Applications, Shipments, and Lifetimes

	Top Applications by Shipments	BC Shipments in 2009 (Thousand Units)	Average Lifetime (Years)
1.	Uninterruptible Power Supplies (Res.)	5,064	7.3
2.	Uninterruptible Power Supplies (Comm.)	2,936	7.3
	Total	**8,000**	**7.3**

Table 3-25 shows the distribution of BC shipments by efficiency level in 2009. These efficiency distributions are shipment-weighted averages of the efficiency profiles assigned to each application within the product class or representative unit of analysis. DOE tested 224 BCs with battery energies ranging from less than 0.5 Wh to over 1100 Wh. DOE had sufficient test data to develop application-specific BC efficiency distributions for the following applications: MP3 players, notebooks, uninterruptible power supplies, in-vehicle GPS, mobile phones, cordless phones, handheld vacuums, portable DVD players, universal battery chargers, lawn mowers, rechargeable toothbrushes, shavers, DIY power tools (integral), DIY power tools (external), professional power tools, wheelchairs, and marine/automotive/RV chargers. For the remaining applications DOE assigned efficiency profiles based on the test results of a similar application or the test results of other applications in the product class. The efficiency distributions for product classes 6 and 7 are based on manufacturer interviews (discussed in chapter 5). DOE assumed that all applications in product class 8 had similar efficiency profiles to MP3 players. See BCEPS_BC_Efficiency_Distributions.xlsx for a complete presentation of DOE's calculations.

Table 3-25 Energy Performance of New Battery Chargers in 2009

Class ID		Battery Energy	Battery Voltage	Percent of Market at Each CSL			
				CSL 0	CSL 1	CSL 2	CSL 3
1	AC - DC	<100 Wh	Inductive Connection	78%	11%	11%	0%
2			<4 V	21%	26%	51%	3%
3			4<10 V	20%	71%	9%	0%
4			≥10 V	11%	45%	44%	0%
5		100–3000 Wh	<20 V	32%	60%	8%	0%
6			≥20 V	41%	33%	26%	0%
7		>3000 Wh		50%	50%	0%	0%
8	DC-DC		<9 V Input	50%	40%	10%	0%
9			≥9 V Input	25%	50%	25%	0%
10	AC-AC		AC Output from Battery	100%	0%	0%	0%

3.2.3 Other Energy Efficiency Programs

There are many domestic and foreign energy efficiency programs designed to improve the energy performance of BCs and EPSs. Those programs that might affect the United States market are discussed below, first EPS and then BC programs. Information about these programs informed DOE’s base case efficiency forecasts, which it developed as part of the shipments analysis (see chapter 9).

The first mandatory energy efficiency standards for EPSs were introduced in California and Oregon in 2007. On December 19, 2007, the President signed into law the Energy Independence and Security Act of 2007 (EISA 2007) (P.L. 110-140), which set a Federal standard for Class A EPSs that took effect on July 1, 2008. Because the EPS market is global, this standard led to improvements in the efficiency of EPSs sold worldwide. Furthermore, the standard, while intended to regulate only Class A EPSs, is likely having a spillover effect on the efficiency of BCs and non-Class A EPSs. The standard for Class A EPSs has increased the demand for, and lowered the cost of, some of the more efficient components and has stimulated the adoption of improved designs. Because some of the same techniques and components are used to manufacture both Class A EPSs and other EPSs and BCs, DOE assumes that some of these components and designs are being carried over into the design and manufacture of BCs and non-Class A EPSs.

In the United States, manufacturers can use the ENERGY STAR label to differentiate more-efficient EPSs from less efficient ones. Version 2.0 of the ENERGY STAR criteria for EPSs took effect on November 1, 2008. In calendar year 2009, EPA estimated that ENERGY STAR qualified EPSs made up 59 percent all EPSs sold in the United States, which was an increase from 47 percent in 2008.[36] As of September 15, 2009, there were already over 3,000 qualified models.[37] EPA decided to sunset the EPS specification effective December 31, 2010; however, the ENERGY STAR criteria for certain other end-use products will continue to require the use of highly efficient EPSs.[38]

In April 2010 an EPS standard that is equivalent to the current Federal standard for Class A EPSs took effect in the European Union. In April 2011 a more stringent standard, equivalent to version 2.0 of the ENERGY STAR criteria, took effect. The Darnell Group estimates that the E.U. will receive 33 percent of all EPS shipments in 2011, which is nearly equivalent to the North American share of shipments. Given the size of the E.U. market, EPS standards there will likely cause spillover effects, increasing the efficiency of EPSs sold in the United States.

Additionally, a recent industry agreement for mobile phones known as the “GSMA Universal Charging Solution” could drive down the energy consumption of EPSs used with these products. The agreement incorporates a no-load (“standby”) power consumption requirement that is stricter than both the current Federal standard and ENERGY STAR criteria.

ENERGY STAR is currently the only efficiency program for BCs in the United States. Because the criteria, which took effect on January 1, 2006, do not cover active mode, they cannot be directly compared to the CSLs in DOE’s analysis. EPA estimated that the market penetration of ENERGY STAR qualified BCs increased from 16 percent in 2008 to 27 percent in 2009. [39] As of January 2011, there were over 200 qualified models.[40]

The California Energy Commission (CEC) has announced BC standards that include active mode. Small, noncommercial battery chargers sold in California will need to comply with these standards beginning February 1, 2013. Because California accounts for 13% of U.S. GDP, it can be assumed that California also accounts for approximately 13% of the U.S. market for battery chargers. These standards will impact the efficiency of least that proportion of the U.S. market, but it is uncertain whether the standards will affect the market outside of California.

DOE encourages interested parties to inform DOE of other upcoming or updated programs that may impact the energy efficiency of BCs and EPSs sold in the United States. Table 3-26 summarizes a number of voluntary and mandatory energy efficiency programs for BCs and EPSs. For detailed information on these programs, please refer to appendix 3B.

Table 3-26 BC and EPS Efficiency Programs Worldwide

Country / State	**Program Name**	**Effective Date**	**Compliance**	**Coverage**
US	EISA 2007	2008	Mandatory	EPS
	ENERGY STAR	2006 (BC) 2008 (EPS)	Voluntary	BC, EPS
California	Tier II Standard for "State Regulated" EPSs	2008	Mandatory	EPS
	Battery Charger Standard	2013	Mandatory	BC
Australia/ New Zealand	Minimum Energy Performance Standards	2008 (AU) 2009 (NZ)	Mandatory (Mark III) Voluntary (Mark IV, V)	EPS
Canada	Canadian Standards Association	2010	Mandatory	EPS
China	National Development and Reform Commission (NDRC)	2007	Mandatory	EPS
	China Standard Certification Center (CSC)	2005	Voluntary	EPS
European Union	Commission Regulation (EC) 278/2009	2010 (Stage 1) 2011 (Stage 2)	Mandatory	EPS
	Commission Regulation (EC 1275/2008	2010 (Stage 1) 2011 (Stage 2)	Mandatory	BC, EPS (standby and off-mode)
	EU Code of Conduct	2009	Voluntary	EPS
	Group for Energy Efficient Appliances	2007	Voluntary	BC, EPS
Manufacturers' Agreement	GSMA Universal Charging Solution (mobile phones)	2012	Voluntary	EPS

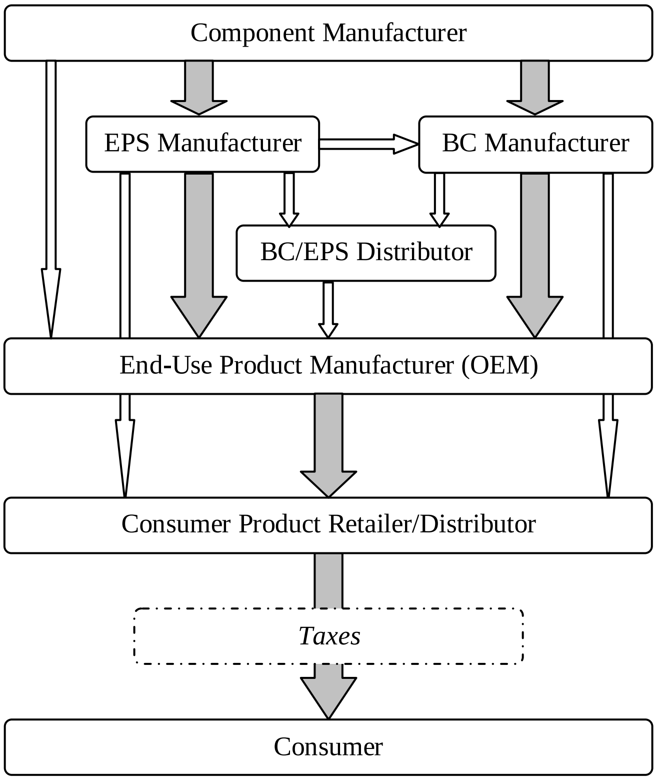
Country / State	Program Name	Effective Date	Compliance	Coverage
Israel	SI 4665.2	2007	Voluntary	EPS
Korea	Minimum Energy Performance Standards	2009	Mandatory	EPS
	e-Standby	2007	Voluntary	BC, EPS

3.2.4 Production and Distribution

DOE's BC and EPS distribution models were created based on information gathered through market research, conversations with industry experts, and stakeholder feedback. The Association of Home Appliance Manufacturers and others commented that, despite several ways to market, most BCs and EPSs follow a similar distribution path. The most common path to market, as identified by DOE, is depicted by the gray arrows in Figure 3.1, while alternative paths are depicted by the white arrows. The distribution channels DOE identified are discussed below.

BC and EPS distribution begins with component manufacturers, who produce the circuitry, circuitry components, wiring, housing, and other materials needed to manufacture BCs and EPSs. DOE learned that demand for specific components can drive their prices down. This is sometimes the case for components used to make a BC or EPS more efficient. Given greater demand for efficient components, due to an efficiency standard, for example, component manufacturers increase production and the increased scale causes prices to fall.

Components are often sold directly to BC/EPS manufacturers, who produce a finished BC or EPS, often for a specific end-use product manufacturer. Although less common, some BCs or EPSs may be manufactured directly by the end-use product manufacturer (OEM). DOE does not have data on the total size of the BC industry, but the Darnell Group estimated the size of the EPS industry. It estimated that in 2005, over 300 manufacturers worldwide made EPSs. Most of these manufacturers are located abroad. In the aggregate, their revenues totaled $5 billion in 2005 and $6.7 billion in 2008.[41, 30] It should be noted that many of these manufacturers also produce other products, including BCs and internal power supplies, so it is difficult to get an exact value of EPS market size.



*Note that widths of arrows are not drawn to scale and are not meant to be an exact indication of a distribution path's relative prominence.

Figure 3.1 Paths of Distribution for Battery Chargers and External Power Supplies

BCs and EPSs are then typically purchased by an end-use product manufacturer, henceforth known as the original equipment manufacturer, or OEM, as an input to an end-use consumer product. The BC and/or EPS is typically packaged with a consumer product, or especially in the case of some BCs, integrated into the consumer product.

Retailers typically purchase BCs and EPSs from OEMs and sell the products to consumers, though DOE has identified a number of instances where the manufacturing and retail operations for a product are owned and managed by one company. An example is Apple, which manufactures its own consumer electronics for sale in its own Apple-branded retail stores.
In addition to the standard distribution chain described above, market research and stakeholder comment revealed additional BC and EPS distribution channels. These are discussed below.
DOE found that many OEMs with low production volumes opt to purchase BCs or EPSs from distributors because they provide easy access to a wide array of components. Because sourcing BCs and EPSs through a distributor may be more costly, most OEMs with larger production volumes eliminate this step by working directly with component and BC/EPS manufacturers.
DOE also notes that while most consumer products are manufactured in an OEM-owned factory, there is a trend towards the use of electronics manufacturing services (EMSs). OEMs can take advantage of greater economies of scale in source materials and components by contracting out the manufacture of specific consumer applications to an EMS. EMSs achieve these economies of scale by producing similar products for several OEMs.

3.2.5 Small Businesses

During this rulemaking process, DOE is considering the possible impacts to small businesses that may be imposed by increased energy conservation standards for battery chargers and external power supplies. The Small Business Administration (SBA) determines appropriate guidance as to what is considered a small business for all industries described under the North American Industry Classification System (NAICS)[1]. BC and EPS manufacturers fall under NAICS code 335999 (*All Other Miscellaneous Electrical Equipment and Component Manufacturing*). DOE also searched for small businesses that are manufacturers of applications that include covered battery chargers under the following NAICS codes: 334310 (*Audio and Video Equipment Manufacturing*), 334210 (*Telephone Apparatus Manufacturing*), 334111 (*Electronic Computer Manufacturing*), 336991 (*Motorcycle, Bicycle and Parts Manufacturing*), 336332 (*Other Motor Vehicle Electrical and Electronic Equipment Manufacturing*), 335212 (*Household Vacuum Cleaner Manufacturing*), 333112 (*Lawn and Garden Tractor and Home Lawn and Garden Equipment Manufacturing*), 333991 (*Power-Driven Hand Tool Manufacturing*), and 335912 (*Primary Battery Manufacturing*). Based on these codes, SBA defines a BC or an EPS manufacturer to be a small business if it employs no more than 500, 750, or 1,000 employees, depending on the industry.

3.2.6 Manufacturers and Market Shares

The Darnell Group estimated revenues of the top EPS manufacturers in their 2005 report on the EPS market. They noted that the great majority of EPS manufacturing takes place in China and Taiwan. Furthermore, many of the largest manufacturers are also based in Asia. Figure 3.2 shows the top EPS manufacturers worldwide in 2005.[41] Because of the global reach of the industry and the reliance of major manufacturers on producing for high volume applications, Darnell notes that there are very few differences in regional market shares. In 2005, there were over 300 manufacturers producing EPSs. DOE learned that the industry has seen consolidation, but it found that the manufacturers shown in Figure 3.2 remain independent of one another. None of the top manufacturers listed in Figure 3.2 are headquartered in the United States. DOE identified SL Power Electronics, a subsidiary of SL Industries, Inc., as an EPS manufacturer based in the United States. SL Power develops, manufactures, and markets products under the brand names CONDOR™ and AULT®. DOE also recognizes that some EPSs for niche applications may be manufactured in the United States.

---

[1] For a more detailed description of SBA's small business definitions, see http://www.sba.gov/idc/groups/public/documents/sba_homepage/sba_010224.pdf

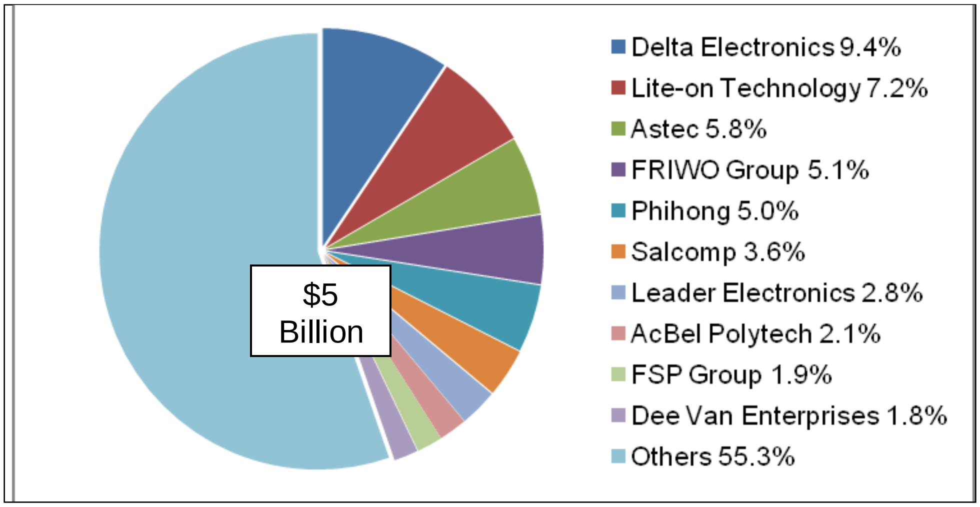


Figure 3.2 Top EPS Manufacturers: Shares of Global Revenue in 2005

Battery charger manufacturing is split between companies that produce BCs for OEMs and OEMs that produce BCs "in house." DOE currently lacks market share information for BC manufacturers but it gathered some data from its manufacturing interviews (discussed in chapter 5). DOE learned that in most cases low-energy BCs are not produced by the OEM of the end-use product; rather, they are purchased from an original device manufacturer (ODM), supplier, or vendor typically based in Asia. Conversely, medium and high energy products' BCs, such as those for wheelchairs and golf cars, are typically manufactured in the U.S. For example, Lester Electrical manufactures BCs for both wheelchairs and golf cars and has U.S.-based manufacturing. Xantrax Technology Inc. is based in Canada, but has facilities in the U.S. They produce BCs for marine applications. Many power tool OEMs also have some U.S.-based manufacturing. Companies include Black & Decker, TTI (maker of Milwaukee, Ryobi, and Hoover brand products), and the Robert Bosch Tool Corporation (Bosch, Skil).

3.2.7 Trade Associations and Other Interested Parties

DOE has identified a number of organizations that may have an interest in this rulemaking. Energy efficiency advocacy organizations with a demonstrated interest in DOE's rulemakings on battery chargers and external power supplies include:

- Appliance Standards Awareness Project,
- American Council for an Energy-Efficient Economy,
- Earthjustice,
- Natural Resources Defense Council,
- Pacific Gas and Electric Company, and
- Southern California Edison.

There are a substantial number of trade associations with member companies that manufacture or sell BCs, EPSs, or the consumer products they power. DOE has identified 40 such trade associations, listed in Table 3-27 along with the products that DOE believes each association has an interest in.

Table 3-27 Trade Associations

Association Name	**Products and Applications**
AdvaMed	Medical Devices
Alarm Industry Communications Committee	Home Security Systems
Amateur Radio Relay League (ARRL)	Amateur Radios
American Association of Cleaning Equipment Manufacturers	Floor Care Appliances
Association of Home Appliance Manufacturers (AHAM)	Home Appliances
Battery Council International	Batteries
Cellular Telecommunications Industry Association (CTIA)	Cell Phones
Computer and Communications Industry Association	Computers and Peripherals
Consumer Electronics Association (CEA)	Consumer Electronics
Craft and Hobby Association	RC Cars (Hobby Grade)
Electric Drive Transportation Association	Electric Vehicles
Electronic Components Association	Battery Chargers, External Power Supplies
Hobby Manufacturers Association	RC Cars (Hobby Grade)
Information Technology Industry Council (ITIC)	Computers and Peripherals
International Disk Drive Equipment and Materials Association	External Media Drives, External Hard Drives
International Housewares Association	Kitchen Appliances, Floor Care, Personal Care
International Music Products Association	Keyboards, Guitar Effects Pedals, Electric Music Instruments
International Recording Media Association	International Recording Media Association
Irrigation Association	Irrigation Timers
Juvenile Products Manufacturers Association	Prenatal to Preschool Electronics
Medical Device Manufacturers Association (MDMA)	Medical Devices
Motorcycle Industry Council	Electric Scooters
Multifunction Products Association	Multifunction Devices (MVD's)
National Association of Manufacturers (NAM)	All
National Bicycle Dealers Association	Electric Bicycles
National Burglar & Fire Alarm Association	Home Security Systems
National Electrical Manufacturers Association (NEMA)	All
National Gardening Association	Outdoor Appliances
National Marine Manufacturers Association	Marine Electronics
National Pest Management Association	Electronic Pest Repellents

Association Name	**Products and Applications**
National Retail Federation	All
Portable Computer and Communications Association	Notebooks, Netbooks, Handheld Computers, Mobile Phones, Bluetooth
Portable Rechargeable Battery Association (PRBA)	Batteries
Power Sources Manufacturers Association (PSMA)	Batteries, Power Supplies
Power Tool Institute (PTI)	DIY Power Tools, Professional Power Tools
Security Industry Association	Home Security Systems
TechAmerica	ALL
Telecommunications Industry Association	Telephony
The National Mobility Equipment Dealers Association	Electric Wheelchairs
Toy Industry Association	RC Toys, Toy Ride-On Vehicles

3.3 PRODUCT CLASSES

When necessary, DOE divides covered products into classes by the type of energy used, the capacity of the product, and any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) DOE then conducts its analysis and considers establishing or amending standards to provide separate standard levels for each product class.

3.3.1 EPS Product Classes

The following sections summarize all of the factors that DOE considered as determinants for EPS product classes. When discussing EPS efficiency, DOE refers to efficiency as the matched pairing of active-mode average efficiency and no-load mode power consumption.

3.3.1.1 Nameplate Output Power

Nameplate output power is a measure of the maximum power that an EPS can deliver, which directly impacts capacity and efficiency. EPSs with greater nameplate output power offer the consumer greater capacity and tend to have higher active-mode average efficiency. EPSs with lower nameplate output power tend to have lower no-load power consumption.

EPS active-mode average efficiency reflects the power consumption (loss) within an EPS, which comes from two sources: conversion losses and overhead losses. Conversion losses are proportional to the power that the EPS outputs whereas overhead losses are essentially fixed losses that do not increase significantly once output power is greater than 49 watts. Therefore, EPSs with higher output powers have proportionally lower overhead losses and are more efficient, when compared to EPSs with lower output power. In contrast to average efficiency, EPS no-load power consumption improves (is less) for EPSs with nameplate output power less than 50 watts because those EPSs have lower overhead requirements and can therefore shut down more fully when not providing output power. Because of these factors, both the EISA standard and the Energy Star 2.0 specification determine a minimum efficiency level as a continuous function of nameplate output power, as shown by the average efficiency levels in Figure 3.3 and the no-load power levels in Figure 3.4. DOE acknowledges that nameplate output power significantly affects utility and efficiency. However, rather than create distinct product classes by nameplate output power, DOE followed the precedent set by EISA and Energy Star 2.0 and has proposed an efficiency standard level that is a continuous function of nameplate output power.

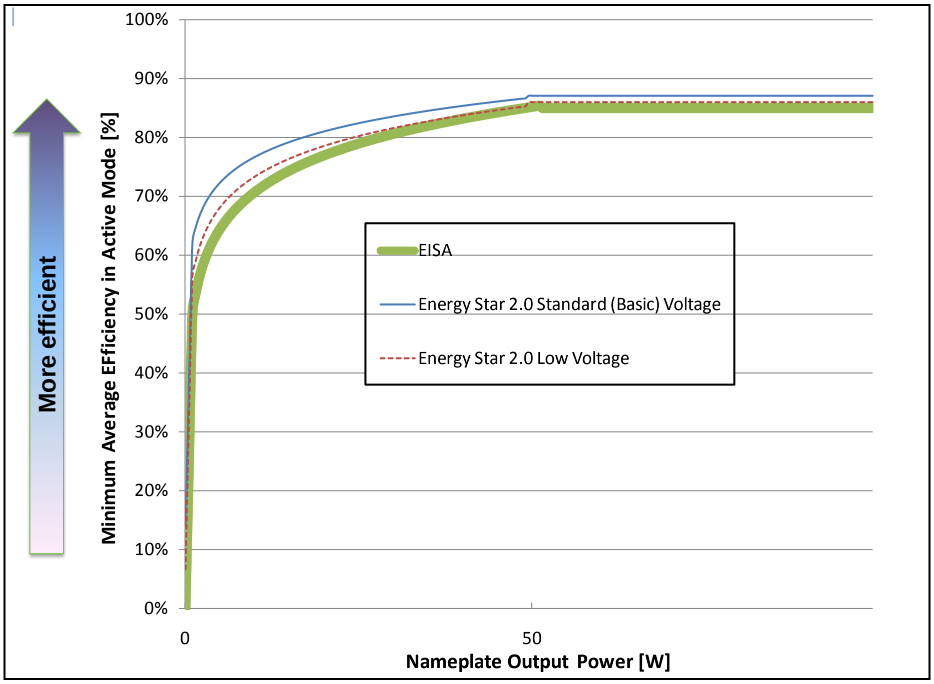


Figure 3.3 The EISA Standard and Energy Star 2.0 Specification for Average Efficiency[v]

---

[v] Energy Star 2.0 describes the two specification levels as "standard" and "low voltage." Because DOE uses "standard" as a term of art, the Energy Star 2.0 "standard" level is referred to as the Energy Star 2.0 "regular" level throughout this document.

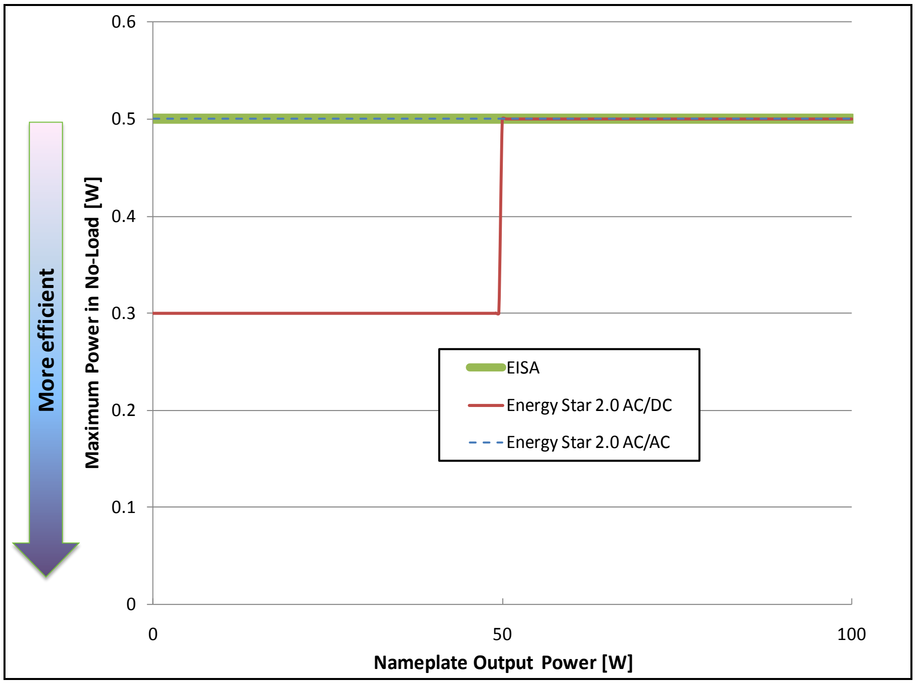


Figure 3.4 The EISA Standard and Energy Star 2.0 Specification for No-Load Power Consumption

3.3.1.2 Nameplate Output Voltage

Nameplate output voltage affects utility because the main function of an EPS is to provide an application with power at a certain voltage rather than the 115 volts provided by mains. The specific nameplate output voltage is determined by the characteristics of the application. For instance, certain applications such as modems and computer monitors have digital circuitry that requires specific power at a specific voltage, such as 12 V. For these applications the EPS provides power at the necessary voltage. Therefore, output voltage offers consumers a distinct utility that affects efficiency, which is one of the factors highlighted for special consideration under 42 U.S.C. 6295(q)(1).

EPSs with higher output voltage will tend to be more efficient. This arises because of the relationship between power, voltage, and current: power (P) = current (I) × voltage (V). For an EPS with a given output power, the voltage decreases as current increases. This is important because many of the losses in a BC or an EPS are functions of current. For instance, the resistive losses through a wire are $I^2 \times R$ and the power consumption of a diode is $I \times V_{diode}$. Table 3-28 illustrates this phenomenon. In the example, EPS A's output voltage is half that of EPS B's, but EPS A's $I^2 \times R$ losses are four times as high. Although the example is for a 20-watt EPS, it is applicable to all EPSs because they all have $I^2 \times R$ losses.

Table 3-28 Comparison of $I^2 \times R$ Losses for Two 20-watt EPSs

	Nameplate Output Voltage [volts]	Nameplate Output Current [amps]	$I^2 \times R$ Losses [watts]
EPS A	10	2	4 × R
EPS B	20	1	1 × R

Energy Star 2.0 acknowledged the relationship between voltage and efficiency by setting less stringent active-mode average efficiency criteria for EPSs with low voltage and high current output (Figure 3.3). Energy Star 2.0 defined "low voltage" models as EPSs with nameplate output voltage less than six volts and nameplate output current greater than or equal to 550 milliamps. Figure 3.5 shows the distribution of EPSs qualifying for Energy Star 2.0 as of 2009; many low-voltage EPSs would not have qualified at the basic voltage level. DOE created different product classes for EPSs with basic-voltage output and low-voltage output using the Energy Star criteria to define low-voltage EPSs because the criteria adequately captures many low voltage EPSs in the market and to follow precedent.

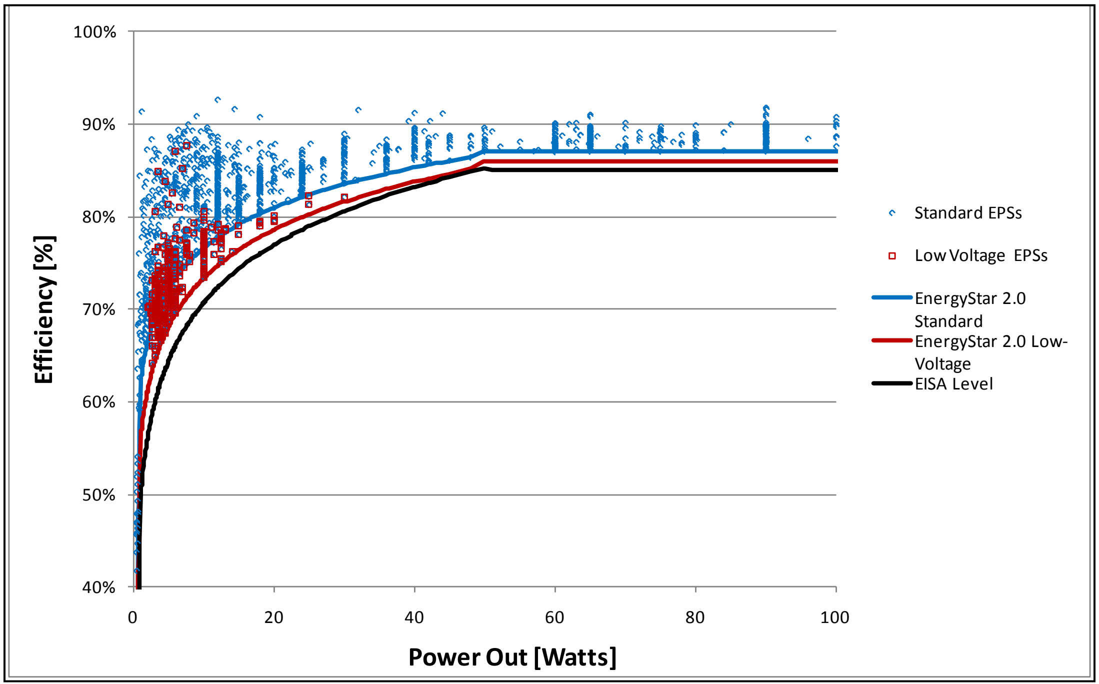


Figure 3.5 EPSs Qualifying for Energy Star 2.0 as of September 2009.

3.3.1.3 Type of Power Conversion (AC/AC versus AC/DC)

All EPSs receive input power from mains in the form of alternating current (AC) and provide output power in the form of either AC power or direct current (DC) power. This is another key functionality of an EPS, along with providing power at a specific voltage. Again, the type of power the EPS provides is governed by its application. Applications such as mobile phones and laptops require DC power to match the type of power provided by the battery. Applications that tend to use EPSs that provide AC power, such as cordless phones, often have circuitry within the application that converts the EPS's AC output into DC power.

The type of power conversion is indicative of an EPS's internal circuitry, and therefore its ability to conserve energy. EPSs that provide AC output power typically consist of just a transformer. The no-load power losses of those EPSs are dominated by transformer core losses. Alternatively, EPSs that provide DC power output typically contain a transformer as well as overhead circuitry that controls the flow of power through the EPS. Overhead circuitry provides EPSs with DC-output power the ability to reduce power consumption in no-load mode whereas EPSs with AC-output power do not typically contain overhead circuitry. Energy Star 2.0 acknowledges this relationship by setting a less stringent no-load mode power consumption criterion for EPSs with AC output power (Figure 3.4). DOE created different product classes for EPSs with AC output power and DC output power based on the Energy Star 2.0 precedent.

3.3.1.4 Use with Medical Equipment

EPCA excluded any device that "requires Federal Food and Drug Administration listing and approval as a medical device in accordance with section 513 of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 360c)" from the definition of Class A EPSs and their corresponding energy efficiency standards. (42 U.S.C. 6291(36)(C)(ii)(I)) Thus, all EPSs used with medical devices must meet the special requirements of UL 60601 (Underwriters Laboratories standard for power supplies for medical devices) such that they are approved by the Federal Food and Drug Administration (FDA).

Use with medical devices is a utility that is unique to medical EPSs. For that reason, DOE created a separate product class for EPSs used in medical devices during the preliminary analysis. However, DOE found that there were no inherent technical differences between them and Class A EPSs. Since that time, DOE has grouped medical EPSs with the four product classes that were previously composed of just Class A EPSs. DOE believes this is appropriate because the same technology options apply to both Class A and medical EPSs making them technologically equivalent. Therefore, medical EPSs can meet the same efficiency standards as Class A EPSs and should adhere to the same product class divisions.

3.3.1.5 Multiple Voltage and High Power EPSs

EPCA also excluded EPSs that convert AC mains power into more than one output voltage and EPSs with a rated output power greater than 250 watts from the definition of Class A EPSs. As their name intimates, multiple voltage EPSs can provide more than one output voltage to an end-use application simultaneously, providing an additional utility to the consumer. As a result of this added utility, DOE has created a separate product class for these devices. As for high power EPSs, or those with a nameplate rating greater than 250 watts, DOE has also created a separate product class. As discussed in DOE's determination analysis, DOE found that the topologies generally used in these higher power devices differed from those considered to be Class A EPSs. As a result, DOE believed it was likely that different technology options may be applicable to these devices and therefore, examined them separately.

3.3.1.6 Indirectly Operating an Application

One final characteristic that DOE examines when establishing its product classes is the ability of an EPS to directly operate its end-use application. In order to determine if a product meets this characteristic, DOE has developed a procedure that is outlined in Appendix 3C. The procedure in Appendix 3C determines an EPS's ability to directly operate an end-use application by monitoring the flow of power from the EPS to the application. Figure 3.9 shows a flow chart of an EPS that directly operates an application while Figure 3.7 shows a flow chart of an EPS that indirectly operates an application.

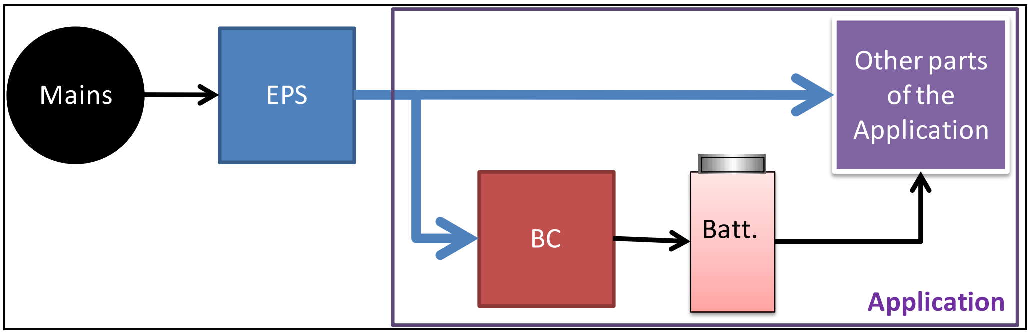


Figure 3.6 EPS that can directly power the application

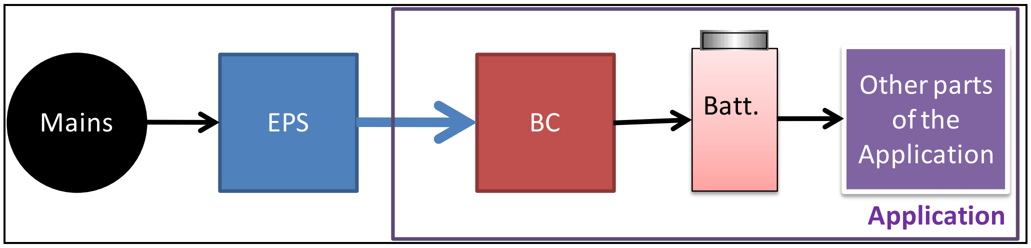


Figure 3.7 EPS whose power all flows to the BC

The EPS is evaluated based on its ability to operate the application once the battery has been fully discharged while taking into account the time required before the application can operate. By comparing startup times under fully charged and fully discharged battery conditions, the procedure acknowledges firmware limitations or bias conditions which can temporarily restrict power flow from the EPS to the application.

The expected result of the test procedure in Appendix 3C is that direct operation EPSs will be able to power the application regardless of the state of the battery while indirect operation EPSs will need to charge the battery before the application can be used as intended. Recording the time for the application to reach its intended use is necessary because certain applications, typically smartphones, contain firmware that can delay operation of the application, but is not a product of the state of charge on the battery. DOE believes the procedure in Appendix 3C for classifying an EPS as direct or indirect is only necessary when the EPS can be connected to the end-use application and the application contains a battery.

The vast majority of EPSs are considered direct operations EPSs, but for those products that cannot directly operate their end-use product, DOE has created an additional product class. These products offer a different utility from those that can directly operate an end-use product, and such differences equate to changes in circuitry and topologies that also cause changes in the technology options and cost versus efficiency relationship.

3.3.1.7 EPS Product Classes

For all the reasons discussed above, DOE generated the seven EPS product classes listed in Table 3-29. Under these product classes, an EPS's product class is determined by some special characteristic (e.g. multiple voltage output) or the combination of its power conversion type and its output voltage. DOE used the same criteria as Energy Star 2.0 to distinguish low-voltage EPSs from basic-voltage EPSs, as discussed in section 3.3.1.2. Within each product class, the standard level will vary with nameplate output power with the exception of the product class for high power EPSs, product class H, which will adopt a single efficiency standard level for all EPSs with a nameplate output power greater than 250 watts.

Table 3-29 EPS Product Classes

Product Class Description	Product Class Letter
AC/DC Basic Voltage	B
AC/DC Low Voltage*	C
AC/AC Basic Voltage	D
AC/AC Low Voltage*	E
Multiple Voltage	X
High Power	H
Indirect Operation	N

* Low voltage output EPSs have nameplate output voltage less than six volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic voltage output.

3.3.2 BC Product Classes

In this section, DOE presents the BC characteristics it considered for use in setting BC product classes, the impacts of power converter topology on BC design, and finally, the resultant product classes DOE used in the NOPR.

3.3.2.1 BC Product Class Criteria

When establishing product classes for BCs, DOE evaluated several product characteristics against the statutory requirements for setting product classes laid out in 42 U.S.C. 6295(q). The various characteristics that DOE considered for BCs were:

- output power;
- battery voltage;
- battery capacity;
- battery energy;
- inductive charging capability; and
- automatic voltage regulation

The above factors were combined with additional factors that DOE took into account based on its review of BCs in the market, including:

- input voltage type (line AC or low-voltage DC); and
- AC output.

Output power, battery voltage, battery capacity, and battery energy apply to all BCs, and are related through the following equations.

$P_{max} \gtrsim E_{batt} \cdot r$,
$E_{batt} = C_{batt} \cdot V_{batt}$

Where:

P_{max} is the maximum output power, in watts,
E_{batt} is battery energy, in watt-hours,
r is the charge rate, in units of C or 1/hour,
C_{batt} is the battery capacity, in ampere-hours, and
V_{batt} is the battery voltage, in volts.

As can be seen in the above equations, the four BC characteristics are related. BC output power is primarily affected by the charge rate and the battery energy, which in turn, is the product of battery capacity and voltage.

Of these BC characteristics, DOE uses battery voltage and battery energy as the primary means of dividing product classes for the NOPR. In addition, DOE is also using input and output characteristics, such as inductive charging capability, input voltage type (line AC or low-voltage DC), and AC output to divide BCs into further product classes.

Battery voltage greatly affects consumer utility because the electronics of a portable consumer product are designed to require a particular battery voltage. Whereas a change in battery capacity would impact the runtime of a battery-operated product, a change in battery voltage may stop it from running altogether. Furthermore, BCs charging lower-voltage batteries tend to be less efficient, and could be disproportionately affected by an equally stringent standard level across all voltages. Therefore, DOE uses battery voltage and not battery capacity as a characteristic for setting product classes in the NOPR.

Whereas battery voltage specifies which consumer product applications can be used with a particular battery (and its corresponding BC), battery energy describes the total amount of work that the battery can perform, regardless of the application. Battery energy is therefore also a measure of utility. Furthermore, because a BC must provide enough output power to replenish the energy discharged during use, the capacity and physical size of the BC depends on the battery energy.[w] By using battery energy as a proxy for output power, DOE is using one criterion for classifying BCs instead of two, simplifying the potential BC energy conservation standards while sufficiently accounting for any differences in BC capacity or utility in the standards analysis.

Finally, DOE also uses the presence of inductive charging capabilities, DC input voltage, and AC output from the battery as additional characteristics for setting product classes.

---

[w] The minimum output power is a product of battery energy and charge rate. However, while charge rates rarely fall outside the range of 1 C to 10 C, the battery energy of consumer BCs can span over 5 orders of magnitude from 1 watt-hour to over 10,000 watt hours. Therefore, the output power is more dependent on battery energy.

Inductive charging is a utility-related characteristic designed to promote cleanliness and guarantee uninterrupted operation of a BC in a wet environment. Inductive charging in a wet environment is also a safety related feature because the end user is electrically isolated from mains power.

While conducting an analysis of the market for BCs, DOE identified BCs that do not include a wall adapter, connecting instead to a personal computer's USB port or a car's cigarette lighter receptacle. Because input voltage can have a differential impact on BC efficiency and, furthermore, input voltage determines where the BC can be used, impacting utility, DOE uses this characteristic as a criterion for developing further product classes beyond the ones specified above. BCs differentiated on the basis of the aforementioned criteria have been further divided based on input voltage in the NOPR analyses to account for the efficiency losses associated with the AC-DC conversion process.

3.3.2.2 Impacts of Topology on Product Class Selection

As explained in the above discussion, battery voltage, battery energy, and the presence of certain input or output characteristics (*e.g.*, inductive charging) may impact the efficiency of battery chargers. However, since they also affect the capacity and utility of a charger, DOE must specify a separate standard level that takes into account any differences in energy consumption due to differences in these characteristics. Whereas this is straightforward in the case of inductive charging—*i.e.*, there can be separate product classes with separate standards, depending on whether a BC uses inductive charging—matters are more complicated in the case of battery voltage and battery energy.

Battery voltage depends on the number and chemistry of electrochemical cells in the battery; while battery energy further depends on the amount of active material in the battery (*i.e.*, its capacity). Because the size of the battery is infinitely variable, and the battery can contain a large number of cells, it is possible to establish an arbitrary number of product classes based on these criteria. While too many product classes would unnecessarily complicate the analysis and any resultant energy conservation standards, too few product classes may lead to product classes so large that the BCs that fall inside them have few characteristics in common. Because DOE conducts its standards analysis by estimating the cost impacts of increasing the efficiency of a representative unit, it is important that the product classes be delineated such that the products within the class are similar to the representative unit.

To resolve the question of product class size, DOE examined the topology, or underlying design, of the power converters that transform input voltage to DC voltage suitable for charging a battery. The power converter topology affects which technology options can be practically used to improve the efficiency of a BC. Even though converters of a given topology can vary depending on capacity and other requirements, many of the technology options will remain applicable. Basing its product classes on the underlying BC topology therefore allows DOE to focus its BC standards analysis on a representative unit within each product class and extrapolate the results for that unit to all products of a similar topology within the class.

3.3.2.3 Uninterruptible Power Supply Battery Chargers

Uninterruptible power supplies are used only for emergency situations when power is lost and users need time to safely shut down their electronic devices. Consequently, these devices generally do not fully charge a completely depleted battery. Additionally, these devices typically use integral batteries and generally remain on continuously. Because of its role in providing power in emergency situations, the battery chargers within these devices primarily remain in maintenance mode, which constitutes the most relevant portion of its energy consumption.

During manufacturer interviews with UPS producers, DOE discussed additional functionality as it pertains to these devices. Manufacturers suggested that DOE classify UPSs into three different categories: basic UPSs, UPSs that have automatic voltage regulation (AVR), and UPSs that are extended-run capable (i.e., the ability to attach a second battery to increase battery capacity within the UPS). After further investigation, DOE decided that two of these categories were appropriate and warranted separate standards, but the third category (extended-run UPSs), as it was simply representative of a change in battery capacity, could be accounted for through its scaling methodology.

AVR UPSs use circuitry that monitors input voltage from the wall and ensures that all products plugged into the UPS see a steady flow of voltage despite any fluctuations at the wall. This circuitry provides added utility to the consumer by preventing any spikes or dips in voltage, but it comes at the expense of additional power consumption by the UPS. This additional power consumption of the UPS is always on when the device is plugged in and it is indistinguishable from the power consumption due to the battery charger within the UPS.

To account for these characteristics, DOE has divided its preliminary analysis product class 10 into two product classes, one for basic UPSs and one for UPSs that contain AVR circuitry. However, even though DOE has created two product classes to account for these categories of UPSs, the underlying engineering analysis and other downstream analyses for both product classes is the same. This assumption was used because the addition of AVR is irrelevant to and inconsequential on UPS battery charger power consumption, yet it cannot be completely disaggregated from that battery charger power consumption due to the integrated nature of the circuitry components within a UPS. In other words, there is no technical reason why the battery charger within a basic UPS should be different from the battery charger within a UPS with AVR functionality. However, when the latter is tested via DOE’s battery charger test procedure (76 FR 31750), it will demonstrate a higher maintenance mode power consumption and will not be able to meet as stringent an energy efficiency standard as a basic UPS. Consequently, for all of DOE’s analyses in this technical support document, battery chargers for UPSs are examined as an aggregated product class, product class 10, rather than separately, however the proposed standard for each product class is different. DOE seeks comment on its analytical approach and whether separate classes are appropriate in this context.

3.3.2.4 Resultant BC Product Classes

DOE first divided BCs into three groups by type of input and output: those with AC input and DC output, those with DC input and DC output, and those with AC input and AC output.

While many factors influence the choice of topology—including experience of the designer, capabilities of the production facility, time to market, and cost of materials, among others—output power also has a significant effect. Since output power is correlated to battery energy, DOE researched power converter design guides and manufacturer literature and evaluated BCs for various applications, in an attempt to generalize the division of topologies by battery energy. Based on this initial review of topologies, DOE has divided BCs into three battery energy product classes:

i. **Battery energy less than 100 watt-hours.** Most BCs for consumer products charge batteries smaller than 100 watt-hours and typically rely on line-frequency and flyback designs. Batteries tend to have lithium-ion or nickel chemistries.

ii. **Battery energy greater than or equal to 100 watt-hours and less than 3,000 watt-hours.** BCs that charge batteries in this range tend to use forward and half-bridge power converter designs. They are used with wheelchair, marine, and lawn mower applications that rely on sealed lead-acid batteries.

iii. **Battery energy greater than or equal to 3,000 watt-hours.** BCs that charge batteries larger than 3,000 watt-hours tend to use ferro-resonant or full-bridge designs. They are used with only one consumer application, mobility—*i.e.*, golf cars and utility vehicles, which use flooded lead-acid batteries.

Battery energy (and therefore topology) is not the only factor that determines the practicality of technology options that can be used to increase the efficiency of a given BC. Battery voltage not only constrains which end-use consumer product a given BC can service, as mentioned above, it also impacts the design of the charger itself. In particular, while certain technology options may be practical at one voltage, the same may not be true at another voltage, even within the same topology.

Therefore, in the NOPR, DOE further divided the above battery-energy based product classes by voltage, dividing the low-energy product class (number I, above) into low-, medium-, and high-voltage product classes. Similarly, DOE divided the medium-energy product class (number II, above) into low- and high-voltage product classes. These product classes along with the others used for the BC preliminary analysis are shown in Table 3-30.

Table 3-30 BC Product Classes Analyzed

Input/Output Type	Battery Energy (Wh)	Special Characteristic or Battery Voltage	Product Class #	Example Applications
AC In, DC Out	< 100	Inductive Connection	1	Toothbrushes
		< 4 V	2	Telephones
		4 – 10 V	3	Cameras and Small Tools
		> 10 V	4	Laptops and Large Tools
	100 – 3000	< 20 V	5	Marine Chargers, Wheelchairs
		≥ 20 V	6	Electric Bikes, Lawnmowers
	> 3000	-	7	Golf Cars
DC In, DC Out	-	< 9 V Input	8	USB Chargers
	-	≥ 9 V Input	9	Car Chargers
AC In, AC Out	-	-	10a	Uninterruptible Power Supplies without AVR
AC In, AC Out	-	-	10b	Uninterruptible Power Supplies with AVR

3.4 TEST PROCEDURES

Section 323 of EPCA (42 U.S.C. 6293) sets forth generally applicable criteria and procedures for DOE's adoption and amendment of test procedures, which manufacturers of covered products must use to quantify the efficiency of their products and certify to the DOE that their products comply with EPCA energy conservation standards. Also, these test procedures must be used whenever testing is required in an enforcement action to determine whether covered products comply with EPCA standards.

DOE has adopted test procedures for both BCs and EPSs. These are described in turn in the sections below, along with a discussion of testing and efficiency metrics and their application to the analysis of achievable performance.

3.4.1 EPS Test Procedures

On December 8, 2006, DOE codified a test procedure final rule for EPSs in appendix Z to subpart B of 10 CFR Part 430 ("Uniform Test Method for Measuring the Energy Consumption of External Power Supplies"). 71 FR 71340. DOE's test procedure, based on the ENERGY STAR EPS test procedure, measures active-mode efficiency and no-load mode (standby mode) power consumption. In the standby and off mode test procedure NOPR for BCs and EPSs, 73 FR

48054 (August 15, 2008), DOE proposed to amend the EPS test procedure to add a measurement of power consumption in off mode, where, if the EPS has an on-off switch, the EPS is connected only to mains and the switch is turned off. These amendments were included in the final rule, published March 27, 2009. 74 FR 13335. DOE also amended the EPS test procedure as part of its revision to the BC test procedure. That final rule was published on June 1, 2011. 76 FR 31750.

Active-mode conversion efficiency is the ratio of output power to input power. DOE averages the efficiency of an EPS at four loading conditions—25, 50, 75, and 100 percent of maximum rated output current. DOE also measures the power consumption of the EPS when disconnected from the consumer product, which is termed no-load power consumption. If the EPS has an on-off switch, the switch is on when conducting the measurement.

3.4.2 BC Test Procedures

On December 8, 2006, DOE adopted a test method to measure the efficiency of battery chargers. 71 FR 71340. This test method, based on the U.S. Environmental Protection Agency's (EPA) ENERGY STAR "Test Methodology for Determining the Energy Performance of Battery Charging Systems," measures the power consumed by BCs in maintenance and no-battery modes, as well as the energy recovered from the battery during discharge, calculating an energy ratio.

In the December 8, 2006, Test Procedure Final Rule, DOE stated that it intended to study BC active-mode energy consumption in a future rulemaking and reserved a section in the test procedure (section 4(b) of appendix Y to subpart B of 10 CFR Part 430). 71 FR 71340, 71360. As a result, DOE published another test procedure final rule that amended certain provisions of the BC test procedures for determining maintenance mode and no-battery mode power consumption as well as added provisions for testing battery chargers in active mode and off mode. 76 FR 31750.

As previously mentioned, DOE has found that there are five modes of operation that a BC can be in at any given time. These modes of operation are: active (or charge) mode, maintenance mode, no-battery (or standby) mode, off mode, and unplugged mode. These five modes are defined below:

Active (or charge) mode: During active mode, a BC is charging a depleted battery, equalizing its cells, or performing functions necessary for bringing the battery to the fully charged state.

Maintenance mode: In maintenance mode, the battery is plugged into the charger has reached full charge and the BC is performing functions intended to keep the battery fully charged while protecting it from overcharge.

No-Battery (or standby) mode: In no-battery mode, the battery is not connected to the charger, but the BC itself is still plugged into mains.

Off mode: In off mode, the charger remains connected to mains power, but the battery is removed and all manual on-off switches are turned off.

Unplugged mode: In unplugged mode, the BC is disconnected from mains and therefore not consuming any electrical power.

For each BC mode of operation, DOE's new BC test procedure (76 FR 31750) has a corresponding test that is performed that outputs a metric for energy consumption in that mode. The description of the tests to perform to obtain these metrics can be found in said BC test procedure. Below is a brief description of the pertinent performance parameters that come from those tests.

24-Hour Energy: This quantity is defined as the power consumption integrated with respect to time of a full metered charge test that starts with a fully depleted battery. In other words, this is the energy consumed to fully charge and maintain at full charge a depleted battery over a period that lasts 24 hours or the length needed to charge the tested battery plus 5 hours, whichever is longer.

Maintenance Mode Power: This is a measurement of the average power consumed while a BC is known to be in maintenance mode.

No-Battery (or standby) Mode Power: This is a measurement of the average power consumed while a BC is in no-battery or standby mode (only if applicable).

Off-Mode Power: This is a measurement of the average power consumed while a BC is in off mode (only if applicable).

Unplugged Mode Power: This quantity is always 0.

This amended test procedure stops the use of the non-active energy ratio in favor of the metrics related to energy consumption in each of the BC modes of operation. As described above, these include active, maintenance, standby, and off modes; thus, the test procedure returns four separate metrics. How these four mode-specific metrics are combined for the purpose of an energy conservation standard is discussed further in chapter 5.

3.5 TECHNOLOGY ASSESSMENT

3.5.1 Introduction

This technology assessment examines EPS and BC technology, with a focus on the factors affecting their efficiency. It begins by explaining the purpose of EPSs and BCs and their modes of operation (sections 3.5.2 and 3.5.7). Next, the technology assessment reviews efficiency metrics established for assessing the performance of EPSs and BCs in the major energy-consuming modes of operation (sections 3.5.2.1 and 3.5.8). Finally, the assessment discusses the designs necessary for EPSs and BCs to perform their required function (sections 3.5.5 and 3.5.9), and the technology options available to improve the performance of those designs against the energy efficiency metrics (sections 3.5.6 and 3.5.10). In chapter 4, the screening analysis, DOE discusses its review of these technology options and which ones pass DOE's screening criteria and are considered further in the engineering analysis.

3.5.2 EPS Modes of Operation

3.5.2.1 EPS Active Mode

In active mode, the external power supply takes power from mains and converts it to a form usable by the consumer product or load. Since the determination analysis, DOE has used the definition of active mode codified in 10 CFR part 430 subpart B appendix Z: “Active mode is the mode of operation when the external power supply is connected to the main electricity supply and the output is connected to a load.”

In this mode, EPS efficiency is the conversion efficiency when the load draws some or all of the maximum rated output power of the EPS. To provide that output power, the EPS also consumes power due to internal losses as well as overhead circuitry. The amount of power the EPS consumes varies with the power demands of the load; together, those two parameters define the EPS’s efficiency at a particular loading point:

$$\eta_{EPS} = \frac{P_{out}}{P_{In}} = \frac{P_{out}}{P_{out} + P_{EPS\_consumption}} \qquad \textbf{Eq. 3.1}$$

EPS efficiency varies with the amount of output power. Typically, EPS efficiency is lower between 0 and 20 percent of maximum rated output power and higher between 20 and 100 percent of maximum rated output power, where EPSs tend to operate. The lower efficiency at lower output current is due to the proportionally larger power consumption of internal EPS components, relative to output power. At higher power, EPS overhead losses increase slightly, but have less of an effect on EPS efficiency than losses associated with power conversion. The EPS test procedure evaluates active-mode conversion efficiency at four loading points: 25 percent, 50 percent, 75 percent, and 100 percent of maximum rated output power, which captures a general picture of EPS efficiency. Figure 3.8 shows an example of a typical efficiency curve for an EPS in active mode.

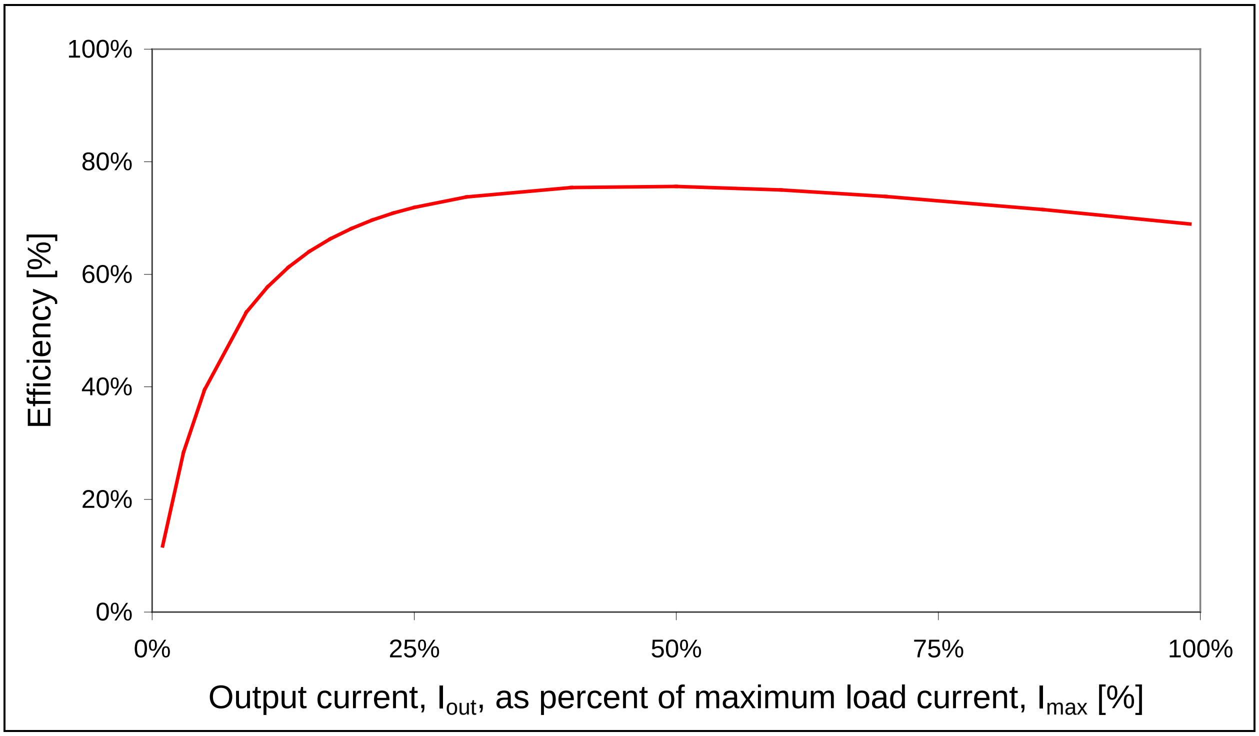


Figure 3.8 Example of an Efficiency Curve of an EPS in Active Mode

3.5.2.2 EPS No-Load Mode

Since the determination analysis, DOE has used the definition of no-load mode codified in 10 CFR part 430 subpart B appendix Z: "No load mode means the mode of operation when the external power supply is connected to the main electricity supply and the output is not connected to a load."

EPS efficiency in no-load mode is characterized by EPS power consumption, rather than conversion efficiency because the EPS does not deliver power to the load in this mode. However, the EPS might provide functionality. For example, certain consumer products may require the EPS to deliver output power within moments of being connected. Thus, the EPS may consume power to provide the useful function of reduced start-up time. Nonetheless, EPS power consumption can be low (less than 0.5 watts) in no-load mode.

3.5.3 EPS Efficiency Metrics

An evaluation of the technology options for efficiency improvement and the tradeoffs between them depends on the metrics used. DOE has previously adopted test procedures for measuring the energy consumption of both EPSs and BCs.[x] This section presents a brief overview of the test procedures for EPSs, and any issues related to the test procedures that may affect the energy conservation standards rulemaking. See section 3.5.8 for a similar discussion of BCs.

---

[x] 10 CFR Part 430 Subpart B Appendix Y and Appendix Z

3.5.4 Energy Efficiency Metrics for External Power Supplies

On December 8, 2006, DOE codified a test procedure final rule for EPSs in Appendix Z to Subpart B of 10 CFR Part 430 (“Uniform Test Method for Measuring the Energy Consumption of External Power Supplies.”) DOE’s test procedure, based on the California Energy Commission (CEC) EPS test procedure, measures active-mode efficiency and no-load-mode (standby-mode) power consumption.

Active-mode conversion efficiency is the ratio of output power to input power. DOE averages the efficiency at four loading conditions—25, 50, 75, and 100 percent of maximum rated output current—to assess the performance of an EPS when powering diverse loads. DOE also measures the power consumption of the EPS when disconnected from the consumer product, which is termed no-load power consumption. DOE combines both of the above metrics into “matched pairs” that describe the candidate standard levels considered in setting potential energy conservation standards. This “matched pairs” combination affected the analysis and is discussed further in Chapter 5, Engineering Analysis.

3.5.5 EPS Designs

EPS’s must meet several specifications in order to power a consumer product; EPSs are generally designed to provide power at a fixed output voltage with variable current to a consumer product. The consumer product is what determines the EPS design criteria, including output power, output voltage and the tolerance of the output voltage. EPSs designed for consumer products that require precise voltages (*e.g.*, computers) will also incorporate output voltage regulation to minimize voltage fluctuations caused by load or power source variations. Other applications that can tolerate voltage fluctuation may use simpler EPSs that do not regulate the output voltage as tightly.

Together, output power and output voltage determine the current, which has the greatest impact on conduction losses and associated power dissipation in the EPS.

Unregulated and two-stage regulated EPSs are called line-frequency EPSs because the frequency of the current passing through their transformers is the same as that of the AC mains current (nominally 60 Hz in the United States). Switched-mode power supplies (SMPS) convert power differently than line-frequency EPSs. SMPSs first rectify the AC mains voltage to DC, converting it back to AC by switching the current on and off at high frequency. The high-frequency AC current then passes through the primary winding of a transformer while the output from the secondary winding of the transformer is rectified, resulting in a low-voltage DC output. Because of the high frequency of the AC current passing through the transformer, the transformer can be made smaller, resulting in lower weight, material costs, and losses in the transformer.

3.5.5.1 AC/AC External Power Supplies

An AC/AC external power supply is the simplest type of EPS, typically consisting only of a transformer. A transformer contains two wires wrapped around a metal core; as current passes through the primary wire, power is transferred to the secondary wire (usually at a lower voltage) through magnetic induction in the core. The induced voltage depends on the relative number of turns between the primary and the secondary wires. The windings of the transformer are wound so that the voltage generated in the secondary wire is at the design voltage for the consumer product when mains voltage is applied to the primary wire. Because the primary and secondary windings are two separate wires, the transformer also provides a safety function, electrically isolating the consumer product from mains. The key factors that determine transformer losses are core size, core material, number of windings, and wire gauge.

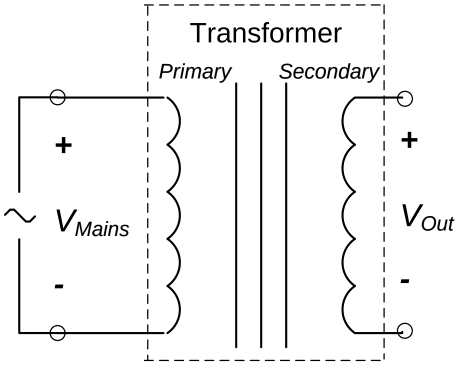


Figure 3.9 Circuit Diagram for an AC/AC External Power Supply

3.5.5.2 Unregulated Line-Frequency AC/DC External Power Supplies

In unregulated line-frequency EPSs, the two main sources of loss are the transformer and the rectifying diodes. After passing through the transformer, current passes through rectifier diodes, which have voltage drops that also dissipate power. Typically, diodes have a drop of 0.6 volts, which constitutes a proportionally larger share of the losses at lower output voltages. For AC-DC EPS that have a low output voltage, below approximately 12 V the power consumed by the diodes also becomes significant. A line-frequency raw supply has three distinct stages (Figure 3.10): a transformer to isolate and step down mains voltage, a rectifier to convert AC voltage to DC voltage, and a filter capacitor to smooth the output voltage.

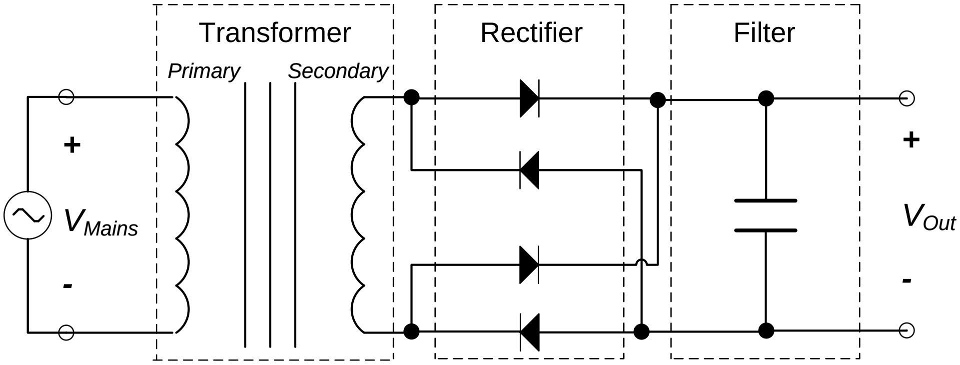


Figure 3.10 Circuit Diagram of a Line-Frequency Raw Supply

The raw supply, consisting of a transformer, rectifier, and filter capacitor, is directly responsive to the load. A change in mains power or the resistance of the load directly affects the output voltage of the raw supply. If required, a regulator circuit follows the raw supply circuit, housed either in the EPS or in the end-use product before the load.

3.5.5.3 Linear-Regulated Line-Frequency AC/DC External Power Supplies

To achieve voltage regulation, manufacturers can add a second stage, such as a linear regulator, to the line-frequency power conversion stage described above, or redesign the power conversion stage entirely using a switched-mode topology. Of the two regulator technologies, linear regulators are simpler, bulkier, cheaper, and generally less efficient at higher power levels than switching regulators. Switching regulators, although more complicated and costly, provide a good alternative when portability or over-heating is a concern, such as when an EPS is used with a mobile phone charger or a high-power flat-panel television.

The AC-DC conversion stage of a regulated line-frequency EPS is essentially the same as that of an unregulated EPS, with the same sources of power consumption. The linear voltage regulation stage adds to these losses by passing power from the AC-DC converter to the consumer product through a power-dissipating element. This regulation stage senses the output voltage and adjusts the voltage across it to keep the output voltage proportional to a fixed reference voltage. Loss in a regulated line-frequency EPS is caused by the conversion stage delivering current at a higher voltage than needed by the consumer product, and dropping the excess voltage across the regulator to achieve the lower regulated output voltage. Dissipated as heat, the power lost in the regulator is the product of the voltage drop and the load current.

Linear regulators have two key elements: a sensor and a pass device, which work together to produce a fixed output voltage (Figure 3.11). To determine those adjustments, the sensor element continuously compares the output voltage to a reference voltage. Whenever there is a difference between the two voltages, the sensor directs the pass device to adjust the output in order to reduce that difference. This continuous adjustment allows the regulator to yield a constant output voltage as the load resistance or mains voltage varies. The output voltage of the linear regulator circuit is what the user sees as the output voltage of the EPS.

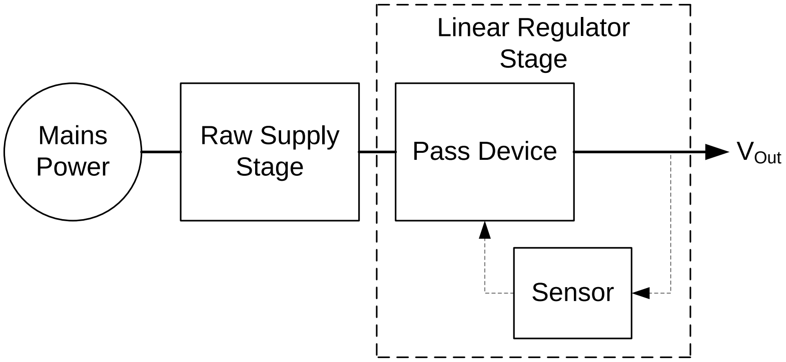


Figure 3.11 Block Diagram of a Linear Regulator

Figure 3.12 shows a circuit diagram of a “low-dropout” linear regulator, one of the more common types of linear regulators. To determine that voltage drop, an operational amplifier (commonly referred to as an “op-amp”) acts as a sensor that compares the output voltage against a reference voltage. Based on those two signals, the op-amp controls a transistor, which is the pass device. The voltage drop across the transistor determines the output voltage but also dissipates energy. The energy dissipated by the pass device is the main source of energy consumption in the linear regulator, and hence the main source of inefficiency and heat generation. Together, the sensor and the pass device adjust the output of the regulator to produce a relatively stable output voltage, which is what the load receives as the output voltage of the EPS.

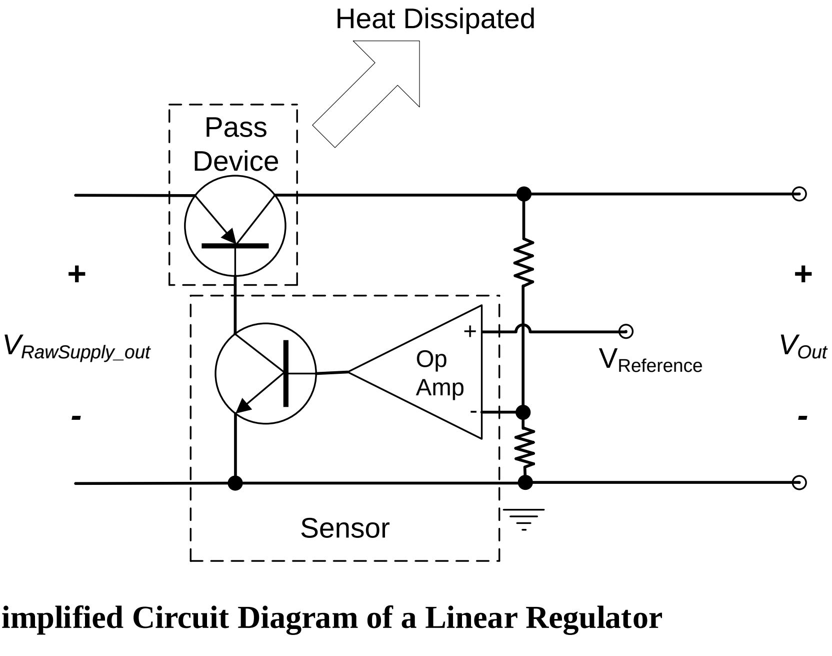


Figure 3.12 Simplified Circuit Diagram of a Linear Regulator

The efficiency of the linear regulator, η_{LinReg}, is:

$$\eta_{LinReg} = \frac{P_{LinReg\_out}}{P_{LinReg\_in}} = \frac{V_{LinReg\_out} I_{LinReg\_out}}{V_{LinReg\_in} I_{LinReg\_in}} \quad \textbf{Eq. 3.2}$$

where

P_{LinReg_out} is the power out of the linear regulator,
P_{LinReg_in} is the power into the linear regulator,
V_{LinReg_out} is the voltage out of the linear regulator,
V_{LinReg_in} is the voltage into the linear regulator,
I_{LinReg_out} is the current out of the linear regulator, and
I_{LinReg_in} is the current into the linear regulator.

Because the linear regulator connects to the raw supply, V_{LinReg_in} is equal to $V_{RawSupp\_out}$, the output voltage of the raw supply. Furthermore, because the input current flows directly to the output through the pass device, with other currents being negligible, $I_{LinReg\_out} \approx I_{LinReg\_in}$. Therefore, the efficiency of the linear regulator alone is approximately:

$$\eta_{LinReg} \approx \frac{V_{LinReg\_out}}{V_{LinReg\_in}} \qquad \textbf{Eq. 3.3}$$

The total efficiency of an EPS with a linear regulator depends on the efficiency of both the linear regulator stage and the raw supply stage. Depending on the load conditions, η_{LinReg} generally ranges from 0.6 to 0.8, meaning the linear regulator is about 60 to 80 percent efficient. The efficiency of the raw supply, η_{RawSup}, also varies with the load, but is generally from 0.7 to 0.9. The raw supply and linear regulator each are most efficient at different load conditions. Multiplied, η_{LinReg} and $\eta_{RawSupp}$ yield the total efficiency of an EPS with a linear regulator, η_{Lin_EPS}, which is generally about 50 percent, but is lower for EPSs with output power below 10 W:

$$\eta_{Lin\_EPS} = \eta_{RawSupp} * \eta_{LinReg} \qquad \textbf{Eq. 3.4}$$

For an EPS consisting of a raw supply and a linear regulator, mains voltage at line frequency (60 Hz) is directly applied to the transformer. If the power applied to the transformer had similar voltage and current characteristics but a higher frequency, the transformer could be smaller and lighter. Those benefits are part of the motivation for choosing switching regulators, which, unlike their linear counterparts, have transformers that operate at high frequency (greater than 20 kHz).

3.5.5.4 Switching-Regulated Line-Frequency AC/DC External Power Supplies

A switching regulator can also follow the line-frequency AC-DC power-conversion stage in place of the linear regulator described above, which is different from the switched-mode EPS discussed below. These tend to be much more efficient than linear regulators because they do not dissipate excess power through a linear control element. Rather, they switch the current at high frequency, adjusting the proportion of on time during each switching cycle (*i.e.*, the duty ratio) to maintain the regulated output voltage proportional to a fixed reference. Due to their higher costs, these switching regulators tend not to be as common as linear regulators.

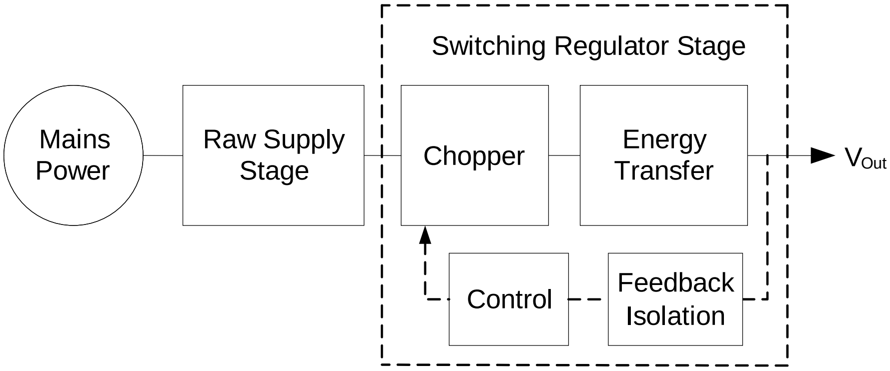


Figure 3.13 Block Diagram of a Switching-Regulated Line-Frequency AC/DC EPS

3.5.5.5 Switched-Mode AC/DC External Power Supplies

The most common method for regulating power to a consumer product is a switched-mode EPS. The critical elements in a switched-mode EPS are the transistor, output rectifier, bulk capacitor, transformer, and controller. A transistor acts as a switch that constrains the flow of power rectified from mains into the transformer (or choke), through the output rectifier, and, ultimately, to the consumer product. A controller, typically an integrated circuit (IC), switches the transistor on and off based on the output voltage. By adjusting the duty ratio, the IC controls the rectified mains current into the primary winding of the transformer and thereby the output voltage of the EPS. The IC can also limit power dissipation in active mode by switching at low current or low voltage. Further, the IC can greatly increase efficiency by reducing power consumption in no-load mode, the condition when the EPS has been disconnected from the load, resulting in zero output current. After passing through the transformer, the current is rectified and filtered before reaching the consumer product. Principal sources of loss in a switched-mode EPS are the transistor switching transients, magnetization and resistive losses as a result of transformer current, controller IC power consumption, and rectifier losses. Although there are more sources of loss for switched-mode EPSs than line-frequency EPSs, in total, losses in switched-mode EPSs tend to be lower.

The switching regulator consists of five stages: an AC-DC conversion stage, a chopper stage, an energy transfer stage, a control stage, and a feedback isolation stage (Figure 3.14). First, the current is rectified and passed to the chopper, which converts the DC voltage back to AC, but at high frequency. The energy transfer stage then takes energy from the chopper, briefly stores it, and then passes it to the rectifier to be output to the consumer product. The energy transfer stage also serves to isolate the user from the mains. The level of the output voltage is fed back through an isolation stage to the controller, which tracks the output voltage and adjusts the chopper to make the desired voltage.

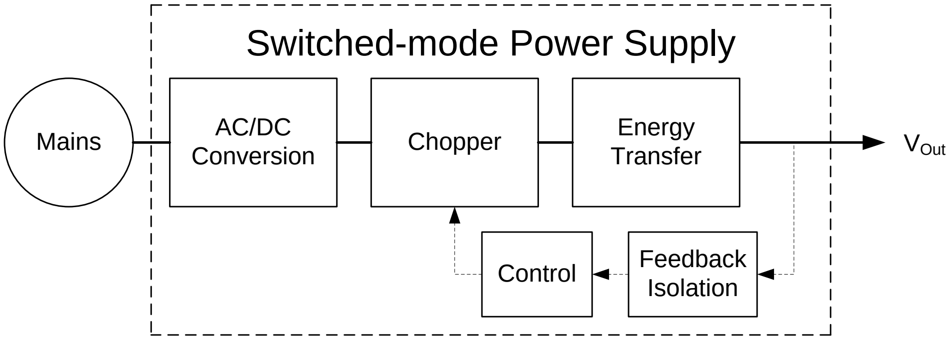


Figure 3.14 Block Diagram of a Switched-Mode Power Supply

The switching regulator usually consists of an integrated circuit controller and discrete components. The circuit diagram in Figure 3.15 depicts a “flyback” switching regulator, one of the more common types; however, many other switching regulator designs also exist. The AC/DC conversion stage consists of a diode bridge and filter capacitor, similar to a raw supply. In this case, current flows directly from mains to the diode bridge, rather than through a transformer.

The chopper stage uses a transistor, which switches on and off at high frequency to convert the DC current from the AC/DC converter back to an AC current for the energy transfer stage. A control stage drives the transistor, where the longer its on time in the duty cycle, the more energy is transferred. The switching frequency is in the kilohertz range, with lower frequencies having lower switching losses. Typically, the minimum frequency is 20 kHz, above the audible range of human hearing.

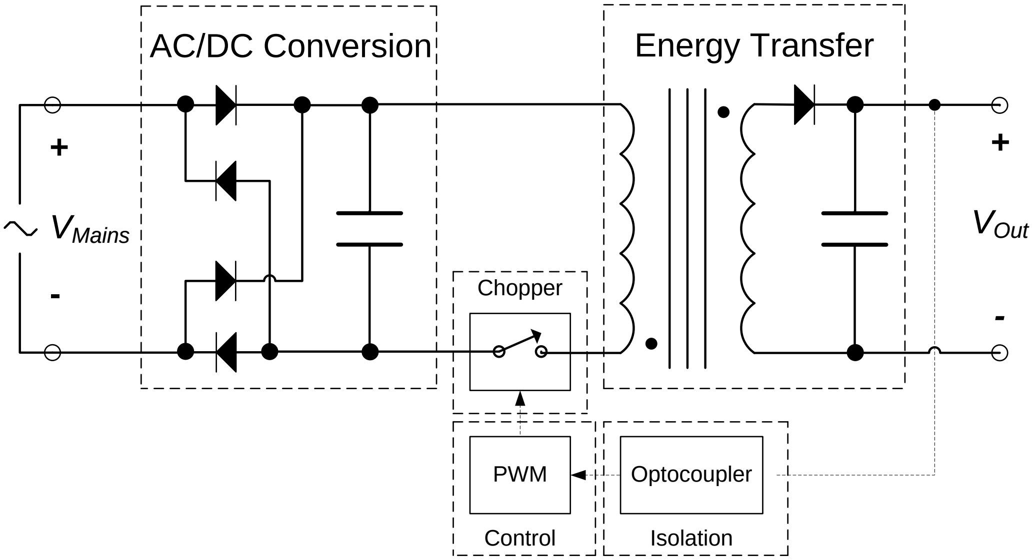


Figure 3.15 Simplified Circuit Diagram of a Flyback Switching Regulator

The energy transfer stage consists of a choke, a capacitor, and a diode. The choke is similar to a transformer and has the same symbol in the circuit diagram. One difference is that a transformer in a line-frequency EPS is designed to pass energy from one winding to another with minimal energy storage, while a choke in a switched-mode EPS is designed to store and release energy. Also, the phasing of the windings is not important in the line-frequency transformer, but it is critically important in the flyback switching regulator. This is represented in Figure 3.15 by dots on the choke.

When the chopper switch is closed, the primary winding of the choke takes energy from the chopper and stores the energy in the choke. When the chopper switch opens, the secondary winding transfers that energy through the diode to the capacitor and provides the output for the switching regulator, electrically isolating the load from the mains. Because the choke operates at a high frequency, it benefits from the associated decreases in size and weight. The energy transfer scheme of the switching regulator is more efficient than a linear regulator, in part because the choke stores and returns energy with relatively low losses.

The isolation stage typically uses an optocoupler that consists of a light source and a photosensitive detector. By converting the electrical feedback signal to an optical one, the optocoupler maintains the load electrically isolated from the mains. The detector converts the optical signal back to an electrical signal that it provides to the controller.

Generally, the controller is an integrated circuit that drives the chopper with a high-frequency pulse-width-modulated (PWM) waveform. The controller monitors the EPS output voltage and adjusts the pulse width to increase or decrease the amount of energy transferred by the chopper. If the output voltage dips, the controller will increase the duty cycle, thus increasing the energy passed by the energy transfer stage and increasing the output voltage. Conversely, if the output voltage rises, the controller will decrease the duty cycle or possibly skip cycles. This cycle-skipping feature is especially useful when there is no load attached, because the EPS will only take from the mains the small amount of power it needs to power itself.

Instead of an IC controller, a switched-mode EPS can also use discrete components, as in the case of a ringing choke converter. In that topology, discrete transistors control the chopper and the resulting energy transfer. EPSs without ICs tend to be more common at lower output powers. However, without an IC, an EPS cannot offer functions such as cycle-skipping at low load, which can be used to decrease losses.

Both linear-regulated and switching-regulated EPS use regulating circuits to achieve a stable output voltage. However, voltage is not the only output variable that can be regulated. Current regulation, as discussed in the following section, is a fundamental consideration in BC design.

3.5.6 EPS Technology Options

DOE considered seven technology options that may improve the efficiency of EPSs:

- *Improved Transformers.* In line-frequency EPSs, the transformer has the largest effect on efficiency. Transformer efficiency can be improved by replacing their cores and windings with ones made of lower-loss material or adding extra material.

- *Switched-Mode Power Supply*. Line-frequency EPSs may use linear regulators to maintain a constant output voltage. By using a switched-mode circuit architecture, a designer can limit both losses associated with the transformer and the regulator. The differences between the two EPS types are discussed in section 3.5.5.3 and section 3.5.5.4.

- *Low-Power Integrated Circuits.* The efficiency of the EPS can be further improved by substituting low-power IC controllers, which can switch more efficiently in active mode and reduce power consumption in no-load mode. For instance, the IC can turn off its start-up current (sourced from the primary side of the power supply) once the output voltage is stable. In addition, when in no-load mode, the IC can turn off the switching transistor for extended periods of time (termed "cycle-skipping").

- *Schottky Diodes and Synchronous Rectification.* Both line-frequency and switched-mode EPSs use diodes to rectify output voltage. Schottky diodes and synchronous rectification can replace standard diodes to reduce rectification losses, which are increasingly significant at low voltage. Schottky diodes have a voltage drop of 0.3–0.4 volts, compared to approximately 0.6 volts for standard diodes. Synchronous rectification (typically only used in switched-mode EPSs) further reduces losses by substituting transistors for the diodes. The voltage drop across the drain-to-source resistance of transistor is much lower than that across even a Schottky diode, leading to lower losses in the output rectifier.

- *Low-Loss Transistors*. The switching transistor dissipates energy due to its drain-to-source resistance (R_{DS_ON}) when the current flows through the transistor to the transformer. Using transistors with low R_{DS_ON} can reduce this loss.

- *Resonant Switching.* In addition to reducing the R_{DS_ON} of the transistor, power consumption can be lowered further by the IC controller decreasing switching transients through zero-voltage or zero-current switching. The power consumption of the transistor is influenced by the voltage across the R_{DS_ON} and the current flowing through it. An IC can control the switching to minimize that voltage or current, although some components in addition to the IC may also be needed.

- *Resonant ("Lossless") Snubbers*. In switched-mode EPSs, a common snubber protects the switching transistor from the high voltage spike that occurs after the transistor turns off by dissipating that power as heat. A resonant or lossless snubber recycles that energy rather than dissipating it.

3.5.7 BC Modes of Operation

Like the design of EPSs, the design of BCs is driven by the anticipated power requirements and time spent in their various modes of operation. Section 325(gg)(1)(A) of EPCA, as modified by EISA, defines active, standby, and off modes for consumer products in general. (42 U.S.C. 6295(gg)(1)(A)) However, section 2 of appendix Y to 10 CFR part 430[42] (hereafter referred to as appendix Y) defines additional modes as well as redefines some of the EISA modes to be more applicable to BCs (as allowed under 42 U.S.C. 6295(gg)(1)(B))

3.5.7.1 Active or Charge Mode

Active mode is defined as “the condition in which an energy-using product–(I) is connected to a main power source; (II) has been activated; and (III) provides 1 or more main functions.” (42 U.S.C. 6295(gg)(1)(A)(i)) However, paragraph 2.i of appendix Y further specifies that the charger is in active mode specifically when charging a depleted battery, equalizing its cells,[y] or “performing other one-time or limited-time functions necessary for bringing the battery to the fully charged state.”

3.5.7.2 Maintenance Mode

Once the batteries have reached full charge, the BC typically enters a *maintenance mode*, intended to maintain the fully charged state of the battery, while protecting it from overcharge. BCs without a maintenance mode (some high-power BCs for consumer motive equipment, for example) either use a timer to disconnect the BC from the batteries after charging or rely on the user to manually disconnect.

3.5.7.3 Standby or No-Battery Mode

Alternatively, following a full charge, the user can remove the battery (or in the case of integral-battery products, the end-use product *and* the battery), placing the battery charger in standby or no-battery mode. Typically, the BC is in the mode when the application it serves is in use; however, the user may also place the BC in off mode, or disconnect it from mains entirely.

---

[y] Equalization serves to balance the voltage across each of the cells in a multi-cell battery, a process that is most commonly performed with large lead-acid batteries. Unbalanced cells limit charge and discharge, reducing the usable capacity; they can also suffer more overcharge than the other cells.

3.5.7.4 Other Modes and Applicability

Appendix Y defines standby or no-battery mode as “the condition in which (1) the battery charger is connected to the main electricity supply; (2) the battery is not connected to the charger; and (3) for battery chargers with manual on-off switches, all such switches are turned on.” However, if (1) the charger remains connected to mains, (2) the battery is removed, and (3) all manual on-off switches are turned off, the charger is then placed in *off mode*.

Because it has purposely been disabled by the user via a switch, the BC must no longer perform standby-mode functions such as powering circuitry that detects the presence of a battery or indicates its status. It therefore has the potential to consume less energy than in standby mode. Finally, the user can also disconnect the charger from mains, in which case it does not consume any energy.

Whether each of the modes described above apply to a particular BC depends on whether the battery is integral or detachable, the presence of manual on-off switches, etc. For example, BCs without a manual on-off switch cannot be placed in off mode, while a BC with a non-removable AC cord and integral batteries that are not removed from the application for charging cannot be placed in no-battery mode.

Nonetheless, all BCs operate in the active or charge mode by definition. This mode has the largest effect on the BC’s size and efficiency because the charger must be designed to accommodate the maximum amount of power output, which happens during active mode. While the requirements of the other modes factor into the design as well—as does the chemistry of the battery—their effects on efficiency are not as great, since they don’t affect the power handling components, but rather sub-circuits tasked with assessing the state of charge and ensuring safety.

3.5.8 BC Efficiency Metrics

On December 8, 2006, DOE adopted a test method to measure the efficiency of battery chargers. 71 FR 71340. This test method, based on the U.S. Environmental Protection Agency’s (EPA) ENERGY STAR “Test Methodology for Determining the Energy Performance of Battery Charging Systems,” integrates the power consumed by BCs in maintenance and no-battery modes over fixed periods of time. This “non-active energy” is divided by the battery energy, measured at a discharge rate of 0.2 C, resulting in an energy ratio. Normalizing by battery energy is meant to account for proportionally higher losses in chargers intended for higher-energy batteries. A higher energy ratio represents higher BC non-active energy consumption.

However, in the December 8, 2006, Test Procedure Final Rule, DOE stated that it intended to study further BC active-mode energy consumption and reserved a section in the test procedure (section 4(b) of appendix Y to subpart B of 10 CFR Part 430) to cover measurement of active-mode energy consumption. 71 FR 71340, 71360. DOE has continued developing its approach for measuring BC active—*i.e.*, charging—mode energy consumption and on June 1, 2010 published a final rule adopting an active-mode test procedure based on a test procedure previously adopted by the California Energy Commission.76 FR 31750.

This amended procedure stops the use of the non-active energy ratio in favor of metrics corresponding to energy consumption in each of the energy-consuming modes of operation of a

BC. As described above, these include active, maintenance, standby, and off modes; thus, the test procedure returns four separate metrics. These separate metrics are weighted by an average usage profile[z] that reflects the typical usage of BCs in each product class. For the analysis in this TSD, DOE used these metrics to evaluate BC efficiency.

The potential energy conservation standards for each class will likewise be written in terms of a single metric, even though the test procedure would measure consumption in each of the modes separately. Manufacturers will then be free to trade off power consumption in one mode for that in another, as long as they meet the usage-weighted energy consumption required by the standard.

3.5.9 Battery Charger Design

The design of a battery charger depends on the application it serves, and as mentioned in the discussion of product classes in section 3.3, specifically its voltage and energy requirements. As a result, the design of battery chargers varies with product class, which is defined by battery voltage and energy. Therefore, following a brief introduction, this section will be divided by product class.

A general schematic of a battery charging system (BC and battery) can be seen in Figure 3.16. As indicated in the figure, the primary function of a BC is regulating the flow of current from a power supply to a battery to safely charge the battery and maintain its charge.

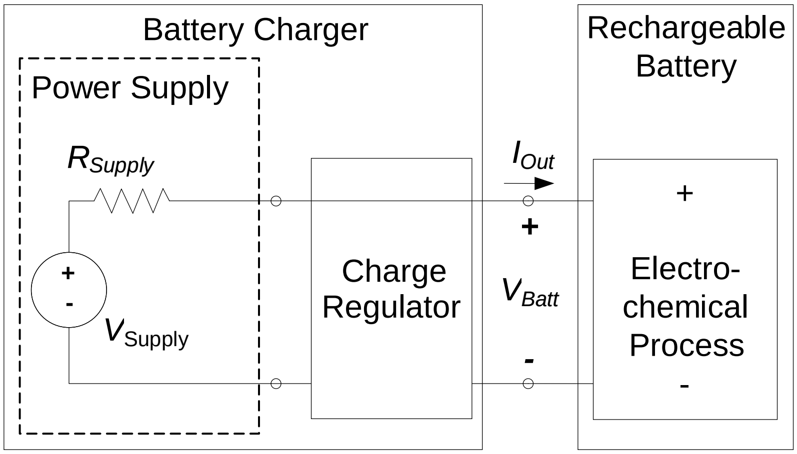


Figure 3.16 General schematic of a BC and battery.

As depicted in Figure 3.16, the first stage of most BCs is a power supply that converts line-voltage AC power to DC power at a voltage low enough to charge the battery (through a charge regulator) as well as power any overhead circuitry in the charger responsible for safety and other user function (*e.g.*, status indicators, etc.; not pictured in the figure). Because of this general AC/DC conversion requirement, the design of the input power supply stage often mimics

---

[z] The calculation of product-class-average usage profiles and the calculation of typical energy consumption is described in detail in the energy use analysis (chapter 7).

that of the EPSs described in section 3.5.5, in particular unregulated line-frequency AC/DC and various switched-mode AC/DC designs, including flyback. This power supply stage can be either internal (*i.e.*, in the same enclosure as the rest of the BC circuitry) or in an external wall adapter. Although the circuits are similar, the key difference between an EPS and a BC is charge control. An EPS is designed to provide output current so as to maintain a constant output voltage to the load. In contrast, a BC provides power to a battery that may either be constant current or constant voltage, depending on the state of the battery. Further, a battery sets a voltage in the BC circuit, whereas a load does not set a voltage for an EPS.

Methods of improving BC efficiency depend on whether the BC is a slow charger or a fast charger. The distinction between the two types of BCs is based on the charge rate (also referred to as C-rate), often defined as the average charging current flowing into the battery, divided by the nominal battery charge capacity. For current expressed in amperes and battery capacity expressed in ampere-hours, the resulting quantity is expressed in units of 1/hours or C. For example, a BC with a 0.2 ampere (A) output current charging a 2 ampere-hour (Ah) battery would result in a charge rate of 0.1 C. Charging time is approximately the inverse of the charge rate, adjusted for the efficiency of the battery itself, which varies with chemistry. In the previous example, the battery would take slightly longer than 10 hours to charge.

DOE considers BCs with charge rates less than 0.2 C (typically around 0.1 C) to be slow chargers. At this low charge rate, nickel-based batteries can be charged continuously without concern for excessive battery overheating or safety. Slow chargers do not typically include cutoff or monitoring circuitry. However, as the battery nears full charge and its voltage increases, the difference between the BC output and battery voltages decreases and the charge-control resistance used in a slow charger will cause the charging current to decrease. This reduces power consumption and lessens battery heating due to overcharge (thereby extending battery life). Slow chargers are not typically used in combination with lithium-based batteries, because of the safety concerns associated with overcharging lithium-based batteries.

Slow chargers are typically composed of a line-frequency transformer followed by a rectifier and charge-control element. The function of the charge-control element is to limit charging current into the battery, which can be accomplished by either a discrete resistor or the parasitic internal resistance of the transformer windings. The power conversion losses in a slow charger are mostly due to magnetization losses in the transformer core steel, resistive losses in the charge-control element, and voltage drops across the rectifier diodes.

In addition, slow chargers typically continue to deliver current to the battery even after it is fully charged, usually at a rate much higher than that necessary to maintain the charge lost due to battery self-discharge. The excess power is dissipated as heat in the battery. The power conversion losses in the BC identified earlier continue to have an impact in this maintenance mode, further increasing power consumption. Even in no-battery mode, when the battery is disconnected from the charger, the slow charger continues to consume significant power due to the transformer magnetization losses. For a detailed discussion of slow-charger power consumption in all modes, please see sections 3.3 and 3.5 of the draft technical report that accompanied the Framework Document published on June 4, 2009. 74 FR 26816.

A battery charger that contains monitoring, cutoff, or limiting circuitry can safely charge lithium-based batteries and fast-charge nickel-based batteries. DOE considers BCs with charge rates greater than 0.2 C (typically between 0.6 C and 1 C) to be fast chargers. Because the charge rate of fast chargers is much greater than that of slow chargers, the maximum rated output power of a fast charger can be 5 to 20 times greater than that of slow chargers, even when charging a battery of the same voltage and capacity. For this reason, fast chargers typically use switched-mode power supplies, which are smaller and lighter than line-frequency power supplies. Fast chargers also employ monitoring and cutoff circuitry, as the high currents used during charging may overheat the battery and lead to a safety hazard if not reduced at the proper time. Because of these design differences, fast chargers are composed of more complex circuits and are susceptible to different loss mechanisms than slow chargers.

The high-frequency switched-mode power supply (whether internal or external) that typically performs the energy conversion in a fast charger is usually more efficient than the line-frequency transformer and rectifier discussed previously. High-frequency power supplies can use transformer cores made of ferrite that are smaller and more efficient than the steel cores typically found in line-frequency designs. However, there are still conversion losses associated with switching and rectification, as well as fixed overhead losses associated with powering the IC switching controller and any safety circuitry. Also, although fast chargers terminate (*i.e.*, limit charging current once the battery has reached full charge), most chargers continue to supply a small amount of maintenance current. As with slow chargers, this maintenance current and the associated conversion losses contribute heavily to maintenance-mode power consumption. Finally, even with the battery removed, the charger can continue consuming significant power due to the overhead of powering the control and safety circuitry mentioned above. For a more detailed discussion of fast-charger power consumption, please see sections 3.3 and 3.5 of the draft technical report.

Further, manufacturers may, and often do, choose to substitute a fast charger for a slow one as a means of improving portability and energy efficiency. Because both types of chargers can often be used with the same battery powering the same consumer product, they provide the same utility to the consumer, which means the fast charger can be considered a replacement for a slow charger.

Finally, because changes in battery temperature and voltage happen more slowly at lower charge rates, monitoring circuitry that depends on these changes to stop the charging process is typically not sensitive enough to be used at rates below 0.3 C. Therefore, although DOE differentiates between BCs with charge rates greater than or less than 0.2 C, DOE does not expect to find many BCs with charge rates between 0.15 C and 0.3 C.

3.5.10 Battery Charger Technology Options

Battery charger efficiency in active mode is governed by BC component losses and overhead circuitry. BCs share with EPSs similar options for reducing component losses in active mode. However, some BCs have safety circuitry to monitor the battery during charging, which EPSs typically do not include. Safety circuits are often present in BCs that are fast chargers; safety concerns also affect design of slow charging BCs. Thus, if a BC were compared to an EPS with similar power ratings, it might appear to have lower conversion efficiency due to the additional power consumption of its safety circuitry.

The following list, organized by charger type, provides technology options that DOE evaluated during the NOPR. Although many of these technology options could be used in both fast and slow chargers, doing so may be impractical due to the cost and benefits of each option for the two types of chargers. Therefore, in the list below, the options are grouped with the charger type where they would be most practical.

Slow charger technology options include:

- *Improved Cores*: The efficiency of line-frequency transformers, which are a component of the power conversion circuitry of many slow chargers, can be improved by replacing their cores with ones made of lower-loss steel.

- *Termination*: Substantially decreasing the charge current to the battery after it has reached full charge, either by using a timer or sensor, can significantly decrease maintenance-mode power consumption. Because most slow chargers have a charge rate of approximately 0.1 C, and maintenance-mode current below 0.05 C is typically sufficient to keep a battery fully charged, a slow charger that employs termination can roughly halve its maintenance-mode power consumption.

- *Elimination/Limitation of Maintenance Current*: Constant maintenance current is not required to keep a battery fully charged. Instead, the BC can provide current pulses to "top off" the battery as needed. Elimination or limitation of maintenance can decrease maintenance-mode power consumption even further and has the added benefit of extending the battery lifetime by reducing heating due to overcharge.

- *Elimination of No-Battery Current*: A mechanical AC line switch inside the battery charger "cup" automatically disconnects the BC from the mains supply when the battery is removed from the charger. Although manual (*i.e.*, user-controlled) switches are also possible, this method guarantees that the BC ceases to consume power once the battery is removed from the battery charger.

- *Switched-Mode Power Supply*: To increase efficiency, line-frequency power supplies can be replaced with switched-mode EPSs, which greatly reduce the biggest sources of loss in a line-frequency EPS: the transformer. Because a switched-mode EPS operates at high frequency (greater than 20 kHz), its transformer can be smaller, and because transformer losses are a function of volume, a smaller transformer is usually more efficient. It is worth noting that this technology option is not often found in practice, because the inclusion of a switched-mode power supply within the BC design allows the higher power levels necessary for fast charging. The universal consumer preference for shorter charging times limits the occurrence of slow chargers with high-frequency switched-mode power supplies.

Fast charger technology options include:

- *Low-Power Integrated Circuits*: The efficiency of the BC's switched-mode power supply can be further improved by substituting low-power IC controllers, which can switch more efficiently in active mode and reduce power consumption in no-load mode. To increase efficiency in active mode, the IC controller can decrease switching transients through zero-voltage or zero-current switching. Furthermore, the IC can turn off its start-up current (sourced from the primary side of the power supply) once the output voltage is stable. In addition, when in no-load mode, the IC can turn off the switching transistor for extended periods of time (termed "cycle-skipping").

- *Elimination/Limitation of Maintenance Current*: See above.

- *Schottky Diodes and Synchronous Rectification*: Both line-frequency and switched-mode EPSs use diodes to rectify output voltage. Schottky diodes and synchronous rectification can replace standard diodes to reduce rectification losses, which are increasingly significant at low voltage. Schottky diodes are rectifiers constructed from a metal-silicon junction rather than a *p-n* silicon junction and have a voltage drop of 0.3–0.4 volts, compared to approximately 0.6 volts for standard *p-n* junction diodes. Synchronous rectification (which is typically used only in switched-mode EPSs) further reduces losses by substituting field-effect transistors (FETs) for the diodes. The voltage drop across the drain-to-source resistance of the FET is much lower than that of a Schottky diode, leading to lower losses in the output rectifier.

- *Elimination of No-Battery Current*: See above.

- *Phase Control to Limit Input Power*: Even when a typical BC is not delivering its maximum output current to the battery, its power conversion circuitry continues to draw significant power. A phase control circuit, like the one present in most common light dimmers, can be added to the primary side of the BC power supply circuitry to limit input current in lower-power modes.

REFERENCES

---

[1] Consumer Electronics Association Market Research Department. *U.S. Consumer Electronics Sales and Forecasts 2006-2011* July 2010. Consumer Electronics Association: Arlington, VA.

[2] AppleInsider.com. *Apple snags 10 percent of U.S. retail notebook sales in March*. May 11, 2007. (Last accessed September 13, 2010.) <http://www.appleinsider.com/articles/07/05/11/apple_snags_10_percent_of_u_s_retail_notebook_sales_in_march.html.> The September 13, 2010 material from this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[3] RocketFish. *Digital Wireless Speakers*. 2008. Available at: <http://www.rocketfishproducts.com/cms/documents/RF-WS01_WS02_WS02-W_08-1669_ENGLISH_WEB.pdf>

[4] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. FY2005 Preliminary Priority-Setting Summary Report and Actions Proposed. Appendix A: FY2005 Technical Support Document. Table A9-1: Background Data on Battery Chargers and Power Supplies.

[5] "PRESS RELEASE: Tablet Gold Rush Strains Display Industry in 2011," Wall Street Journal Online, January 13, 2011. (Last accessed on January 14, 2011) <http://online.wsj.com/article/BT-CO-20110113-706713.html>

[6] EE Times Asia. *HDD shipments hit 15.5% growth amid challenges.* 2007. (Last accessed September 13, 2010.) <http://www.eetasia.com/ART_8800456083_499486_NT_67de3825.HTM> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[7] World Bank. *Gross domestic product 2008*. 2009. Available at: <http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf>

[8] EPA. ENERGY STAR Uninterruptible Power Supply (UPS) Version 1.0: Kickoff Meeting. March 24, 2010. <http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/uninterruptible_power_supplies/Stakeholder_Presentation032410.pdf>

[9] Navigant Consulting. Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances. December 21, 2009.

[10] Comcast. "Comcast Now the Third Largest Residential Phone Services Provider in the U.S." March 11, 2009. Last accessed on October 22, 2010) <http://www.comcast.com/About/PressRelease/PressReleaseDetail.ashx?PRID=844>

[11] Comcast. "Corporate Overview." June 20, 2010. (Last accessed October 22, 2010) <http://www.comcast.com/corporate/about/pressroom/corporateoverview/corporateoverview.html>

[12] RCR Wireless News. "Bluetooth adoption set for continued expansion". 2009. (Last accessed September 13, 2010.) <http://www.rcrwireless.com/article/20090119/WIRELESS/901199989/1080/bluetooth-adoption-set-for-continued-expansion> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[13] IT Facts. *240 mln GPS-enabled phones to sell in 2009.* 2009. (Last accessed September 13, 2010.) <http://www.itfacts.biz/240-mln-gps-enabled-phones-to-sell-in-2009/12494> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[14] IT Facts. *500 mln music phones shipped in 2007*. 2008. (Last accessed September 13, 2010.) <http://www.itfacts.biz/500-mln-music-phones-shipped-in-2007/10294> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[15] GSM World. *Universal Charging Solutions*. 2009. (Last accessed September 13, 2010.) <http://www.gsmworld.com/our-work/mobile_planet/universal_charging_solution.htm> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[16] IT Facts. *Americans discard 125 mln phones annually*. 2008. (Last accessed September 13, 2010.) <http://www.itfacts.biz/americans-discard-125-mln-phones-annually/10093> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[17] GSM World. "Mobile Industry Unites to Drive Universal Charging Solution for Mobile Phones". 2009. (Last accessed September 13, 2010.) <http://www.gsmworld.com/newsroom/press-releases/2009/2548.htm> The

---

September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[18] Shambora, Jessica. *Consumers Flip for Mini Camcorders.* CNN Money. January 27, 2009. (Last accessed September 13, 2010.) <http://money.cnn.com/2009/01/27/technology/flip_cams.fortune/> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[19] Clairmont, Kristy. PMA Data Watch: DSLR purchasers most likely to be purchasing an additional camera. June 22, 2009. (Last accessed July 15, 2010.) <http://pmaforesight.com/?page_id=490>

[20] Appliance Magazine. May 2009. 66 (4): pp 34-37.

[21] iRobot Corporation. *2008 iRobot Annual Report*. 2009. Bedford, MA. Report No. 000-51598

[22] Appliance Magazine. *56th Annual Industry Forecast.* January 2009. 65 (1): pp 38.

[23] Saxman, Donald. *Portable Battery Powered Products: Global Markets*. 2008. BCC Research: Wellesley, MA. Report No. FCB023D

[24] American Pet Products Manufacturers Association. *2007-2008 national Pet Owners Survey*. Quoted in: The Pet Haven. *Pet Ownership Statistics*. July 18, 2007. (Last accessed September 13, 2010.) <http://the-pet-haven.blogspot.com/2007/07/pet-ownership-statistics.html> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[25] Graystone Creations. *Frequently Asked Questions.* (Last accessed July 15, 2010.) <http://www.graystonecreations.com/definitions.htm> The July 15, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[26] Southwest Garden Arts. *FAQ.* February 26, 2008. (Last accessed July, 14 2010.) <http://www.arizonafountains.com/FAQ.htm> The July 14, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[27] Teng, Tina. "Wireless Charging Market Set to Expand by Factor of Nearly 70 by 2014." iSuppli. June 30, 2010. Accssessed November 15, 2010 at <http://www.isuppli.com/Mobile-and-Wireless-Communications/News/Pages/Wireless-Charging-Market-Set-to-Expand-by-Factor-of-Nearly-70-by-2014.aspx>

[28] Appliance Magazine. *32nd Annual Portrait of the U.S. Appliance Industry*. September, 2009. p. 34.

[29] Berner, Robert. *Why P&G's Smile is So Bright*. Business Week. August 12, 2002. (Last accessed September 13, 2010.) <http://www.businessweek.com/magazine/content/02_32/b3795072.htm> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[30] Darnell Group. External AC-DC Power Supplies: Worldwide Forecasts. 3rd ed. May 2008. The Darnell Group: Corona, CA.

[31] Toy Industry Association. "State of the Industry." (Last accessed November 10, 2010) <http://www.toyassociation.org/AM/Template.cfm?Section=12_Rolling_Months>

[32] International Market Solutions. *Golf Car-Type Vehicles and the Emerging Market for Small, Task-Oriented Vehicles in the United States.* December 2007.

[33] United States Census Bureau. *U.S. Population Projections*. 2008.

[34] New York Times. Goodman, David. "An Electric Boost for Bicyclists" February 1, 2010. (Last accessed September 13, 2010.) <http://www.nytimes.com/2010/02/01/business/global/01ebike.html?pagewanted=all#> The September 13, 2010 version of this website is available in Docket # EERE-2008-BT-STD-0005. For more information, contact Ms. Brenda Edwards at (202) 586-2945.

[35] Marketstrat, Inc. *Total Powered Mobility Aids Market - United States (2004 - 2012).* 2006.

[36] US Environmental Protection Agency, *ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2009 Summary*. 2009; and US Environmental Protection Agency, *ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2008 Summary.* 2008.

[37] US Environmental Protection Agency. *Energy Star External Power Supply Qualified Products*. September 2009.

[38] US Environmental Protection Agency, May 26, 2010 letter to stakeholders. Accessed January 7, 2011 at <http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_eup_sunset_stakeholder_proposal.pdf>

[39] US Environmental Protection Agency, *ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2009 Summary*. 2009; and US Environmental Protection Agency, *ENERGY STAR Unit Shipment and Market Penetration Report Calendar Year 2008 Summary.* 2008.

---

[40] US Environmental Protection Agency, *Qualified Product (QP) List for ENERGY STAR Qualified Battery Charging Systems*. January 3, 2011.

[41] Darnell Group, Inc. *External AC-DC Power Supplies Second Edition.* August 2005.

[42] Title 10—Energy, Chapter II—Department of Energy, Part 430—Energy Conservation Program for Consumer Products, Subpart B—Test Procedures.

CHAPTER 4. SCREENING ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the U.S. Department of Energy's (DOE's) screening analysis of the technology options identified for battery chargers (BC) and external power supplies (EPS). As discussed in chapter 3 of the technical support document (TSD), DOE consults with industry, technical experts, and other interested parties to develop a list of technology options for consideration. The purpose of the screening analysis is to determine which options to consider further and which to screen out.

Section 325(o)(2) of the Energy Policy and Conservation Act (EPCA) provides that any new or revised standard must be designed to achieve the maximum improvement in energy efficiency that is determined to be technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)) In view of the EPCA requirements, Appendix A to Subpart C of Title 10, Code of Federal Regulations (CFR), part 430 (10 CFR part 430), *Procedures, Interpretations, and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the Process Rule) sets forth procedures to guide DOE in its consideration and promulgation of new or revised efficiency standards. These procedures elaborate on the statutory criteria provided in 42 U.S.C. 6295(o) and, in part, eliminate problematic technologies early in the process of prescribing or amending an energy efficiency standard. In particular, sections 4(b)(4) and 5(b) of the Process Rule provide guidance to DOE for determining which design options are unsuitable for further consideration:

1. **Technological feasibility.** DOE will consider technologies incorporated in commercial products or in working prototypes to be technologically feasible.
2. **Practicability to manufacture, install, and service.** If mass production and reliable installation and servicing of a technology in commercial products could be achieved on the scale necessary to serve the relevant market at the time the standard comes into effect, then DOE will consider that technology practicable to manufacture, install, and service.
3. **Adverse impacts on product utility or product availability.** If DOE determines a technology would have significant adverse impact on the utility of the product to significant subgroups of consumers, or would result in the unavailability of any covered product type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not consider this technology further.
4. **Adverse impacts on health or safety.** If DOE determines that a technology will have significant adverse impacts on health or safety, it will not consider this technology further.

Section 4.2 discusses the EPS technology options DOE screened out from further consideration. Section 4.3 lists the remaining design options DOE considered in its analyses.

4.2 SCREENED OUT EPS TECHNOLOGY OPTIONS

DOE did not screen out any technology options for EPSs, having considered the following four factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product utility to consumers; and (4) adverse impacts on health or safety.

4.3 REMAINING EPS DESIGN OPTIONS

DOE is considering the design options in Table 4-1 as viable means for improving EPS efficiency. Chapter 3 provides a detailed description of each of these design options, which DOE considers in the engineering analysis (chapter 5).

Table 4-1 External Power Supply Design Options

Technology Option	Description
Improved Transformers	Use transformers with low losses.
Switched-Mode Power Supply	Use switched-mode power supplies instead of linear power supplies.
Low-Power Integrated Circuits	Use integrated circuit controllers with minimal power consumption.
Schottky Diodes and Synchronous Rectification	Use rectifiers with low losses.
Low-Loss Transistors	Use transistors with low drain-to-source resistance.
Resonant Switching	Use an algorithm to turn on the transformer only when losses are minimal.
Resonant ("Lossless") Snubbers	Reuse energy sent to the snubber.

4.4 SCREENED OUT BC TECHNOLOGY OPTIONS

This section addresses the BC technologies that DOE screened out, having considered the following factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) adverse impacts on product utility to consumers; and (4) adverse impacts on health or safety.

DOE examined all of the technology options presented in the technology assessment. The table below lists out the options that DOE decided to screen out and which criterion that technology option failed to meet:

Table 4-2 Screened Out Battery Charger Technology Options

Technology Option	Failed Screening Criterion
Lowering charging current or increasing voltage	Adverse impacts on product utility to consumers
Capacitive reactance	Adverse impacts on safety
Non-inductive chargers for toothbrush and other wet applications	Adverse impacts on safety

4.5 REMAINING BC DESIGN OPTIONS

After screening out the aforementioned technology options in accordance with the policies set forth in 10 CFR Part 430, Subpart C, Appendix A, (4)(a)(4) and 5(b), DOE is considering the design options in Table 4-3 as viable means for improving battery charger efficiency. Chapter 3 provides a detailed description of the design options that DOE considers in the engineering analysis (chapter 5).

Table 4-3 Battery Charger Design Options

Technology Option		Description
Slow charger	Improved Cores	Use transformer cores with low losses.
	Termination	Limit power provided to fully-charged batteries.
	Elimination/Limitation of Maintenance Current	Limit power provided to fully-charged batteries.
	Elimination of No-Battery Current	Limit power provided drawn when no battery is present.
	Switched-Mode Power Supply	Use switched-mode power supplies instead of linear power supplies.
Fast charger	Low-Power Integrated Circuits	Use integrated circuit controllers with minimal power consumption.
	Elimination of No-Battery Current	Limit power provided drawn when no battery is present.
	Schottky Diodes and Synchronous Rectification	Use rectifiers with low losses.
	Elimination of No-Battery Current	Limit power provided drawn when no battery is present.
	Phase Control to Limit Input Power	Limit input power in lower-power modes.

CHAPTER 5. ENGINEERING ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

The U.S. Department of Energy (DOE) performed an engineering analysis to establish the relationship between the manufacturer selling price (MSP) and the energy efficiency of battery chargers (BCs) and external power supplies (EPSs). The relationship between the MSP and energy efficiency, or the cost-efficiency relationship, serves as the basis for cost-benefit calculations in terms of individual customers, manufacturers, and the Nation. This section provides an overview of the engineering analysis, discusses the representative product classes, establishes baseline unit specifications for those product classes, discusses incremental efficiency levels, discusses the analysis and results for the representative product classes, and establishes a scaling methodology to those products not analyzed directly.

The primary inputs of the engineering analysis are cost and efficiency data derived from 1) test data and teardown analysis, and 2) manufacturer interviews. Additional inputs include design options from the screening analysis (technical support document (TSD) chapter 4). The primary output of the engineering analysis is a set of cost-efficiency curves. In a subsequent life-cycle cost analysis (TSD chapter 8), DOE used the cost-efficiency curves to determine customer prices for each of the products analyzed in the engineering analysis by applying the appropriate distribution channel markups.

5.2 ENGINEERING ANALYSIS METHODOLOGY

DOE structured its engineering analysis using two methodologies: (1) the testing and teardown approach, which involves testing commercially available products and tearing down the products to determine "bottom-up" manufacturing costs based on a detailed bill of materials and (2) the efficiency-level approach, which involves interviewing manufacturers to determine the relative costs of achieving increases in efficiency, without regard to the particular design options used to achieve such increases. The following summarizes the general steps taken throughout the engineering analysis:

Market Survey: DOE surveyed applications that use BCs and EPSs to determine the most popular units in the market. DOE focused its analysis on these popular units.

Representative Product Classes and Representative Units: DOE reviewed covered BCs and EPSs and their associated product classes. DOE selected certain classes and units as "representative" and concentrated its analytical effort on these because they represent a significant majority of units and because analysis on these units and classes can be extended to all units and classes. For those product classes that are not analyzed directly, DOE extrapolates the analysis from representative product classes.

Baseline Efficiency Level: For all representative units, DOE establishes baseline efficiency levels, which serve as reference points against which DOE measures changes resulting from potential amended energy conservation standards. To determine energy savings and changes in price, DOE compares each higher energy-efficiency level with the baseline efficiency level. For direct operation EPSs the baseline efficiency level is determined by Federal energy conservation standards set by EISA 2007. Because of the wide variety of designs that manufacturers use to meet EISA 2007 standards, DOE does not describe specific baseline units with particular designs. For multiple-voltage and high power EPSs, the baseline CSL corresponds to the lowest-efficiency EPS on the market. There are no existing federal standards for BCs, so the baseline BC CSLs also reflects the lowest-efficiency units currently in the market.

Unit Testing: DOE purchased and measured the efficiency of BC and EPS units to characterize the full range of efficiencies in the market and the ranges of efficiencies of the representative units.

Candidate Standard Levels. After identifying baseline efficiency levels, DOE developed candidate standard levels based on: (1) voluntary efficiency specifications, (2) commercially available high-efficiency units determined by testing units, (3) intermediate points in the market and (4) the maximum technologically feasible (max-tech) efficiency level determined by interviewing manufacturers of BCEPS, integrated-circuit controllers for BCEPS, and applications that use BCEPS. The max-tech level was independently verified by subject matter experts.

Unit Teardowns: DOE selected certain test units to characterize the costs for the representative units to meet the CSLs. To determine costs, DOE subcontracted iSuppli Corporation, an industry expert in costs of consumer electronics, to perform teardowns.

Manufacturer Interviews: DOE’s contractors interviewed manufacturers of BCEPS, manufacturers of integrated circuit (IC) controllers for BCEPS, and manufacturers of products with applications that use BCEPS. During these interviews DOE obtained confidential design cost and efficiency information which DOE aggregated to derive manufacturer-based relationships between cost and efficiency for BCEPS.

Price Analysis. The costs output from the engineering analysis are at the point in the product value chain where the BCEPS manufacturer sells its product to the application manufacturer, termed the manufacturer selling price (MSP). However, in some cases DOE obtained costs for BCs and EPSs earlier in the production process such as the (1) bill of materials (BOM), which describes the product’s components in detail, including all manufacturing steps required to make and/or assemble each part, or the (2) manufacturer production costs (MPCs), which is the cost of the BC or EPS after it leaves the factory, or the (3) retail price, which is the price the consumer pays for purchasing the EPS. By applying manufacturer markups to the BOMs and MPCs, DOE calculated the MSPs used in the final cost-efficiency curves. DOE divided by retail markups to obtain the MSPs in cases where the retail price was known.

The sections that follow discuss how DOE applied this methodology to create the engineering analysis.

5.3 MARKET SURVEY TO SELECT REPRESENATIVE UNITS

DOE began the development of its analysis with a market survey in the summer of 2009 as the basis for selecting representative units for both BCs and EPSs. At the time of the survey multiple-voltage and high power EPSs, as well as some indirect-operation EPSs were part of a separate determination analysis and therefore were addressed separately in that rulemaking. The goal of the survey for BCs and EPSs was to determine market segments from which to select the representative units. To best capture the BC and EPS markets, DOE focused on the most popular applications that use BCs and EPSs. The survey consisted of the following steps:

1. Identify the types of applications that use BCs and EPSs
2. Estimate the annual shipments and the energy consumption for those applications
3. Select applications to focus on based on significant shipments and/or energy consumption
4. Visit websites and retail outlets to survey product characteristics of popular models
5. Combine the results into BC and EPSs market profiles
6. Select representative units based on the market profiles

As discussed in Chapter 3 of this NOPR TSD, to date DOE identified 79 applications that use BCs and/or EPSs. When DOE conducted a market survey in the summer of 2009 it had identified 51 applications. Of those applications, DOE had obtained estimated annual shipments for 43. Among those applications, DOE prioritized EPS-focused research on 13 application types that were expected to have large shipments and/or energy consumption.

1. Computer Speakers
2. Cordless Phones/Answering Devices
3. Digital Photo Frames
4. E-Books
5. External Hard Drives
6. Inkjet MFDs and Printers
7. LAN Equipment
8. Mobile Phones
9. MP3 Speaker Docks
10. Notebook Computers
11. Portable DVD Players
12. USB Wall Adapters
13. VoIP Adapters

DOE conducted similar model counts to assess models that would most impact the BC analysis.

1. Camcorders
2. Consumer Two-Way Radios
3. Cordless Phones/Answering Devices
4. Digital Cameras
5. E-Books
6. Electric Bicycles
7. Electric Shavers

8. GPSs
9. Golf Carts
10. Handheld Vacuum Cleaners
11. Handheld Video Games
12. Hedge and Lawn Tools
13. Marine Chargers
14. Mobile Phones
15. Notebook Computers
16. Portable DVD Players
17. Portable Music Players
18. Power Tools
19. Rechargeable Toothbrushes
20. Robotic Vacuum Cleaners
21. Uninterruptible Power Supplies
22. Universal Battery Chargers
23. Wheelchairs/Scooters

For the selected applications, DOE identified the most popular product models, considered to be those on the best-seller lists of several popular online retailers (*e.g.*, Amazon.com, BestBuy.com, etc.). In total, DOE identified 366 application models among the 13 EPS-focused application types. For each model, DOE noted whether the model included a wall adapter, a battery, both, or neither. Among the 366 models, 281 were identified as having wall adapters, and DOE was able to discern the expected nameplate output power for 230 of the models – from 1.2 watts for a cordless phone to 120 watts for a notebook computer. In cases where the BC or EPS information was not readily available, DOE consulted publicly available manufacturer information and noted the characteristics of the product.

Subsequently, for EPSs, DOE combined the information it gathered on application shipments, model count, and model power rating to characterize popular wall adapters by nameplate output power, which DOE used as an approximation of the EPS market. Figure 5.1 and Figure 5.2 show the results of the market characterization in two formats: bubble chart and bar chart, respectively. The size of the “bubbles” in Figure 5.1 gives a relative measure of how many models DOE counted for each application at each nameplate output power rating. The height of a bubble corresponds to the total shipments of the application. For example, mobile phones have the highest shipments at approximately 143M per year.

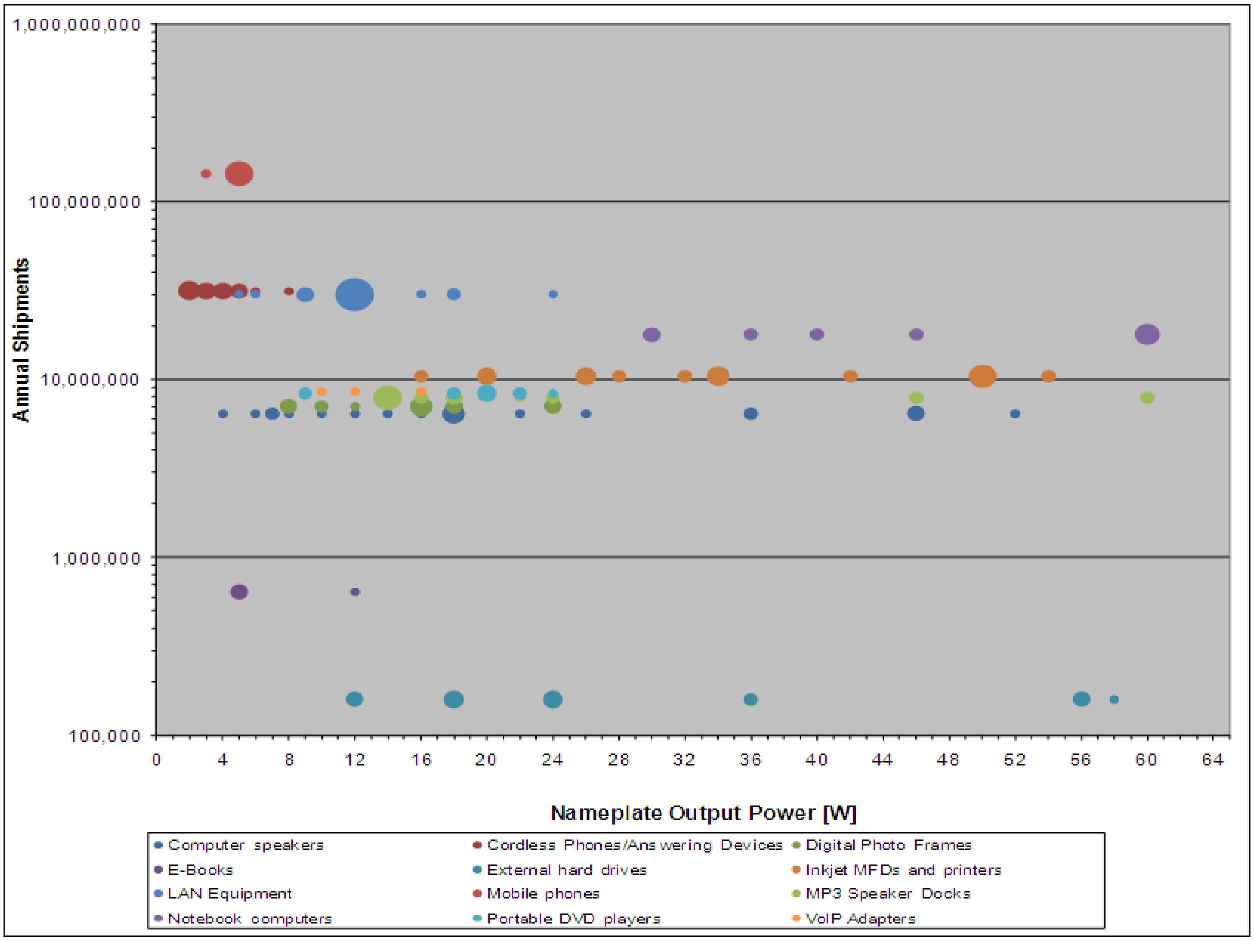


Figure 5.1 Market Characterization for Popular Wall Adapters (bubble chart)

In Figure 5.2 application shipments have been apportioned relative to model count; the height of each bar indicates the cumulative EPS shipments at a particular nameplate output power. For example, the 143M shipments for mobile phones are divided between wall adapters with nameplate output power ratings of approximately 3 watts and 5 watts, 16M and 127M respectively. The bar on the x-axis corresponding to 3-watt EPSs consists of the 16M mobile phone EPSs and 7M cordless phone EPSs. Thus the total estimated shipments for 3-watt EPSs are 23M units per year. These volumes were a major factor in the process of selecting the representative units, which is detailed in 5.4.1.

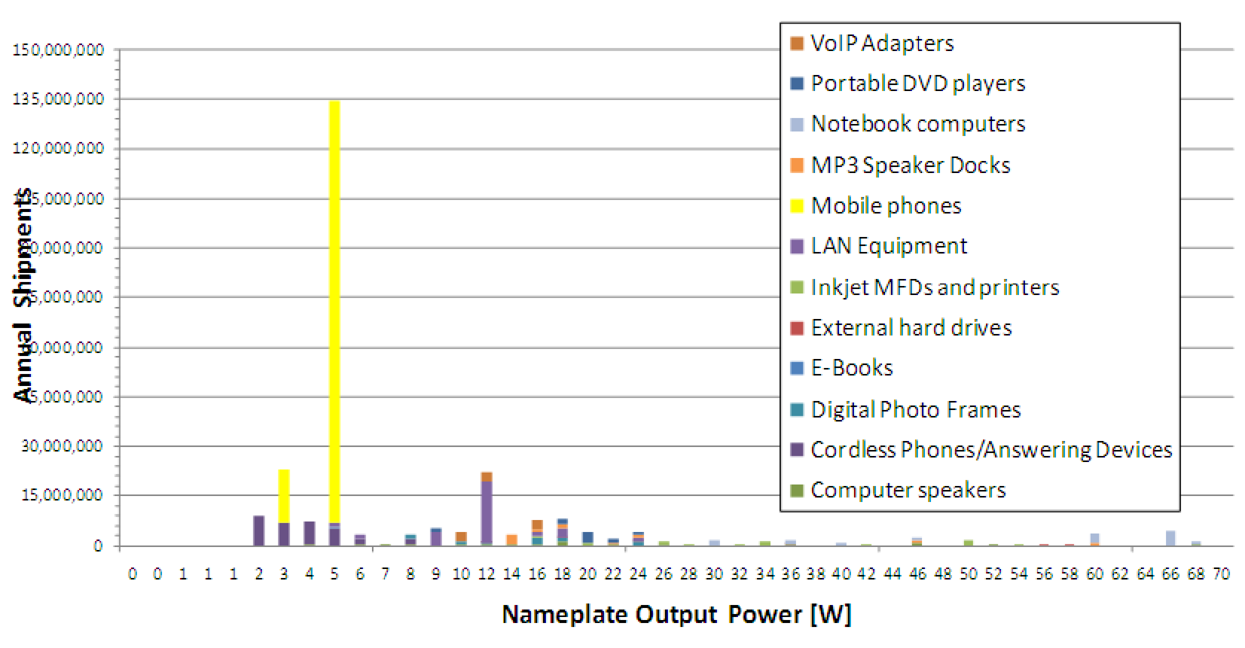


Figure 5.2 Market Characterization for Popular Wall Adapters (bar chart)

Full details on the market assessment for multiple-voltage and high power EPSs can be found in the Notice of Proposed Determination (NOPD) that DOE published on November 3, 2010. 74 FR 56928.

While the EPS products were grouped by nameplate output power, the BC product classes—described in chapter 3—are defined by battery voltage (in volts) and energy (in Wh). Therefore, DOE grouped the models evaluated during the market survey by battery voltage and energy. A comparison of the resultant market distribution to the BC product classes can be seen in Figure 5.3. This market distribution was subsequently used to select the EPS and BC representative product units, as detailed in sections 5.4.1, 5.5.1, and 5.7.1, respectively.

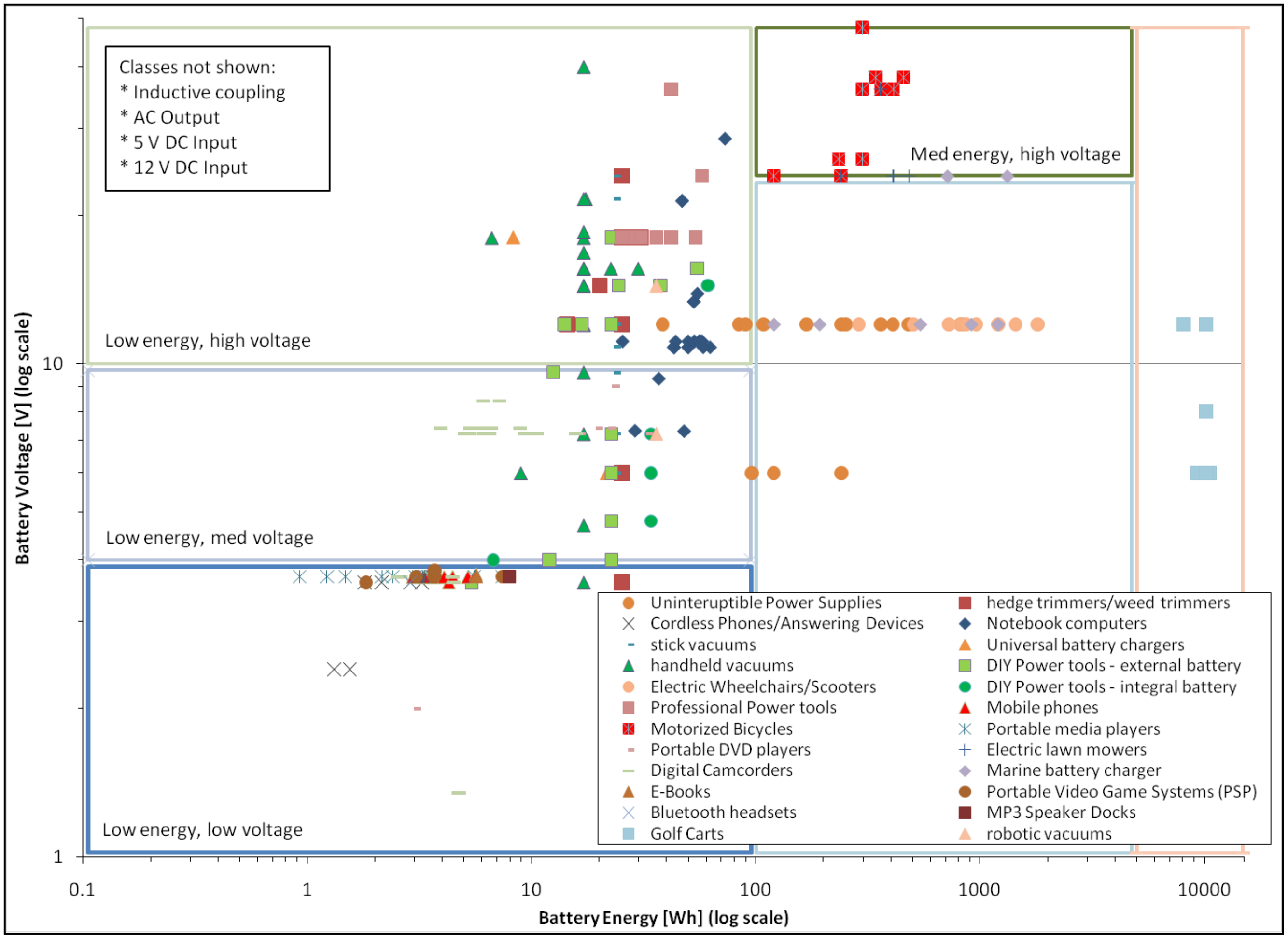


Figure 5.3 Distribution of Battery Voltage and Energy for High-Volume Applications.

5.4 DIRECT OPERATION EXTERNAL POWER SUPPLY ENGINEERING ANALYSIS

In this section, DOE presents a full engineering analysis including cost-efficiency curves for direct operation EPSs. In section 5.5, DOE presents a discussion of the engineering analysis for multiple-voltage and high power EPSs that includes a description of representative products classes, representative units, candidate standard levels of efficiency, and cost-efficiency relationships.

5.4.1 Direct Operation EPS Representative Product Classes and Representative Units

DOE elected to focus the engineering analysis on the AC-DC basic-voltage output product class B as the representative product class among the four product classes shown in Table 5-1 because the majority of units in the market are in that product class. The other three product classes were not explicitly analyzed in an engineering analysis using physical test units or manufacturer data; rather, the analysis for product class B was extended to the other three product classes using scaling relationships (discussed further in section 5.4.6 and section 5.4.10). Product class B includes EPSs for low-power products such as cordless phones and cellular phones, mid-power products such as modems and routers, and higher-power products such as notebook computers.

Table 5-1 EPS Representative and Scaled Product Classes

	Basic-Voltage Output	Low-Voltage Output *
AC-DC Conversion	B, Representative	C, Scaled
AC-AC Conversion	D, Scaled	E, Scaled

* Low-voltage output EPSs have nameplate output voltage less than six volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic-voltage output.

Within the representative product class, DOE chose representative units based on the following criteria:

- Select units only within the representative product class B
- Select a sufficient amount of nameplate output power points to curve fit the CSLs
- Focus on popular areas in the market
- Ensure that there are many units to test

DOE chose to have multiple representative units for the EPS engineering analysis since EPS product classes span a wide range of output power, and efficiency is strongly affected by output power. Since DOE elected to express the CSLs as continuous functions of nameplate output power it was necessary to select several representative units to characterize each CSL. To accomplish that goal, DOE chose to characterize four nameplate output power regions: low power (1.2 watts to 10 watts), mid power (15 watts to 30 watts), high power (30 watts to 90 watts), and maximum power of 120 watts. The representative units are focused on lower powers because that is where one finds the greatest diversity of EPS efficiency. Above 49 watts, there is much less variation in EPS efficiency; hence there is less need for characterization.

After selecting the number of representative units, DOE selected each unit's nameplate output power and nameplate output voltage – the two characteristics that most influence EPS efficiency. The combination of power and voltage for each representative unit needed to result in the EPS being in the representative product class B, per DOE's decision to analyze only that product class. Further, by ensuring that all units were from the same product class, DOE could scale results across all nameplate output powers within the representative product class

When defining the representative unit values, DOE considered specifying the same output voltage for all representative units, but instead specified different output voltages for each representative unit. DOE took this approach because there is a trend in the market for EPSs with higher nameplate output power to have higher nameplate output voltage. For instance, low-power cell phone chargers tend to have nameplate output voltage at 5 volts whereas higher-power notebook computers tend to have nameplate output voltage at 19 volts. Thus, there is not a single output voltage for all representative units that would accurately reflect the market. Further, because the representative units have the different wattages and voltages, DOE ensured that the CSLs are consistent with the market, since the representative units characterize the CSLs.

DOE's next step in selecting representative units was to focus on popular units in the market, which was straightforward for most representative units, except the low-power representative unit. Figure 5.2 shows a peak at 5 watts in the EPS market. Although DOE considered a 5-watt representative unit because of its prevalence, DOE instead selected a 2.5-watt representative unit because it belonged to the representative product class B whereas the 5-watt EPS was in product class C (shown in

Table 5-2). Specifically, EPSs with both nameplate output voltage less than 6 volts *and* nameplate output current greater than or equal to 550 milliamperes are considered low-voltage EPSs that are in product class C (if they output DC power) or product class E (if they output AC power). All of the 5-watt EPSs had nameplate output voltage of 5 volts, nameplate output current of 1 ampere, and DC output power. Thus, all 5-watt EPSs are in product class C and are not viable options for representative units in the representative product class B. In contrast, 2.5-watt EPSs had nameplate output voltage of 5 volts and nameplate output current of 500 milliamperes. Thus the 2.5-watt EPSs are in product class B and are eligible as representative units.

Table 5-2 Evaluation of Potential Low-Power EPSs as Representative Units

	Power [W]	**Voltage [V]**	**Current [A]**	**Product Class**
Low-voltage criteria	-	< 6 V	≥ 0.55 A	C and E
Valid representative unit	2.5 W	5 V	0.50 A	B
Invalid representative unit	5 W	5 V	1.00 A	C

The last criterion that DOE considered in selecting EPS representative units was unit availability. This requirement was not trivial because, although there are many applications sold with EPSs, a significant amount of those applications do not publish the nameplate output power and voltage of their associated EPSs. Therefore, DOE targeted its analysis on EPSs that were clearly available for purchase at specific output powers. Based on all of the criteria presented, DOE selected four representative units for EPSs, listed in Table 5-3.

Table 5-3 External Power Supply Representative Units

Representative Unit	Nameplate Output Power [watts]	Nameplate Output Voltage [volts]	Example Application	Output Cord Length* [m]
1	2.5	5	Mobile phone	1.66
2	18	12	Modem	1.66
3	60	15	Laptop Computer	1.66
4	120	19	Laptop Computer	1.66

*The standard cord length assumed for all representative units was 1.66 m. Cord length did not influence the selection of units; it was only used to scale efficiency (see Section 5.4.6.3 for details) and cost (see Section 5.4.6.5 for details) data.

See Section 5.4.3 for a detailed discussion of all the EPSs tested, including the representative units.

5.4.2 Candidate Standard Levels for Representative Product Class B

DOE determined the CSLs for the AC-DC basic-voltage representative product class B based on existing standard levels, products available in the market, and information from manufacturers, in the manner shown in
Table 5-4.

Table 5-4 Candidate Standard Levels of Efficiency for Product Class B

CSL	Reference	Basis
0	EISA 2007	EISA 2007 equations for efficiency and no-load power
1	ENERGY STAR 2.0	ENERGY STAR 2.0 equations for efficiency and no-load power
2	Intermediate	Interpolation between test data points
3	Best-in-Market	Most efficient test data points
4	Max Tech	Maximum technologically feasible efficiency

The CSL equations, as well as the representative unit test and manufacturer data are illustrated in Figure 5.4 for efficiency and in Figure 5.5 for no-load power. A discussion of the exact equations and reasoning underlying each of the CSLs illustrated in Figure 5.4 and Figure 5.5 follows below, starting with CSL 0.

Figure 5.4 shows CSL equations that are higher in efficiency with higher CSLs, for a given nameplate output power. This represents increasingly stringent standards with higher CSLs. For each of the representative units and CSLs there is a corresponding aggregated manufacturer data point and testing and teardown data point, except for CSL 4, which has no test data because it is the max-tech level, and CSL 2, which has no test data because it was chosen to be an intermediate level between the Energy Star 2.0 and the best-in-market levels. As shown in Figure 5.4, the CSLs are fit closely to the data (see Section 5.4.10 for details on curve-fitting), with the added constraint that they never go above a manufacturer or test data point in efficiency, for a given nameplate output power.

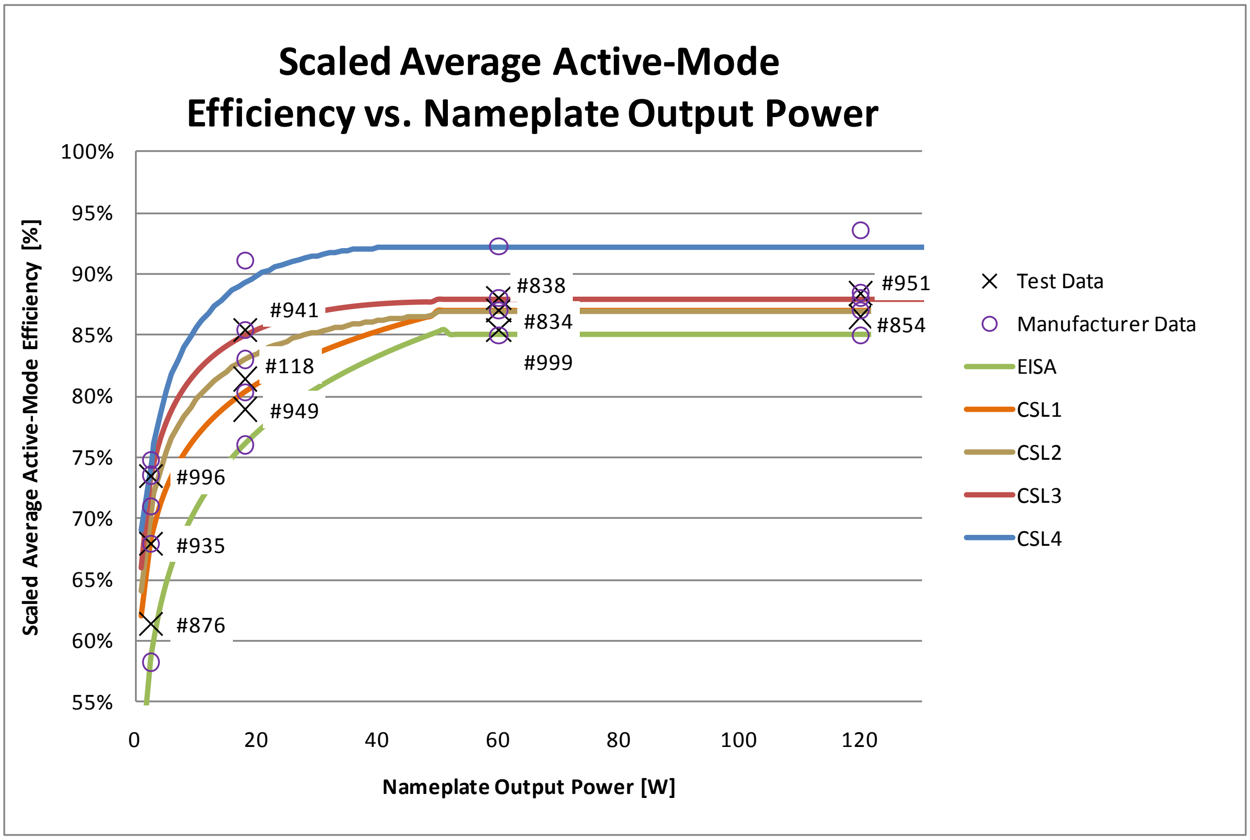


Figure 5.4 CSL Scaled Average Active-Mode Efficiency vs. Nameplate Output Power

Figure 5.5 shows CSL equations that are lower or equal in no-load power with higher CSLs, for a given nameplate output power. This represents increasingly stringent standards with higher CSLs. For each of the representative units and CSLs there is a corresponding aggregated manufacturer data point and testing and teardown data point, except for CSL 4, which has no test data because it is the max-tech level, and CSL 2, which has no test data because it was chosen to be an intermediate level between the Energy Star 2.0 and the best-in-market levels. As shown in Figure 5.4, the CSLs are fit closely to the data (see Section 5.4.10 for details on curve-fitting), with the added constraint that they never go below a manufacturer or test data point in no-load power, for a given nameplate output power.

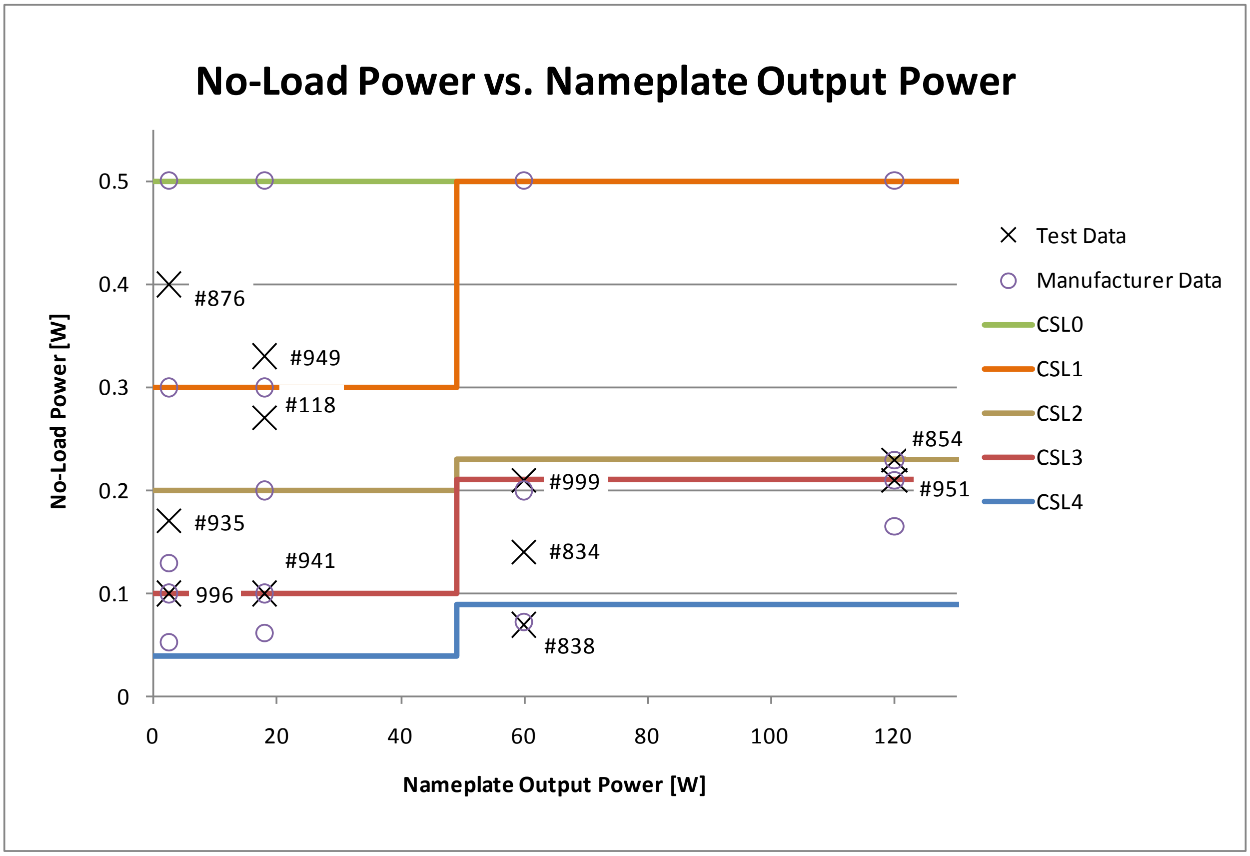


Figure 5.5 CSL No-Load Power vs. Nameplate Output Power

Currently, EPCA, as amended by EISA 2007, determines EPS minimum efficiency and maximum no-load power consumption as a function of nameplate output power (P_{out}), shown in Table 5-5 and

Table 5-6 , respectively. For this analysis, the baseline efficiency level, CSL 0, for each representative unit is equivalent to the EISA 2007 standard. However, the EISA standard sets a more stringent efficiency level for EPSs with nameplate output power greater than 51 watts. For this analysis, that division was shifted to 49 watts for consistency with the Energy Star 2.0 specifications and the higher efficiency CSLs.

Table 5-5 CSL 0 Baseline Average Active-Mode Efficiency for Product Class B

Nameplate Output Power (P_{out})	**Minimum Average Efficiency in Active Mode** *(expressed as a decimal)*
< 1 watt	$\geq 0.5 * P_{out}$
1 to not more than 49 watts	$\geq 0.09 * \ln(P_{out}) + 0.5$
> 49 watts	≥ 0.85

Table 5-6 CSL 0 Baseline No-Load Power Consumption for Product Class B

Nameplate Output Power (P_{out})	**Maximum Power in No-Load**
Not more than 250 Watts	≤ 0.5

Energy Star 2.0 is another level in the market, although it is a voluntary specification rather than a mandatory standard. Similar to EISA, the Energy Star 2.0 level is a function of nameplate output power, shown in
Table 5-7 and
Table 5-8. As explained in chapter 3, Energy Star 2.0 has four product classes distinguished by the type of output power (AC/DC or AC/AC) and the output voltage (basic or low). DOE developed its product class structure in the same manner as Energy Star, hence DOE chose CSL 1 to be identical to the Energy Star 2.0 level for AC/DC basic output voltage EPSs, at the corresponding nameplate output power with the exception of the no-load metric. DOE moved the output power divisions in the Energy Star 2.0 standard such that the no-load equation is divided at 49 watts rather than 50 watts in order to be consistent with the efficiency equation structure for CSL 1. DOE applied these changes to all the higher efficiency CSLs in product class B as well.

Table 5-7 CSL 1 Energy Star 2.0 Average Active-Mode Efficiency for Product Class B

Nameplate Output Power (P_{out})	**Minimum Average Efficiency in Active Mode** *(expressed as a decimal)*
0 to ≤ 1 watt	$\geq 0.480 * P_{out} + 0.140$
> 1 to ≤ 49 watts	$\geq 0.0626 * \ln(P_{out}) + 0.622$
> 49 watts	≥ 0.870

Table 5-8 CSL 1 Energy Star 2.0 No-Load Mode Power Consumption for Product Class B

Nameplate Output Power (P_{out})	**Maximum Power in No-Load**
0 to ≤ 49watt	≤ 0.3 watts
> 49 watts	≤ 0.5 watts

DOE created CSL 2 to be an intermediate level between the Energy Star (CSL 1) and best in market (CSL 3) levels (CSL 3 is explained subsequently). The specific combination of no-load power consumption and average efficiency for CSL 2 was chosen so as to optimize the tradeoff between cost and efficiency between CSL 1 and CSL 3. To do this, DOE evaluated each representative unit individually. DOE developed sets of efficiency and no-load power pairings between CSL 1 and CSL 3 and estimated their resultant unit energy consumptions (UECs) (see chapter 7 for details on calculating UECs). DOE then compared the UECs against their associated MSPs, which were calculated from the aggregation of manufacturer MSP data (see Section 5.4.5 for details on MSP aggregation). Subsequently, the final efficiency and no-load pairing used to characterize CSL 2 was selected by examining which of the prospective pairings had the highest weighted-average savings in the LCC analysis.

DOE then used the CSL 2 pairings for the four representative units to create equations for average efficiency and no-load power by curve-fitting the efficiency characteristics for CSL 2 (see Section 5.4.10 for details on curve fits). For both the average efficiency and no-load power CSL equations, DOE used equations similar to those for CSL 1, involving linear and logarithmic terms in the nameplate output power. DOE chose the divisions at 1 watt and 49 watts in the CSL 2 equations so that they were consistent with the nameplate output power divisions between the equations for CSL 1. The CSL 2 active-mode efficiency and no-load power equations are shown in Table 5-9 and

Table 5-10, respectively.

Table 5-9 CSL 2 Intermediate Average Active-Mode Efficiency for Product Class B

Nameplate Output Power (P_{out})	**Minimum Average Efficiency in Active Mode** *(expressed as a decimal)*
0 to ≤ 1 watt	$\geq 0.49 * P_{out} + 0.15$
> 1 to ≤ 49 watts	$\geq 0.0701 * \ln(P_{out}) - 0.0011 * P_{out} + 0.647$
> 49 watts	≥ 0.870

Table 5-10 CSL 2 Intermediate No-Load Mode Power Consumption for Product Class B

Nameplate Output Power (P_{out})	**Maximum Power in No-Load**
0 to ≤ 49 watts	≤ 0.200 watts
> 49 watts	≤ 0.230 watts

CSL 3 reflects the most efficient products available for sale in the market (“best-in-market” or BIM). As explained in section 5.4.3, DOE purchased EPSs using three sources in order to identify the most efficient unit in the market. First, DOE evaluated the most efficient units of the popular products tested in the market survey in section 5.3. Second, DOE purchased EPS units identified in the Energy Star 2.0 database[a]. Third, DOE purchased units available through EPS distributor websites. From among these three sources, DOE considered the best-in-market EPS to be the most efficient EPSs that DOE tested, in terms of a combination of highest average efficiency and lowest no-load power. For those units, DOE created the equation for average efficiency using a curve-fit of the test results data, shown in Figure 5.4. DOE’s methodology for curve fitting is detailed in section 5.4.10. DOE created the equations for no-load power based on the maximum no-load power among the two lower power representative units (2.5W and 18W) and the two higher power representative units (60W and 120W), respectively (see Section 5.4.10 for details). DOE followed this approach because there was no clear relationship between nameplate output power and no-load power consumption. DOE chose the divisions in the CSL 3 equations so that they were consistent with the divisions between the equations for CSL 1. Figure 5.5 illustrates the CSL 3 no-load power equations, as well as the CSL 3 representative unit test and manufacturer data. The CSL 3 active-mode efficiency and no-load power equations are shown in Table 5-11 and

Table 5-12, respectively.

---

[a] Taken from the Energy Star 2.0 external power supply results database in Sept 2009 http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=ACD.

Table 5-11 CSL 3 Best-in-Market Average Active-Mode Efficiency for Product Class B

Nameplate Output Power (Pout)	**Minimum Average Efficiency in Active Mode** *(expressed as a decimal)*
0 to ≤ 1 watt	$\geq 0.5 * P_{out} + 0.16$
> 1 to ≤ 49 watts	$\geq 0.071 * \ln(P_{out}) - 0.0014 * P_{out} + 0.67$
> 49 watts	≥ 0.880

Table 5-12 CSL 3 Best-in-Market No-Load Mode Power Consumption for Product Class B

Nameplate Output Power (Pout)	**Maximum Power in No-Load**
0 to ≤ 49 watts	≤ 0.10 watts
> 49 watts	≤ 0.21 watts

Unlike the previous CSLs, CSL 4 was not based on an evaluation of the efficiency of EPS units in the market, since EPSs with maximum technologically feasible efficiency are not commercially available due to their high cost. Rather, to estimate the efficiency of a max-tech unit, Navigant asked manufacturers to detail the steps they would take to achieve a maximum efficiency for the four representative units. The interviews included manufacturers of EPSs as well as manufacturers of integrated-circuit controllers for EPSs and manufacturer of applications that use EPSs since those manufacturers are also intimately familiar with EPS technologies. Navigant presented DOE with the manufacturers' aggregated responses for the representative units. The aggregated responses from manufacturers are presented in section 5.4.5.

This rulemaking did not use a design option approach because of the significant variation in the prices of individual components and their effects on efficiency. The topology and parts used in an EPS design are typically inter-related. Hence, it is seldom possible to determine the effects on price and efficiency of one component in isolation.

DOE verified the reasonableness of the aggregated manufacturer max-tech data before creating curve fit equations for CSL 4. To that end, DOE's subject matter experts (SMEs) reviewed the data and confirmed it as reasonable, except for the max-tech value for the 2.5W EPSs. The SMEs believe that 2.5W EPSs may be able to achieve a max tech efficiency of 80% rather than the efficiency derived from manufacturers. During interviews manufacturers confirmed that an 80% efficiency level is achievable for 2.5W EPSs, but not without a decrease in utility. Manufacturers stated that reaching that efficiency level would require an increase in the form factor (*i.e.* the geometry of the design), which would make these devices larger. The increased size of the EPS would, in the manufacturers' views, constitute a decrease in utility that would be undesirable to consumers because of demands for smaller and lighter products. In light of this possibility, DOE used a max-tech efficiency value of 74.8% to characterize CSL 4 for the 2.5W representative unit.

Based on the representative units' max-tech data, DOE created equations across all output powers as shown in Table 5-13 and Table 5-14. DOE's methodology for curve fitting is detailed in section 5.4.10. DOE created the equations for no-load power based on the maximum no-load power among the two lower power representative units (2.5W and 18W) and the two higher power representative units (60W and 120W), respectively (see Section 5.4.10 for details). DOE chose the divisions in the CSL 4 equations so that they are consistent with the divisions between the equations for CSL 1. Figure 5.4 and Figure 5.5 illustrate the CSL 4 efficiency and no-load power equations in Table 5-13 and Table 5-14, respectively, as well as the aggregate manufacturer data for max tech.

Table 5-13 CSL 4 Max Tech Average Active-Mode Efficiency for Product Class B

Nameplate Output Power (Pout)	**Minimum Average Efficiency in Active Mode** *(expressed as a decimal)*
0 to ≤ 1 watt	$\geq 0.52 * P_{out} + 0.17$
> 1 to ≤ 49 watts	$\geq 0.0893 * \ln(P_{out}) - 0.00196 * P_{out} + 0.67$
> 49 watts	≥ 0.922

Table 5-14 CSL 4 Max Tech No-Load Mode Power Consumption for Product Class B

Nameplate Output Power (Pout)	**Maximum Power in No-Load**
0 to ≤ 49 watts	≤ 0.039 watts
> 49 watts	≤ 0.089 watts

5.4.3 Direct Operation EPS Testing Analysis

5.4.3.1 Survey of EPS Efficiencies in the Market

DOE purchased and tested commercially available EPS units to determine the range of efficiencies in the market and to determine where to focus its analysis of representative units. In the market survey (section 5.3) DOE identified 13 EPS-using applications that are important for EPSs because they represent a large amount of shipments, consume large amounts of energy, or both. As part of the market survey, DOE created a database of EPS models available for purchase for each of the 13 applications. DOE purchased a number of models for each application such that they would be roughly proportional to the shipments-weighted distributions shown in Figure 5.2, without giving overwhelming preference to the largest shipments (e.g., cellular phones and notebook computers) and covering applications with the smallest shipments (e.g., digital photo frames).

Accordingly, DOE believes that it has characterized the most popular EPSs from product classes B, C, D, and E in terms of shipments and energy consumption as shown in Figure 5.6. DOE applied the representative unit criteria in section 5.4.1 to this survey of EPS efficiencies by application to select representative units. Detailed explanations and results are available in Appendix 5A of this TSD.

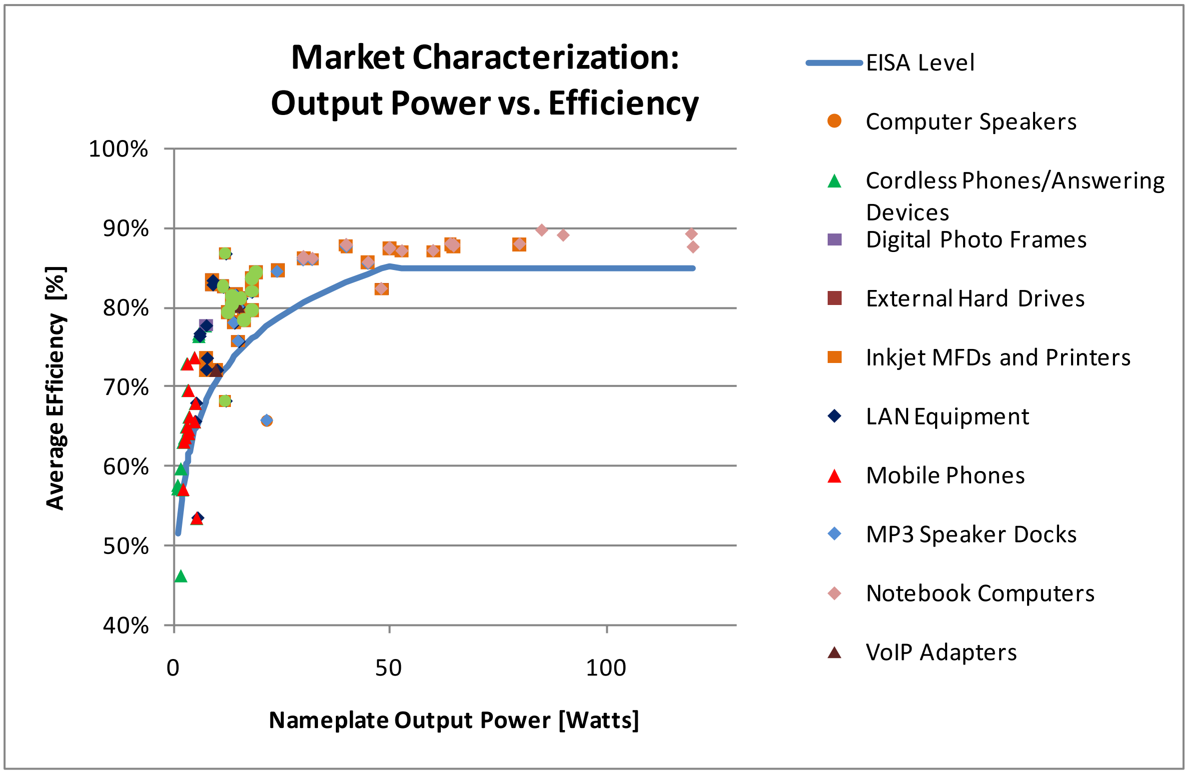


Figure 5.6 Survey of EPS Efficiencies by Application

5.4.3.2 Evaluation of EPS Efficiencies at Representative Unit Values

DOE selected specific EPS units to characterize CSL 0, CSL 1, and CSL 3 for each representative unit. This section describes the selection process and the characteristics of the EPSs chosen to characterize the CSLs. For each representative unit, DOE selected two to three EPS test units on which to focus its analysis. DOE purchased test units with values that were the same as or very close to the representative unit specifications. For the selected test units, DOE commissioned teardowns to estimate their MPCs. For the EPSs that differed slightly from representative unit values, DOE normalized their test results through scaling, as specified in section 5.4.6.

The selected EPS test units were evaluated based on their scaled test results and chosen so as to best characterize the level based on the following criteria:

- All test units must adhere to the matched-pairs criteria, explained in detail below.
- The unit chosen to characterize CSL 0 must meet the CSL 0 requirements, while being as close as possible to CSL 0. Units meeting CSL 1 criteria do not qualify as baseline units.
- The unit chosen to characterize CSL 1 must meet the CSL 1 requirements, while being as close as possible to CSL 1.
- The most efficient unit, based on its combination of average efficiency and no-load power consumption, characterizes and defines CSL 3, Best-in-Market (BIM).
    - Units that did not meet CSL 1 criteria did not qualify.

  - When no single unit was dominant in both dimensions, DOE chose the BIM unit so as not to break the matched-pairs approach.
  - In addition, the CSL 3 unit is chosen such that it is as far away from the CSL 1 unit as possible in the no-load power and efficiency dimensions.
  - In comparing distances in the no-load power and efficiency dimensions, the dimension with more effect on unit energy consumption (as determined by typical application usage profiles at that wattage level) was given precedent.
- There is no test unit to characterize CSL 2, Intermediate, because DOE developed that level after finalizing test and teardown units.
- There is no test unit to characterize CSL 4, "Max Tech," because it is a theoretical unit that does not exist in the market.

The "matched pairs" approach refers to the pairings of average efficiency and no-load power consumption that define the CSLs and EPS efficiency test results. The DOE test procedure for EPSs yields two values whereas many other DOE test procedures only yield one value. DOE evaluated EPSs using the two metrics separately. DOE believes this is the most appropriate way to characterize EPSs because EPSs have a wide variety of usage profiles which would affect any weighting of average efficiency and no-load power. Further, this approach is important because the cost estimates from the teardown apply to the EPS as a whole and cannot be broken down as affecting just active-mode efficiency or no-load power consumption.

DOE has structured the CSLs such that they never decrease in stringency in either metrics and such that they always increase in stringency in at least one metric. Similarly, DOE uses selected test units to characterize the CSLs that have matched pairs of efficiency in that as they progress from least efficient to most efficient in terms of active-mode efficiency requirements, no-load mode power-consumption requirements, or both.

DOE obtained an estimate of the manufacturer production costs for each selected test unit used to characterize the representative units. Below, is a discussion of how DOE selected the specific test units for each representative unit. Note that the max-tech data points in Figure 5.7, Figure 5.8, Figure 5.9, and Figure 5.10 are only shown for context, as they are not test units, instead they are manufacturer responses regarding the best achievable efficiencies and no-load powers in EPSs across representative units.

For the 2.5W, 5V representative unit, DOE considered test units within a wattage range of 1.75W to 3W and a voltage range of 4V to 6V that met the criteria of representative product class B. Figure 5.7 shows a plot of the seven units that DOE considered in characterizing the 2.5W representative unit CSLs.

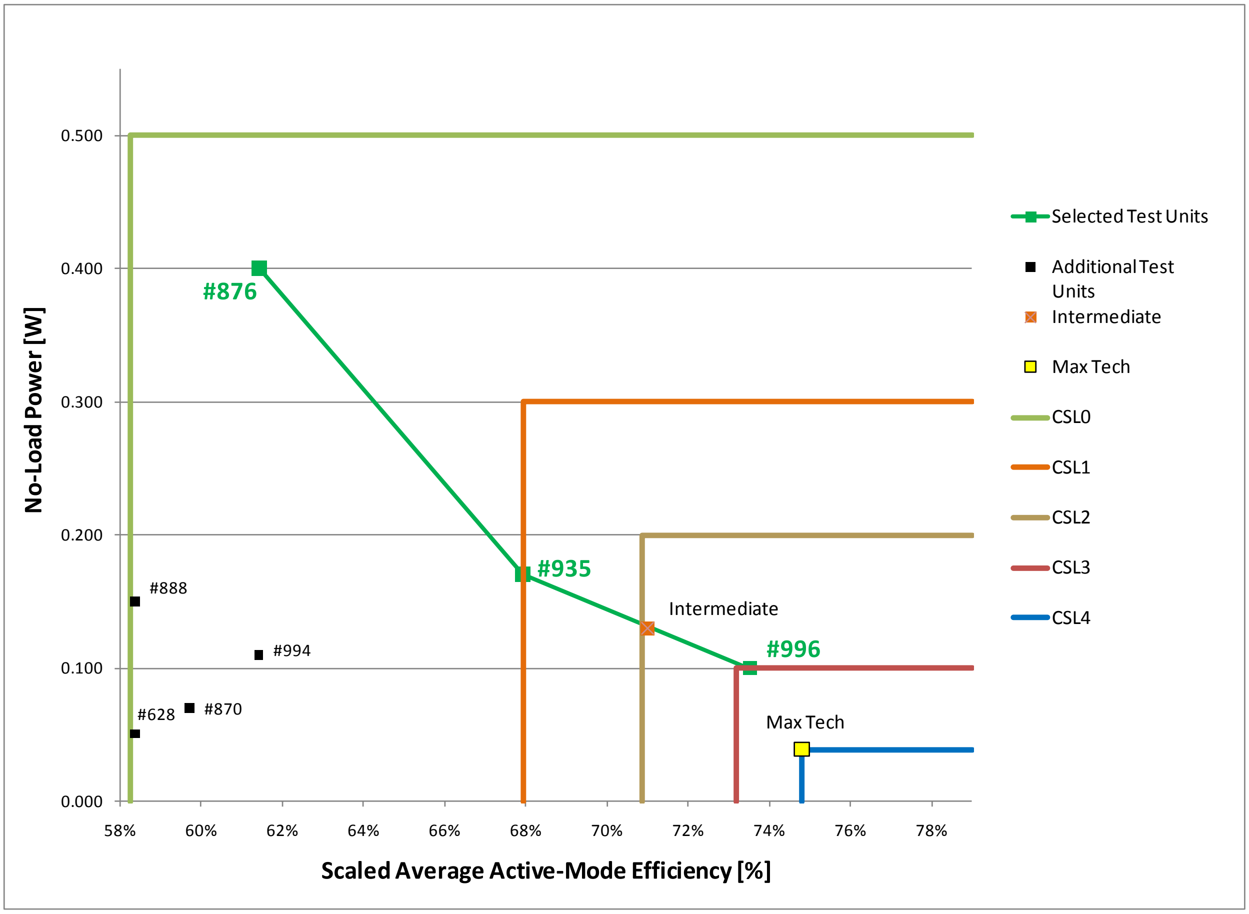


Figure 5.7 No-Load Power vs. Scaled Average Active-Mode Efficiency for 2.5-Watt Units

DOE considered all EPS units in Figure 5.7, and ultimately selected units #876, #935, and #996 to characterize the 2.5-watt CSL 0, CSL 1, and CSL 3 levels, respectively. Unit #876 was chosen because it was close to the minimum CSL 0 efficiency and maximum CSL 0 no-load power allowances, and was the only unit that maintained a matched-pairs approach. Unit #935 was selected because it met the CSL 1 requirements, and unit #996 was the most efficient unit found in the market that also met the CSL 1 criteria. Table 5-15 shows the data for the three units selected to characterize the 2.5W CSLs.

Table 5-15 2.5-Watt Units Used to Characterize the CSLs

Unit #	CSL	Nameplate Output		Cord Length [m]	Cord Resistance [ohms]	No-Load Power [W]	Average Scaled Efficiency [%]	Application
		Power [W]	Voltage [V]					
876	0	2.4	6.0	1.86	0.31	0.400	61.4	Cordless Phones / Answering Devices
935	1	2.0	5.0	1.78	0.30	0.170	67.9	Generic
996	3	1.8	5.0	1.17	0.32	0.103	73.5	Mobile Phones

For the 18W representative unit, all the units considered were at the representative nameplate output power and voltage, 18W and 12V, respectively. Figure 5.8 shows a plot of the sixteen units considered to characterize the 18W CSLs.

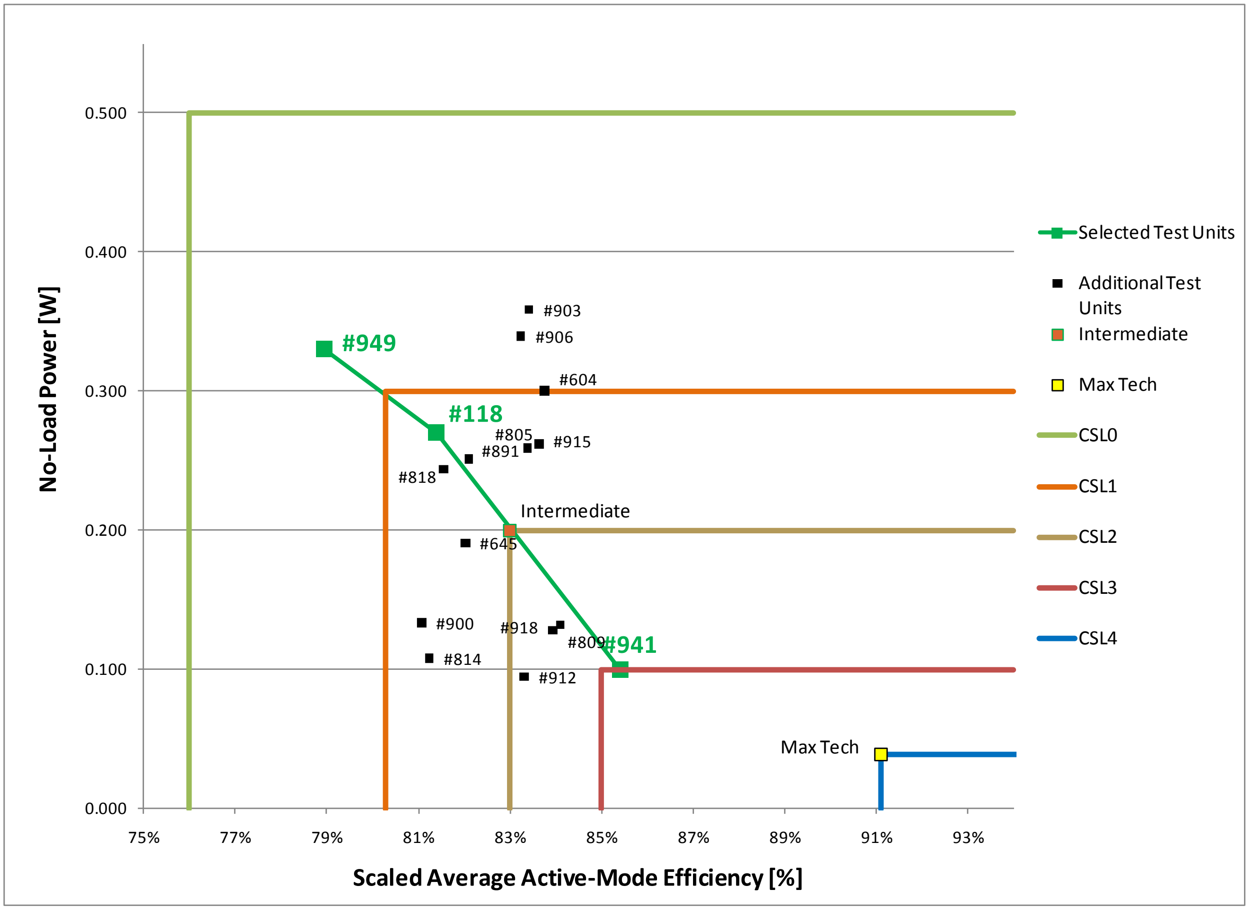


Figure 5.8 No-Load Power vs. Scaled Average Active-Mode Efficiency for 18-Watt Units

DOE considered all EPS units in Figure 5.8, and ultimately selected units #949, #118, and #941 to characterize the 18-watt CSL 0, CSL 1, and CSL 3 levels, respectively. Unit #949 was chosen because it was close to the minimum efficiency and maximum no-load power allowances of CSL 0, and was the only unit that allowed a matched pairs approach. Unit #118 was selected because it met, and was close to, the minimum efficiency and maximum no-load power allowances of CSL 1. Unit #900 was closer to the minimum CSL 1 efficiency requirements, but much farther than unit #118 in terms of no-load power from the 300mW no-load power requirement. Unit #941 was chosen because it was the most energy-efficient unit on the market. Even though unit #912 had a slightly lower no-load power, a difference on the order of 10mW, unit #941 was over one percentage point higher in efficiency. Table 5-16 shows the data for the three units selected to characterize the 18-watt CSLs.

Table 5-16 18-Watt Units Used to Characterize the CSLs

Unit #	**CSL**	**Nameplate Output**		**Cord Length [m]**	**Cord Resistance [ohms]**	**No-Load Power [W]**	**Average Scaled Efficiency [%]**	**Application**
		Power [W]	**Voltage [V]**					
949	0	18.0	12.0	1.75	0.13	0.330	78.9	Generic
118	1	18.0	12.0	1.90	0.11	0.270	81.4	Generic
941	3	18.0	12.0	1.81	0.11	0.100	85.4	Generic

For the 60W representative unit, the representative nameplate output power and voltage were 60W, and 15V, respectively. DOE considered units within a wattage range of 56 to 60W, and a voltage range of 15V to 16V. Figure 5.9 shows a plot of the seven units considered to characterize the 60W CSLs.

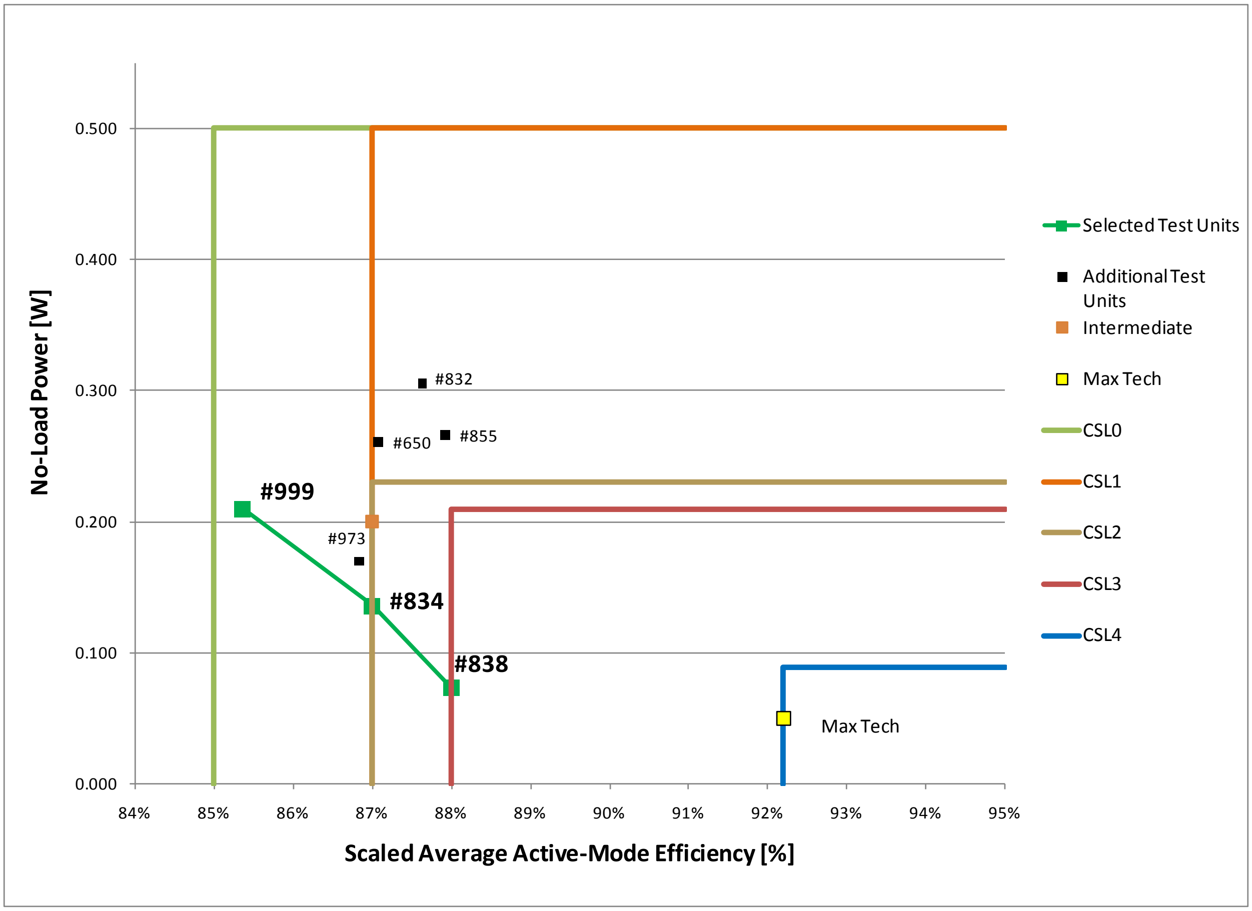


Figure 5.9 No-Load Power vs. Scaled Average Active-Mode Efficiency for 60-Watt Units

DOE considered all EPS units in Figure 5.9, and ultimately selected units #999, #834, and #838 to characterize the 60W CSL 0, CSL 1, and CSL 3 levels, respectively. Unit #999 was chosen because it was closest to the minimum CSL 0 efficiency and maximum CSL 0 no-load power allowances. Unit #834 was selected because it was the only unit that met the CSL 1 criteria, and simultaneously allowed unit #838, the most efficient unit on the market, to be selected to characterize CSL 3 without breaking the matched pairs approach. Table 5-17 shows the data for the three units selected to characterize the 60W CSLs.

Table 5-17 60-Watt Units Used to Characterize the CSLs

Unit #	**CSL**	**Nameplate Output**		**Cord Length [m]**	**Cord Resistance [ohms]**	**No-Load Power [W]**	**Average Scaled Efficiency [%]**	**Application**
		Power [W]	**Voltage [V]**					
999	0	56.0	16.0	1.09	0.08	0.210	85.4	Notebook Computers
834	1	60.0	15.0	1.16	0.04	0.136	87.0	Generic
838	3	60.0	15.0	1.17	0.04	0.073	88.0	Generic

For the 120W representative unit, the representative nameplate output power and voltage were 120W, and 19V, respectively. DOE considered units within a wattage range of 119.7W to 135.1W. Figure 5.10 shows a plot of the nine units considered to characterize the 120W CSLs.

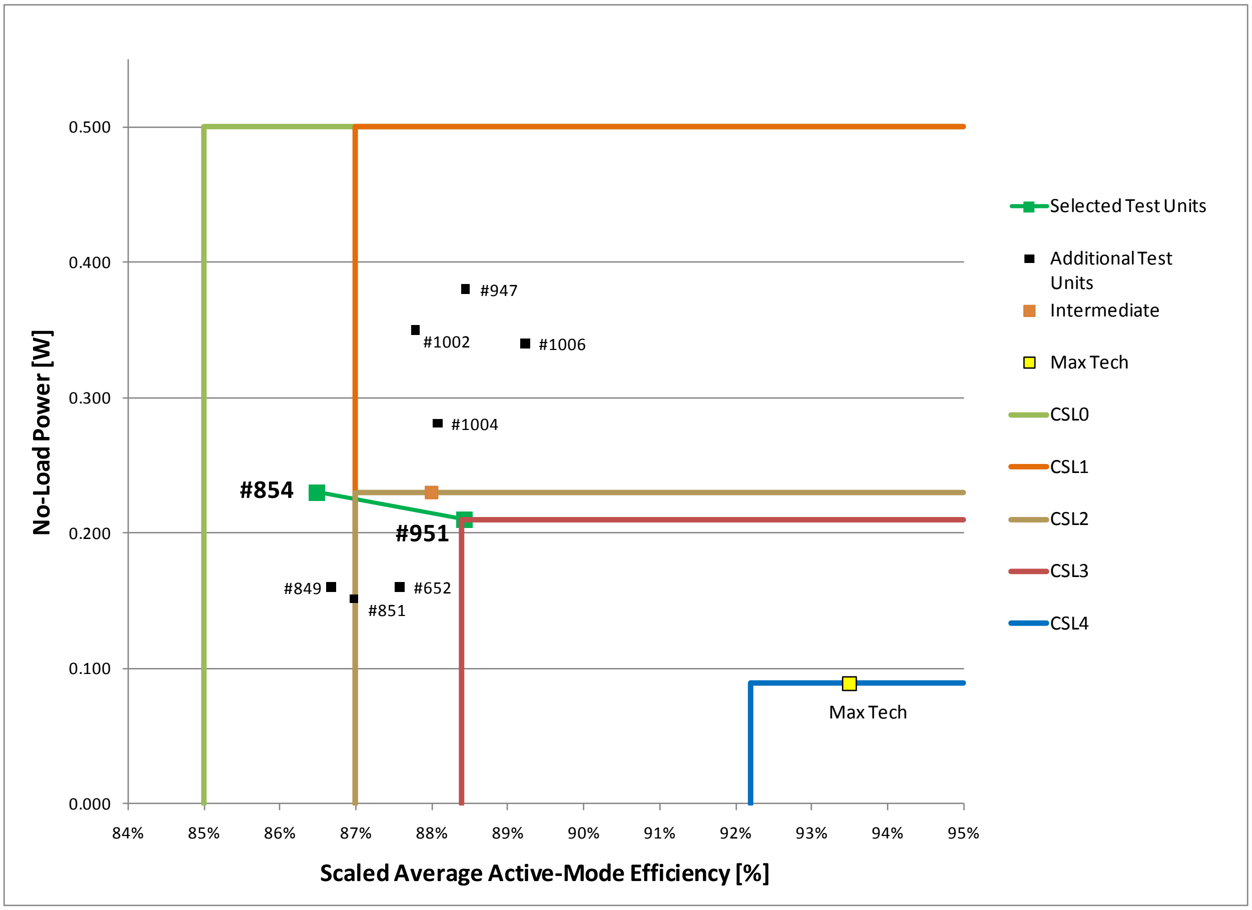


Figure 5.10 No-Load Power vs. Scaled Average Active-Mode Efficiency for 120-Watt Units

DOE considered all EPS units in Figure 5.10, and ultimately selected units #854 and #951. Unit #854 was selected to characterize the 120W CSL 0 level. Unit #951was selected to characterize both the 120W CSL 1 and CSL 3 levels. Unit #854 was chosen because it was closest to the minimum CSL 0 efficiency and maximum CSL 0 no-load power allowances. It was not possible to select two more units, one for CSL 1, and one for CSL 3 without breaking the matched pairs approach. Therefore, unit #951 was selected to characterize both CSL 1 and CSL 3, because it adhered to the matched pairs approach, and was about 1% higher in efficiency than either unit #652 or #851. Notebook computers are the most common application that use 120-watt EPSs and they typically operate a few hours a day. For EPSs for those applications, a 1% difference in efficiency has a more significant effect on unit energy consumption than less than a tenth of a watt in no-load power.

Table 5-18 shows the data for the three units selected to characterize the 120W CSLs.

Table 5-18 120-Watt Units Used to Characterize the CSLs

Unit #	CSL	Nameplate Output		Cord Length [m]	Cord Resistance [ohms]	No-Load Power [W]	Average Scaled Efficiency [%]	Application
		Power [W]	Voltage [V]					
854	0	135.1	19.0	1.78	0.05	0.230	86.5	Notebook Computers
951	1 and 3	120.1	19.0	1.80	0.04	0.210	88.4	Notebook Computers

5.4.4 EPS Teardowns to Estimate Manufacturer Production Cost

DOE contracted iSuppli Corp. to tear down and estimate the materials cost for select units. DOE elected to use iSuppli for its expertise with prices in the consumer electronics industry, since those prices are not publicly available. iSuppli provided DOE with the costs for all parts listed in the bill of materials, and the labor for assembling those parts into an EPS. DOE marked these costs up by the general overhead costs for running a factory to obtain the manufacturer’s production cost (MPC), sometimes called the factory cost. DOE used this information along with a markup to determine the MSPs. The following subsections describe the process for determining MPC and the final results.

5.4.4.1 Generation of Bills of Materials

The end result of each teardown is a bill of materials (BOM). iSuppli developed BOMs for each unit it tore down. BOMs describe each product part and the manner in which manufacturer assembled it. The BOMs describe fabrication and assembly operations in detail, including the process cycle times and the labor associated with each manufacturing step. The BOM includes the following data fields for each component:

- Location: The assembly/sub-assembly in which the component resides, within the device.
- Quantity: The count of the component
- Component Family: The general type of component such as passive and discrete semiconductor.
- Component Type: The specific type of component such as capacitor and diode.
- Manufacturing Name and Part Number: The component’s name and number.
- Component Description: Component-specific information such as “Film - Radial, Dipped, 0.47uF, 10%” and “Zener - 34.6V, 2mA”
- Markings: Any visible markings used in component identification, such as “Logo, 474K, n, 450MFF4” and “TZX, 36, C”
- Package Dimensions: These include component form, diameter, length, height, width and pin count.
- Per Component Cost: The cost to the EPS manufacturer of the individual component at a specified production volume.

- Insertion Method: Either insertion by hand or automated insertion.
- Per Insertion Cost (Auto): The cost of automated insertion for the component.
- Hand Insert Cost: The cost of inserting the component by hand, which is calculated from the insert time and the pay rate for the laborer.
- Data Sheet Links: Any data sheets for the components used in determining pricing.

5.4.4.2 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used a detailed, component-focused technique for calculating the manufacturing cost of a product (direct materials, direct labor, and the overhead costs associated with production). The first step in the manufacturing cost assessment was the creation of a complete BOM from the disassembly of the units selected for teardown. The units were dismantled, and each part was characterized according to manufacturer, dimensions, material, and quantity. iSuppli based its assumptions on the sourcing of parts and in-house fabrication on its industry experience and discussions with manufacturers. The last step was to convert this information into MPC values. To perform this task, iSuppli sums the direct material costs and the conversion costs, to which DOE added a general factory overhead markup, to determine the total MPC for each unit. Figure 5.11 shows the general breakdown of costs associated with manufacturing a product.

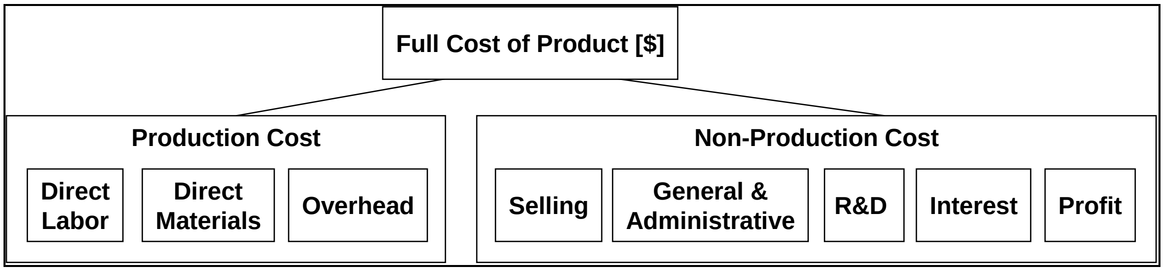


Figure 5.11 Full Cost of Product Breakdown: Production and Non-Production Costs

5.4.4.3 Production Volumes Assumptions

A manufacturer's production volumes vary depending on several factors, including market share, the type of product produced, and if the manufacturer produces other similar products. iSuppli estimated unit costs using three volume assumptions: annual production volume, production lifespan, and lifetime production volume. Annual production volume specifies the number of units a manufacturer produces of the product each year, which affects component costs. Production lifespan specifies the number of years that a manufacturer produces a product, which affects the amount of time over which the manufacturer can amortize equipment costs. The lifetime production volume is the total number of units produced by the manufacturer, which is the product of the annual production volume and production lifespan.

Based on their industry knowledge, iSuppli and DOE jointly developed estimates of production volumes and production lifespans for each representative unit. iSuppli indicated that their cost-estimation model was sensitive only to large differences in production volume so the values provided were rough estimates. Furthermore, iSuppli preferred to use lifetime production volumes for its cost estimates, whereas most manufacturers preferred annual production volumes. As noted in section 5.4.6, DOE considered developing scaling relationships between cost and production volume, but did not do so because it was not needed. In interviews, manufacturers indicated to DOE that production volume, not production lifespan, was the major factor affecting price. Consequently, the manufacturer interviews did not address production lifespans.

5.4.4.4 Teardown Results

iSuppli performed teardowns for all of the EPSs that DOE chose to characterize the representative units and each CSL as specified in section 5.4.3.2. For each of those EPSs, Table 5-19 indicates the estimated MPCs after applying the general factory overhead markup to iSuppli's costs.

Table 5-19 iSuppli Teardown Cost Estimates

Unit #	Representative Unit Wattage	CSL	MPC [$]	Output Cord Cost [$]	Output Cord Length [m]	Lifespan Prod. Volume per iSuppli Teardown (Units)
876	2.5	0	1.42	0.11	1.86	6,000,000
935	2.5	1	1.71	0.17	1.78	6,000,000
996	2.5	2	1.12	0.12	1.17	6,000,000
949	18	0	4.18	0.23	1.75	6,600,000
118	18	1	4.11	0.33	1.90	6,600,000
941	18	2	3.37	0.25	1.81	6,600,000
999	60	0	4.19	0.20	1.09	7,100,000
834	60	1	5.82	0.24	1.16	7,100,000
838	60	2	6.15	0.23	1.17	7,100,000
854	120	0	12.55	0.65	1.78	8,000,000
951	120	1, 2	9.18	0.25	1.80	8,000,000
Additional Teardowns Data (Not Used To Characterize CSLs):						
867	*	N/A	1.59	0.14	1.83	6,000,000
809	18	N/A	3.41	0.37	1.51	6,600,000
650	60	N/A	7.83	0.44	1.75	7,100,000
853	120	N/A	11.53	0.26	1.70	8,000,000
1004	120	N/A	7.38	0.23	1.11	8,000,000

*Unit #867 was a low-voltage unit, because its nameplate output voltage was 5V, and nameplate output current was 0.55A.

5.4.5 Direct Operation EPS Manufacturer Interviews

In 2009 and 2010, on behalf of DOE, Navigant Consulting, Inc. (Navigant) interviewed a total of eight manufacturers of EPSs, integrated circuit (IC) controllers for EPSs, and original equipment manufacturers (OEMs) that use EPSs to obtain data on EPS efficiencies and costs for product classes B, C, D and E. At the request of some manufacturers, Navigant entered into non-disclosure agreements whereby it could present to DOE general information about the EPS market and technology, but no confidential data specific to any individual manufacturer.

Navigant aggregated the manufacturer data and the resulting cost-efficiency data is presented in section 5.4.8.

Before the interviews, Navigant gave each manufacturer an interview guide (Appendix 12A) that included possible questions to be asked during the interview and tables detailing efficiency and no-load values for the manufacturers to populate with associated costs. Navigant asked manufacturers to provide feedback regarding the representation of the market and to supply any data that could improve DOE's estimates and assumptions. Navigant's questions included the following:

1. What are the highest volume products that you sell? Please include output voltage, output power, and application.
2. Please provide a list of any additional applications for which you sell EPSs or EPS components.
3. Are there any specific design concerns unique to certain applications?
4. What are the typical mark ups from the EPS bill of materials (BOM) to the final consumer purchase price?
5. The U.S. Department of Energy (DOE) is required to set no-load and active mode energy efficiency standards for external power supplies. Is there a correlation between no-load power and active mode power efficiency? If not, can the two be optimized separately?
6. What are your design options (e.g. Schottky diodes, improved components, better core material) for improving active mode efficiencies and no-load power consumption?

Manufacturers provided general information and data specific to representative units. The following subsection details Navigant's methodology for aggregating manufacturer data so that it was presentable to DOE. The subsequent subsections provide summaries of manufacturers input on issues affecting the engineering analysis.

5.4.5.1 Aggregation Methodology

Navigant collected manufacturer cost-efficiency data for each representative unit and aggregated manufacturer responses, which it presented to DOE. EPSs are unique because their CSLs are defined by two energy consumption parameters: average efficiency and no-load power dissipation. Hence, the costs provided to Navigant were associated with discrete combinations of efficiency and no-load power. . In the interview guide, Navigant asked manufacturers for costs at the specific CSLs for each representative unit. However, manufacturers provided costs over a range of efficiency and no-load power values because they generally preferred to tie in costs to their own product lines, which often had efficiency and no-load power values slightly different from the CSL values. Consequently, Navigant performed three steps on the manufacturer data before providing DOE with aggregated results: (1) normalize the data to be consistent; (2) develop equations to generalize the data; and (3) apply the CSL values to the equations to determine aggregate costs.

Since manufacturers had used various assumptions in providing their data, Navigant normalized the manufacturer data to ensure that the results from the manufacturers were comparable. For example, some manufacturers had not factored in an output cord. To account for the possible effects on cost and efficiency, the data points were adjusted, assuming the standard

1.66 m cord length. In addition, some manufacturer data assumed nameplate output voltages or wattages that were slightly different than the representative unit values. For details on scaling, please see Section 5.4.6.

First, the manufacturer costs which were given at the BOM or MPC points in the value chain, needed to be marked up to MSP (per Section 5.4.6.6). Second, Navigant ensured that the manufacturer datasets all had an MSP of $0 for baseline units and units at CSL 1. During the final round of interviews, manufacturers consistently stated that they were already manufacturing EPSs at or above Energy Star (CSL 1) standards for the 18W, 60W, and 120W representative units. Therefore, Navigant normalized the data for these units so that they had an MSP of $0 at CSL 0 and CSL 1. Shifting the manufacturer data to the same CSL 1 values meant that the incremental MSPs at CSLs above CSL 1, were based on the same $0 reference point. This was necessary because scaling the datasets sometimes resulted in CSL 1 values that were not $0.

For 2.5W EPSs, manufacturers stated that lower power linear EPSs are being manufactured below Energy Star standards because they are still cost-effective at lower efficiencies. For this reason, Navigant did not normalize the data to CSL 1 for 2.5W EPSs but instead normalized the data to the baseline such that CSL 0 had an associated MSP of $0. Shifting the manufacturer data to the same baseline values meant that the incremental MSP costs at CSLs above the baseline were based on the same $0 reference point. This was necessary because scaling the datasets sometimes resulted in baseline values that were not $0.

The normalized manufacturer data covered a range of values for the other CSLs, as shown in Figure 5.12 and Figure 5.13. Both figures contain illustrative values to show the kind of values that were obtained during manufacturer interviews. Individual manufacturer data points cannot be revealed due to non-disclosure agreements (NDAs) with participating manufacturers. The example is for the 2.5W representative unit. Though the following discussion focuses on the 2.5W unit, the methodology behind the normalization is the same for the 18W, 60W, and 120W representative units though they were normalized to CSL 1 instead of the baseline. During the preliminary analysis, CSL 2 was introduced after manufacturer interviews, and hence the costs used to characterize CSL 2 were interpolated based on data from the other CSLs. For this TSD, Navigant conducted additional manufacturer interviews and received cost data associated with CSL 2 to improve the cost characterization of the CSL.

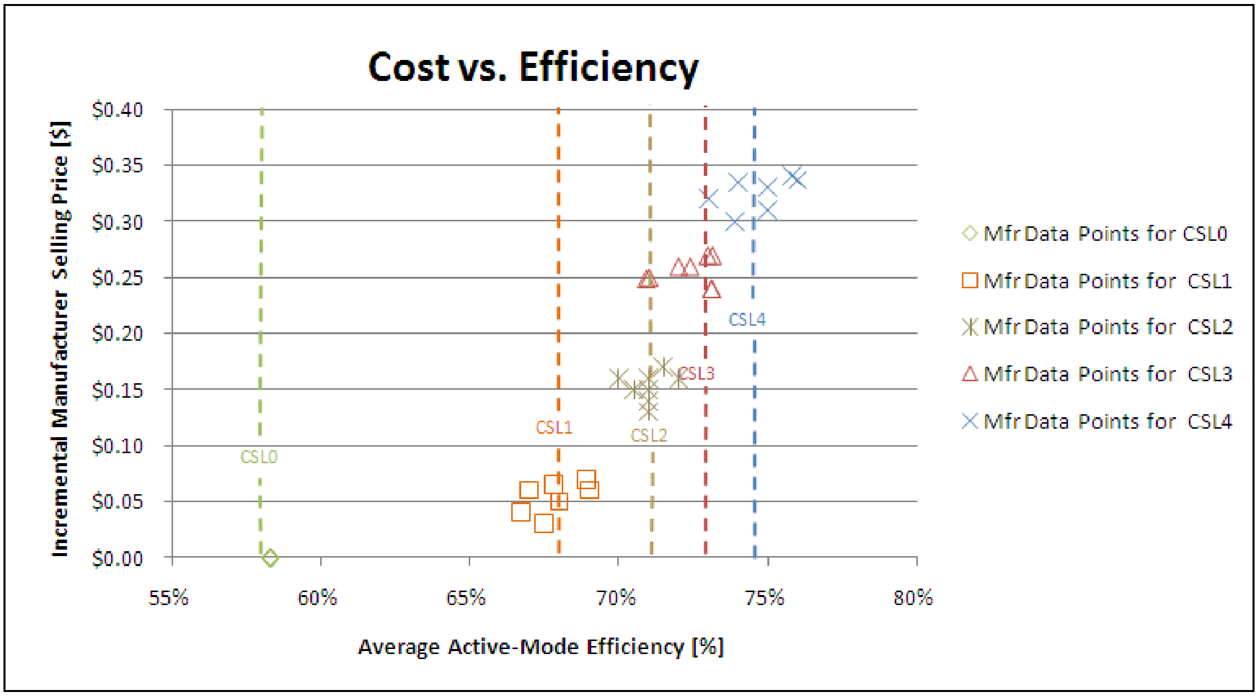


Figure 5.12 Sample Efficiency and MSP Manufacturer Data for the 2.5W Representative Unit.

*The data presented in this plot is for illustrative purposes only. It is not actual manufacturer data.

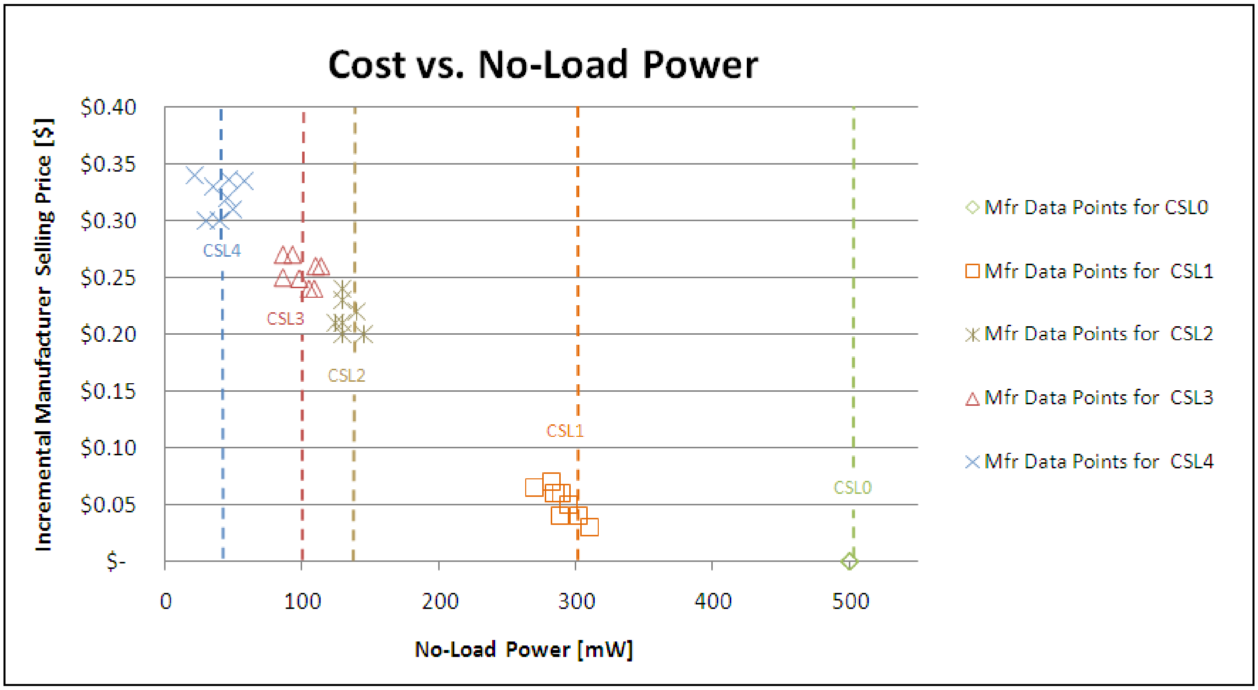


Figure 5.13 Sample No-Load Power and MSP Manufacturer Data for the 2.5W Representative Unit.

*The data presented in this plot is for illustrative purposes only. It is not actual manufacturer data.

The 2.5W CSL 0, CSL 1, CSL 2, CSL 3, and CSL 4 average efficiency values were 58.3%, 67.9%, 71.0%, 73.5%, and 74.8%, respectively. The illustrative data in Figure 5.12 shows that though the CSL 1 efficiency was 67.9%, manufacturer efficiencies might vary significantly, with efficiencies in the range of 65% to 70%. The illustrative data in Figure 5.12 does not exaggerate the variation present in manufacturer responses. Similarly, Figure 5.13 illustrates the type of manufacturer data that Navigant obtained for MSP versus no-load power for the 2.5W representative unit.

This set of manufacturer data presented two challenges: first, Navigant had to account for data in three dimensions (efficiency, no-load power, and cost) and second, Navigant had to develop an aggregate response based on the variation in the manufacturer data along all three dimensions for each CSL of each representative unit.

To address these challenges, it was necessary to fit curves to the manufacturer data. Curve fitting allowed Navigant to estimate an MSP at the CSL efficiency and no-load power values, and allowed for aggregation of the manufacturer data. To explain Navigant's approach of aggregating the data in three dimensions, it is helpful to first illustrate how the approach works in two dimensions. The aggregation methodology is slightly different across the four representative units in product class B as detailed below.

Figure 5.14 illustrates the two-dimensional approach to aggregating manufacturer data. A quadratic curve is fit to the data in each representative unit, and forced to pass through $0 at CSL 0. The linear fit is of the form $Z=a+bX+cX^2$, where Z represents the MSP, X represents the efficiency, and a least-squares fit determines the parameters a, b, and c. Thus, the aggregate MSP at a particular CSL is determined by applying the efficiency value to the equation. This is shown in Figure 5.14 by the black circles.

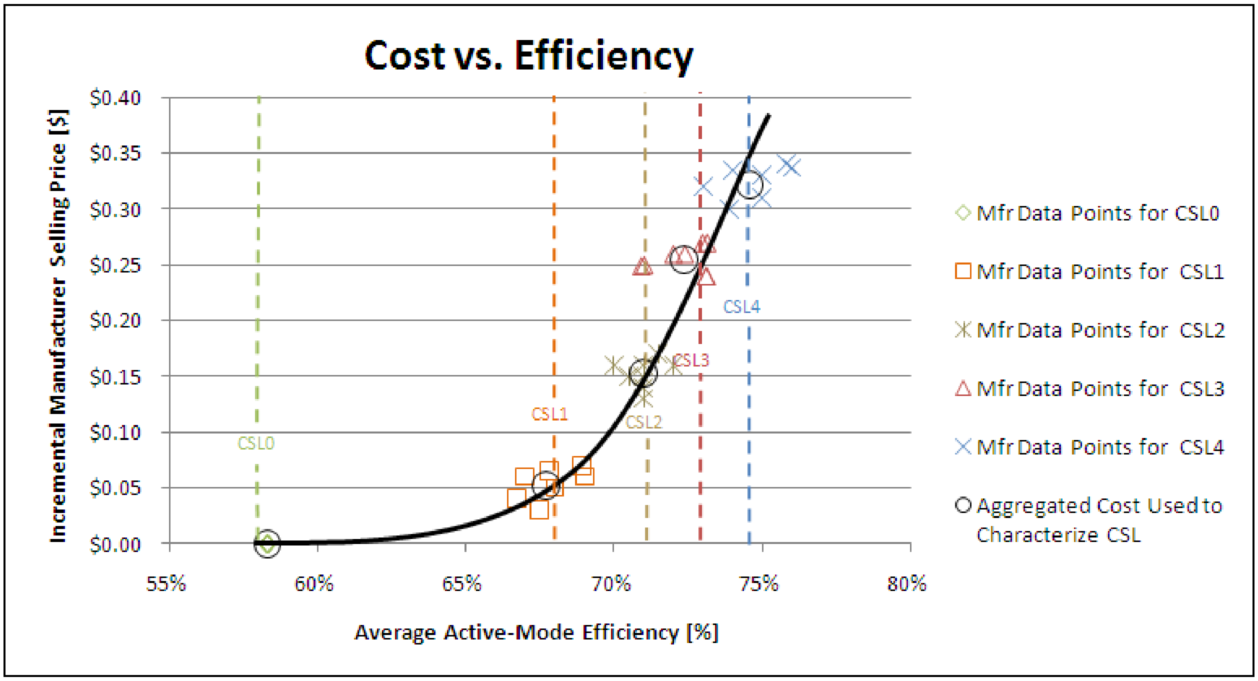


Figure 5.14 Illustration of Aggregation Method in Two Dimensions for the 2.5W Representative Unit

*The efficiency and MSP data presented in the plot is not actual manufacturer data; it is only for illustrative purposes.

The same approach is also applicable to no-load power and MSP values, as shown in Figure 5.15. In this scenario, the quadratic fit would have the form $Z=a+bY+cY^2$, where Z would represent the MSP output, Y would represent the no-load power input, and the parameters a, b, and c would be determined from the least-squares fit.

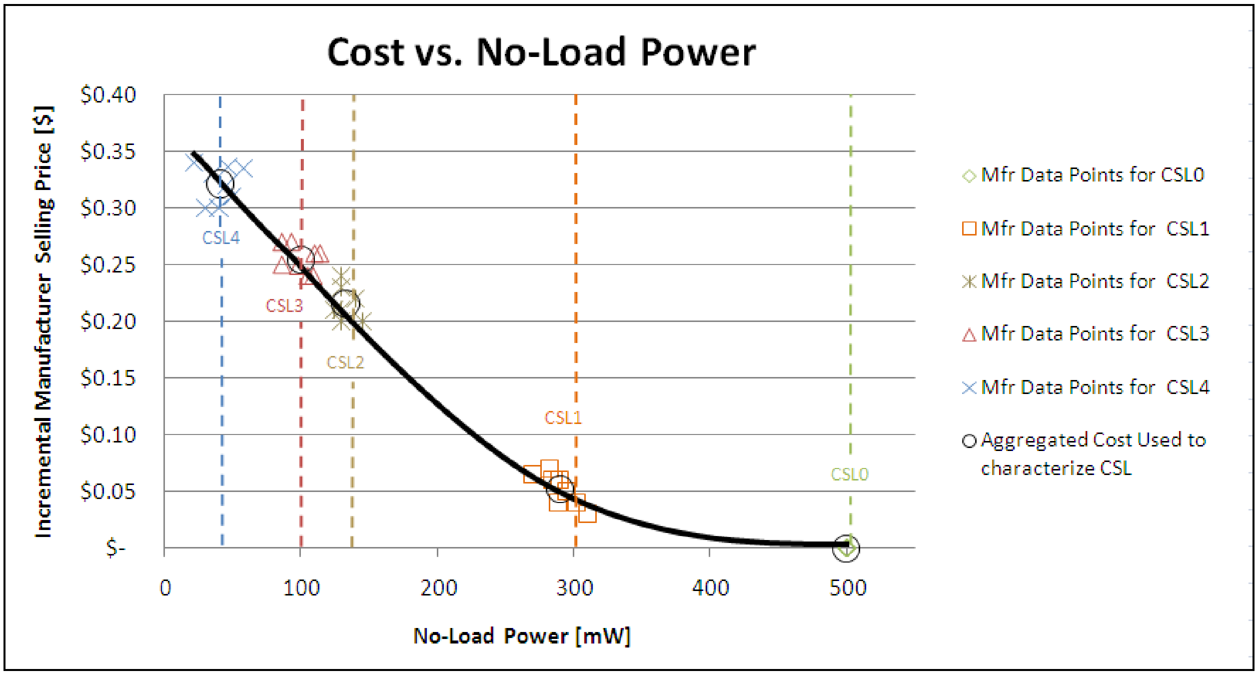


Figure 5.15 Illustration of Aggregation Method in Two Dimensions for the 2.5W Representative Unit

*The no-load power and MSP data presented in the plot is not actual manufacturer data; it is only for illustrative purposes.

In the original problem, the MSPs were dependent on both the efficiencies and no-load powers. Hence, this is a three-dimensional problem where the independent variables are efficiency and no-load power, and the dependent variable is MSP. To obtain aggregate MSPs at the CSL efficiencies and no-load powers, Navigant fit three-dimensional quadratic surfaces to the manufacturer data for the 60W and 120W representative units (the analog of the quadratic curves in the two-dimensional examples). As was done in the two-dimensional examples in Figure 5.14 and Figure 5.15, one quadratic surface was fit for each representative unit. Each quadratic surface was a least-squares fit of the MSP, efficiency, and no-load power data, with the constraint that it pass through $0 at CSL 0 and CSL 1. The form of the equation for the surface was $Z=a+bX+cX^2+dY+eY^2+fXY+gX^2Y+hXY^2$, where Z represents the MSP output, X represents the efficiency input, Y represents the no-load power input, and the parameters a, b, c, d, e, f, g, and h would be determined from a least-squares fit. After fitting the surface to the manufacturer data of each representative unit, Navigant applied the CSL efficiencies and no-load powers to obtain the aggregate MSPs.

During the preliminary analysis, the three dimensional curve-fit approach was applied to all the representative units when generating their associated cost-efficiency curves. After acquiring new data during subsequent manufacturer interviews, DOE believes that the two dimensional aggregation of cost and efficiency, as shown in Figure 5.14, is more appropriate for the lower power representative units (2.5W and 18W).

The three dimensional aggregation gives the best possible fit between the three metrics of interest: cost, average active-mode efficiency, and no-load power, assuming a data set of sufficient size. From the eight EPS manufacturers DOE interviewed to generate the cost-efficiency curves, only two were able to supply data for 2.5W EPSs and four supplied data for 18W EPSs. DOE received data from at least six manufacturers for the higher power representative units (60W and 120W). As such, the three dimensional aggregations for the lower power EPSs were more susceptible to outliers in the data set and generated curves that DOE believes were not the best representation of the cost-efficiency relationship. An inspection of the three dimensional aggregation curves for the lower power representative units showed costs that were lower than manufacturers provided. DOE therefore applied the two dimensional aggregation methodology shown in Figure 5.14 to the 2.5W and 18W representative units to generate their MSPs at all five CSLs, which resulted in a more representative cost-efficiency relationship based on the manufacturer data.

5.4.5.2 Factors that affect conversion efficiency

Conversion efficiency is determined by EPS active-mode power consumption, which is comprised of power lost through components as it flows through the EPS as well as power consumed by EPS overhead control circuitry. Particularly for EPSs with higher nameplate output powers, EPS control circuitry consumes significantly less power than what is lost as power passes through components. Thus, manufacturers indicate that they reduce power consumption by focusing their efforts on the power consuming components.

Design options for reducing components' power consumption can be divided into two categories: (1) improvements to the topology and IC controller and (2) improvements to particular components in the EPS. The combination of topology and IC controller has the most influence on EPS efficiency because the topology dictates which components are used in the EPS and the controller coordinates how power flows. In general, manufacturers would use a flyback topology for most EPSs, with two exceptions. For the baseline model of the 2.5W representative unit, they would use a ringing-choke converter, which does not employ an IC controller, or a linear power supply, which uses a transformer and a linear regulator. For the 60W and 120W representative units, they would use a resonant topology such as a half bridge converter or an LLC (inductor-inductor-capacitor) converter for the higher-efficiency CSLs.

The IC controller dictates how power flows through the EPS by monitoring the EPS output as well as other conditions. Using those input signals, the controller employs algorithms to control a metal-oxide-semiconductor field-effect transistor (MOSFET) switch, which, in turn, controls the input power that flows from mains to the primary side of the EPS's transformer. IC controllers can use algorithms such as zero-voltage switching (ZVS) and frequency fold-back to reduce EPS power consumption. In ZVS, the controller opens and closes the switch only when there are 0 volts across it, which greatly reduces conduction losses in the MOSFET. A controller employs frequency fold-back during light loading conditions by reducing the frequency at which it turns on the MOSFET, minimizing the switching losses in the MOSFET. In addition to these methods, the IC controller can also replace functions provided by discrete components. IC manufacturers indicate that they typically price IC controllers based on the value of their high efficiency and ability to replace discrete components.

Among the discrete components that manufacturers would improve to increase efficiency, the two most often cited were the switching MOSFET and the output rectifier.

Switching MOSFETs have two types of losses: conduction losses and switching losses. Conduction losses can be reduced by reducing the resistance from the drain to the source of the MOSFET while turned on, referred to as the R_{DS_ON}. Typically, increasing the size of the silicon transistor or improving its material properties reduces R_{DS_ON}. Switching losses are the losses caused by activating and deactivating the MOSFET switch, typically governed by gate capacitance. Gate capacitance is reduced through improvement of material properties and use of smaller silicon chips. To improve MOSFETs, manufacturers typically indicated that they would pay for larger, better quality silicon.

The output rectifier is the other key component that manufacturers would improve. There are three types of output rectifiers: regular diodes, Schottky diodes, and synchronous rectification MOSFETs. The power consumption through the output rectifier is governed by: $P_{consumed} = V_{diode} \times I_{out}$. Regular diodes are the cheapest and least efficient. Typically, regular diodes have a diode voltage drop of approximately 1V. Schottky diodes are more expensive and have a diode voltage drop of approximately 0.3V, thus, for the same output current, their power consumption is significantly less. A synchronous rectification circuit uses a controller and a MOSFET instead of a diode so that the MOSFET provides the functionality of a diode without the voltage drop. The benefit of this arrangement is that the power consumed by the MOSFET is typically much lower than the power consumed even by a Schottky diode; however, the MOSFET and its control circuit are more expensive than Schottky diodes. The benefit to using synchronous rectification for EPSs becomes diminished at higher output voltages (above 15V) in which case manufacturers sometimes found Schottky diodes to be the best design option.

As a last step in improving efficiency, manufacturers would switch to a thicker output cable, or reduce the cable length. Changing wire gauge is generally more expensive than minor component changes on the printed circuit board (PCB), so manufacturers first focus on the PCB to improve efficiency at low cost. If active-mode efficiency is still below a desired level manufacturers will change the cable to get a slight boost in efficiency, because at that point in the design process, it is easier than redesigning the whole PCB.

5.4.5.3 Factors that affect no-load power consumption

The IC controller has the most influence over no-load power consumption because it determines which parts of the EPS turn off in no-load mode. The most common technique employed by IC controllers to reduce no-load power consumption is to use cycle skipping or burst mode. In active mode, the IC controller turns on the switching MOSFET often at rates greater than 20 kHz. In no-load mode, the controller can skip cycles, thus saving power that would have been consumed by MOSFET switching losses. When the controller skips many cycles – possibly even for seconds at a time – the EPS is said to operate in burst mode. The number of cycles skipped is limited by the turn on time, which is how quickly the EPS needs to be able to provide full power to the load. Better IC controllers can achieve no-load mode power consumption in the range of 100mW to 200mW, well below the EISA maximum limit of 500mW. Typically the increase in cost is minimal to fabricate an IC controller that reduces no-load power consumption; IC manufacturers charge a price for this feature that reflects its value in the market.

For higher power EPSs (60W and 120W) manufacturers indicated another step that they would take to reduce no-load power consumption: they would employ a small 1-watt “housekeeping” power supply. In no-load mode, an EPS must monitor when there is an output load and must meet the load’s power demands in a timely manner. For higher power EPSs, the first step to providing the monitoring function while reducing no-load power consumption is to use an IC controller with cycle skipping and burst mode. However, that controller will still need to activate all parts of the EPS during the bursts when it checks the presence of a load. This can consume significant amounts of power. As an alternative, manufacturers can include an additional housekeeping power supply circuit in the EPS that can monitor the output load and quickly activate the main EPS when it needs to provide a load. The housekeeping power supply will have a much smaller transformer than the one used during active mode. This reduction in size will reduce quiescent losses. Often the housekeeping supply is a cost-effective way of achieving very load no-load power consumption for a higher power EPS.

5.4.5.4 Factors that affect cost

Manufacturers identified the mark up chain within an EPS manufacturer as beginning as a bill of materials (BOM) that enters a factory to a product valued at the manufacturer’s production cost (MPC) as it leaves the factory to the manufacturer selling price (MSP) – the price at which the EPS manufacturer sells the EPS. Some manufacturers referred to MPC as the “factory cost” since it is the cost of the EPS exiting the factory, typically located in China. In general, manufacturers provided cost data at the MPC level and indicated a typical mark up of about 1.3 from MPC to MSP, although the range of markup varied from 1.2 to 1.85. Manufacturers also indicated that markups varied with efficiency – *i.e.*, EPSs qualifying for Energy Star had higher markups. Nonetheless, the analysis only uses the markups for baseline EPSs because that best reflects what consumers would pay if DOE were to implement a standard.

In addition, manufacturers provided data on cost scaling. They unanimously indicated that cost scaling is unnecessary between EPSs with similar nameplate output power values (within approximately 10% of each other). Specifically, many manufacturers provided data for 65W EPSs, which they believe are more common than 60W EPSs, the representative unit. Nonetheless, they believe that only a few of the components between the two EPSs would be different and the cost difference between those components is negligible.

In other cases, manufacturers provided data for units that were significantly different from the representative unit values. One manufacturer provided data for a 5W EPS and indicated that the costs for a comparable 2.5W EPS would be half. Another manufacturer provided data for a 100W EPS and indicated that the costs for a 120W EPS would be 10% higher.

5.4.5.5 Factors to consider for candidate standard levels

Manufacturers had a consensus view that using matched pairs as the basis for the CSLs is a valid approach. Specifically, they indicated that average efficiency and no-load power consumption vary independently, except at very high efficiencies – *i.e.*, when average efficiency is very high (above 90% for EPSs over 50W) or no-load power consumption is very low (less than 30mW).

5.4.5.6 Factors to consider when interpreting the test and teardown results

Manufacturers have a consensus view that cost increases with efficiency when all other characteristics of EPS design are held constant; hence, the manufacturers' cost-efficiency curves all have positive slopes. They noted, however, that conducting a cost-efficiency analysis by purchasing EPSs might yield questionable results because it is all but impossible to hold constant all design characteristics, other than cost and efficiency, for different EPSs in the market. Example EPS characteristics that they noted might vary:

- Maximum case temperature
- Maximum component temperatures
- Component de-rating (how close a component operates to its maximum rating)
- Hold-up time (how long the EPS outputs power after being disconnected from mains)
- Output voltage regulation
- Efficiency requirements at non-US voltages
- Protection features (e.g., shutting down during short circuit conditions)
- Maximum ambient temperature

Most of these characteristics affect the reliability of the EPS (*i.e.,* when it fails) and the tolerance of the EPS to different electronic and environmental conditions (e.g., how long the EPS provides output power after being unplugged from mains; whether the EPS operates in 110 degree heat). A further complication is that many of these factors significantly affect cost and efficiency, but do not all affect it in the same way – *i.e.,* characteristics leading to more reliable and expensive EPSs may make EPSs more efficient in some cases, but less efficient in others. For instance, increasing component de-rating makes an EPS more expensive and reliable, but less efficient. De-rating is the value for a component, such as a transistor, that specifies the difference between the anticipated maximum voltage the transistor will experience under normal operating conditions in the EPS versus the maximum rated value indicated by the transistor manufacturer. Often transistors in EPSs are expected to endure 400V drops and will often have a maximum rating of 500V or 600V. Of course, the 600V transistor is more expensive, but it is also less efficient than the 500V one. So if two EPSs were identical other than their transistor de-ratings, their cost-efficiency curve would have a negative slope. However, an EPS with a 600V transistor will be more robust. In other cases, a higher-quality specification, such as lowering case temperature, would tend to lead to improved efficiency. Ultimately, the OEM specifies these characteristics so that the EPS functions as desired with the OEM's application or range of applications. EPSs are used with a diversity of applications; thus, their specifications are diverse, which complicates an analysis of cost and efficiency based on commercially available units.

5.4.6 Direct Operation EPS Scaling Relationships

DOE developed scaling relationships that it used both to analyze representative unit data as well as to scale CSLs from product class B to other product classes. In general, the scaling methods for representative unit data were detailed whereas the scaling methods for CSLs were simpler. For the representative unit data DOE adopted the more detailed approach because the detailed methods provide enhanced accuracy, which was paramount, as it was the basis for later analyses, including the LCC and NIA. For the CSL equations, DOE adopted the simpler approach so that stakeholders could more easily evaluate the CSLs.

DOE developed CSL equations that have the general form $Y=a*\ln(P_{out}) + b*P_{out}+c$, for each of the nameplate output power segments, where Y indicates the efficiency or no load-power requirement; P_{out} indicates the nameplate output power; and a, b, and c indicate the specific parameters defined for the respective CSLs. As explained in this section, DOE has determined that output cord and output voltage also have an effect on efficiency. Thus DOE could have included terms in the CSL equations for output cord and output voltage although that would have resulted in much more complicated equations.

In sections 5.4.3, 5.4.4, and 5.4.5 DOE presents the test data, teardown data, and manufacturer data that it used as the basis of this analysis. Wherever possible, DOE selected test units that had the same characteristics as the representative units. Similarly, it sought data from manufacturers at the representative unit values. However, in some cases, test units and manufacturers' data were slightly different from the representative unit specifications. For those cases DOE developed detailed scaling relationships so that the data would be most applicable to the representative unit analysis.

Specifically, the direct operation engineering analysis characterizes the cost-efficiency relationship using average efficiency in active-mode, power consumption in no-load mode, and MSP. DOE did not develop scaling relationships for no-load mode power consumption because it is minimally affected by EPS representative unit characteristics. DOE considered developing a scaling relationship for cost by production volume. Specifically, for the representative units, DOE and iSuppli, the contractor that DOE employed to carry out the teardowns, developed estimate production volumes that were on the order of approximately 1 million units shipped per year. iSuppli indicated that prices did not change appreciably over that range, hence scaling by production volume is not necessary. Thus, to scale data with different production volumes to the representative unit's production volume, DOE did not change the data's costs, which DOE considers to be "scaling with no effect."

For the efficiency and MSP characteristics, DOE developed the following scaling relationships:

- *Efficiency by nameplate output power*. DOE scaled efficiency by output power using the EISA 2007 standard and Energy Star 2.0 specification, which follow the market trend of increasing efficiency with increasing output power. (Section 5.4.6.1).
- *Efficiency by nameplate output voltage*. For EPSs of a given nameplate output power, lower nameplate output voltage results in higher current-associated losses and lower efficiency. DOE analyzed units with the same nameplate output power and different nameplate output voltages to characterize this relationship. DOE also evaluated a voltage scaling approach based on Energy Star 2.0, for low-voltage units (Section 5.4.6.2).
- *Efficiency by output cord length*. Longer output cords provide consumers with the added utility of being able to operate the product farther from mains. Longer

output cords also have higher losses and are more expensive. DOE analyzed output cords to characterize this relationship. (Section 5.4.6.3).

- *Cost by nameplate output power*. EPSs with higher nameplate output powers provide consumers with the added utility of being able to provide power to more power-demanding products. EPSs with higher nameplate output power also have more and larger components and, consequently, cost more. (Section 5.4.6.4).
- *Cost by output cord length*. Longer output cords are also more expensive. DOE analyzed output cords to characterize this relationship. (Section 5.4.6.5).
- *Markups*. Test and manufacturer data costs at different points in the value chain represent different stages in the sale of an EPS. DOE characterized these markups in order to compare costs at the same stage in the value chain, namely MSP (Section 5.4.6.6).

Though in many cases the data did not require applying all of the scaling steps, all the scaling steps are nonetheless illustrated in Figure 5.16 in the order that they would be applied.

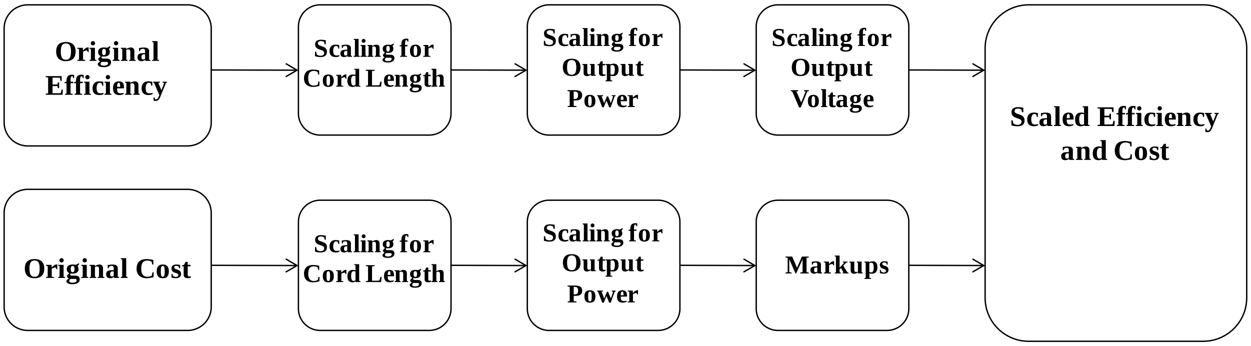


Figure 5.16 Scaling Steps to Normalize Efficiencies and Costs

5.4.6.1 Scaling Efficiency with Output Power

The practically achievable efficiency of an EPS depends on its nameplate output power, with lower-power EPSs tending to exhibit lower active-mode efficiencies than their higher-power counterparts. DOE characterized this relationship using the EISA 2007 standards equation and Energy Star 2.0 standard voltage specification equation that describe this market trend; these equations are the same as CSL 0 and CSL 1 equations, shown in
Table 5-5 and
Table 5-7, respectively.

DOE used these equations as references relative to which it scaled data. To scale the data, DOE ensured that the ratio between the original data point and the reference equations remained constant, as shown in Figure 5.17. The figure shows how the efficiency data point maintains the same relative relationship between the EISA 2007 and Energy Star 2.0 equation as it is scaled from 70% efficient at 5 watts to 75% efficient at 10 watts. DOE believes this scaling approach is appropriate because it ensures that the EPS data does not cross CSLs as it scales between output powers. Further, by comparing the data relative to two levels, rather than shifting based on the absolute difference from one level, there is a lower risk of the data being scaled to unrealistic values.

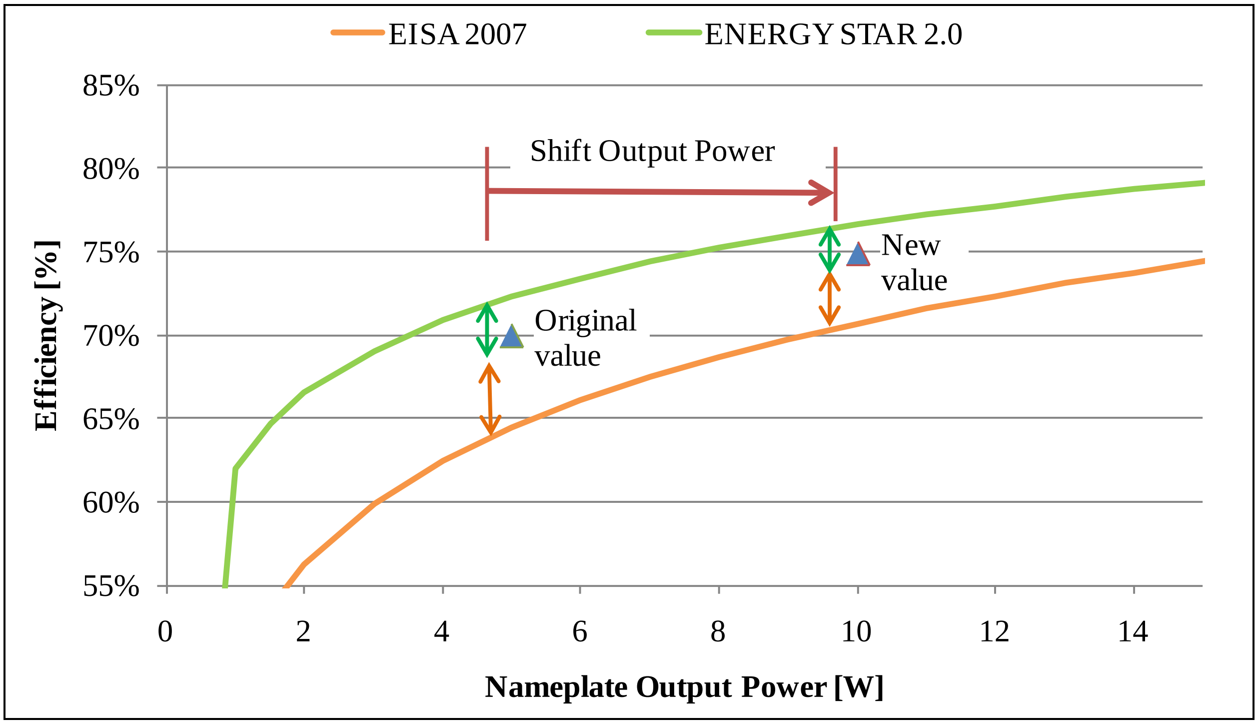


Figure 5.17 Scaling an EPS efficiency data point with nameplate output power

DOE developed the following equation to perform the scaling:

$$\eta_{UNIT_{NEW}} = \eta_{EISA\ NEW} + \frac{\eta_{UNIT\ ORIGINAL} - \eta_{EISA\ ORIGINAL}}{\eta_{ESTAR\ ORIGINAL} - \eta_{EISA\ ORIGINAL}} * \left(\eta_{ESTAR\ NEW} - \eta_{EISA\ NEW}\right)$$

Where

$\eta_{UNIT_{NEW}}$ = the efficiency of the unit under analysis at the new output power
$\eta_{UNIT\ ORIGINAL}$ = the efficiency of the unit under analysis at the original output power
$\eta_{EISA\ NEW}$ = the corresponding EISA 2007 efficiency at the new output power
$\eta_{EISA\ ORIGINAL}$ = the corresponding EISA 2007 efficiency at the original output power
$\eta_{ESTAR\ NEW}$ = the corresponding Energy Star efficiency at the new output power
$\eta_{ESTAR\ ORIGINAL}$ = the corresponding Energy Star efficiency at the original output power

In certain instances scaling by output power does not have an effect. For data where both the ORIGINAL nameplate output power and the NEW output power are greater than or equal to 51W, there will be no effect on the efficiency value. This is because both the EISA and Energy Star 2.0 equations are constant for output powers at or above 51W. Hence, the efficiency value output from the scaling equation will be identical to the efficiency value used as the input.

Unit #876 is an example of an instance where it was necessary to scale based on output power. Unit #876 was chosen for the 2.5W CSL 0 representative unit (see Table 5-15). Since this unit had a nameplate output power of 2.4W, it was necessary to scale its efficiency to that of an equivalent 2.5W unit. The original, tested average active-mode efficiency of unit #876, which was 61.0%, was first scaled using the output cord scaling procedure (see Section 5.4.6.3), to 61.1%. Then, after applying the output power scaling, the efficiency was scaled from 61.1% to 61.4%. The magnitude depends in general on how close the original nameplate output power is to the representative output power and the slope of the curves at those values.

5.4.6.2 Scaling Efficiency with Output Voltage

DOE used two methods for output voltage scaling. The first method was simple and based on Energy Star 2.0. The second method was more detailed and based on test data. DOE applied the first method to scale CSL equations between the basic voltage and low-voltage product classes. DOE applied the second method to scale data for the representative unit analysis. Herein DOE describes the two methods for output voltage scaling in more detail.

The first method involved using the differences between the EPS Energy Star 2.0 efficiency equations for basic and low-voltage (see Section 5.4.10.2 for details). This method was used in scaling CSL efficiency equations from the basic voltage product classes (B and D) to the low-voltage product classes (C and E). This method was particularly appropriate for product class scaling for two reasons. First, the low-voltage product class definitions coincide with the Energy Star 2.0 definitions for basic voltage and low voltage. Second, using the Energy Star 2.0 equations, which span the entire range of nameplate output powers, allowed DOE to set a standard for efficiency at all nameplate output powers, not just those near the representative unit values, where the test data method is focused.

DOE believes that the Energy Star 2.0 scaling method was inappropriate for use directly on representative unit data. Specifically, unlike the Energy Star 2.0 standard voltage equation, the Energy Star 2.0 low-voltage efficiency equation applies to EPSs with output voltage less than 6V, and output current greater than or equal to 550 milliamps. Thus, as the Energy Star 2.0 “standard voltage” and “low-voltage” labels imply, the Energy Star 2.0 efficiency equations only provide a coarse, two-bin, basis for examining the effects of differing output voltages on EPS efficiencies. Thus, this first method was not applicable for scaling the representative unit data to the appropriate representative unit voltages at fine scales.

DOE developed the second, more complex method based on units it had tested in the market near representative unit values. This second method was particularly useful for scaling representative unit data by output voltage. Although DOE could theoretically extend this method to develop scaling relationships at other nameplate output powers, DOE did not do so because of the significant complexity involved. In addition, even if DOE were to extend this method to all output powers, it would still not address the issue of how to scale a basic voltage product class to a low-voltage product class. This is because DOE’s output voltage scaling method requires an exact target output voltage to scale to, and the low-voltage product class only indicates that the output voltage is less than 6 volts. The following is an introduction to this second method, which DOE used to scale representative unit data by output voltage:

EPS power consumption is related to (1) power consumption due to overhead circuitry and (2) losses as power flows through the EPS. For an EPS of a given output power, overhead circuitry consumes power independent of EPS output voltage. In contrast, losses as power flows through the EPS are directly related to output voltage, because the combination of output voltage and output power determines output current. For instance, resistive losses are related to output current by I^2*R; losses due to diode drops are related by $I*V_{diode}$.

DOE analyzed this relationship for each of the four representative units by analyzing EPS product families. Manufacturers create EPS product families by designing an EPS for a specific nameplate output power and a range of nameplate output voltages. Consequently, product families are comprised of EPSs that are very similar, only differing in output voltage. DOE purchased and tested (using the DOE EPS test procedure) all of the EPS product families it could locate with nameplate output power close to or at the representative unit output powers. For those product families with different nameplate output powers, DOE scaled the efficiency results, per section 5.4.6.1.

By analyzing the EPS product families DOE determined a scaling relationship between output voltage and efficiency for all of the representative units, except the 2.5-watt representative unit. DOE believes that 2.5-watt EPSs do not have a scaling relationship because these EPSs have such low nameplate output power ratings that the overhead losses are a very significant portion of the total losses. Thus the overhead losses obscure the changes in power consumption losses that vary with output voltage, so no scaling with output voltage is necessary.

For the remaining three representative units, DOE developed a low-efficiency curve and a high-efficiency curve to characterize the lower-efficiency and higher-efficiency product families. The following discussion illustrates how DOE developed a low-efficiency and high-efficiency curve for the 60-watt representative unit. The same methodology applies to both the 18-watt and 120-watt representative units.

To perform output voltage scaling for 60-watt EPSs, DOE analyzed six manufacturer product families, as shown in Figure 5.18.

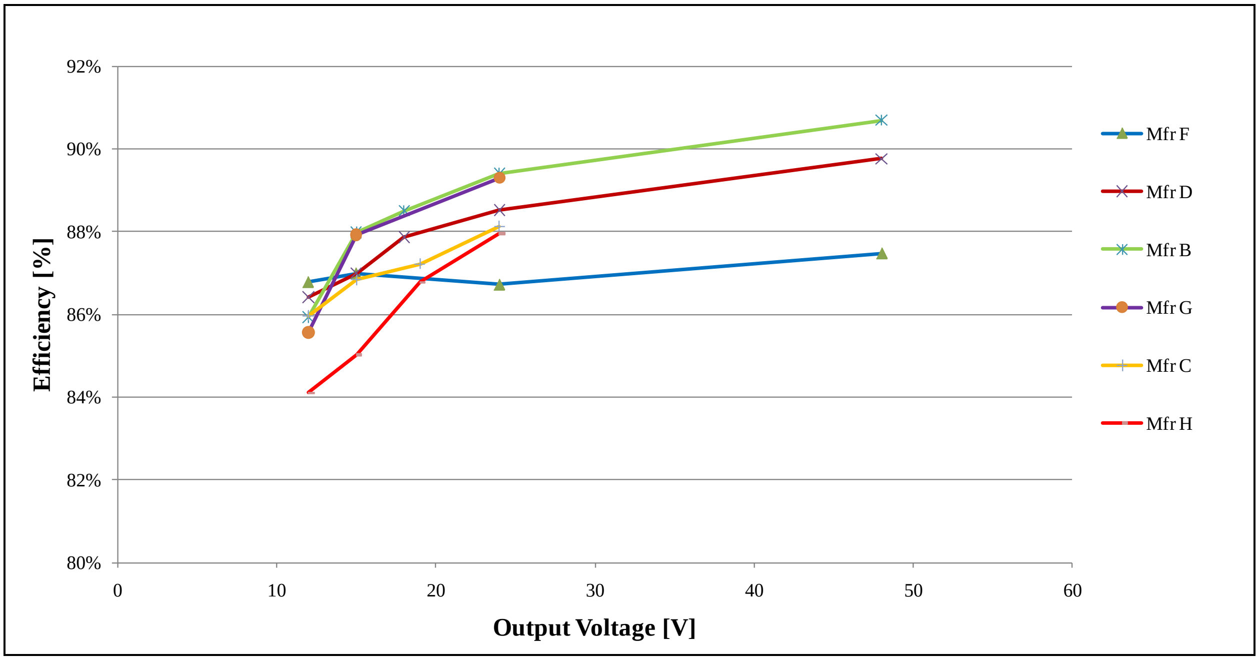


Figure 5.18 60-Watt EPS Product Families for Output Voltage Scaling

DOE identified Manufacturer B’s product family as having the highest efficiencies, and thus used its data points to create a best fit logarithmic curve to represent the higher bound for efficiency. Figure 5.19 presents Manufacturer B’s family product data points and the higher bound best fit logarithmic curve.

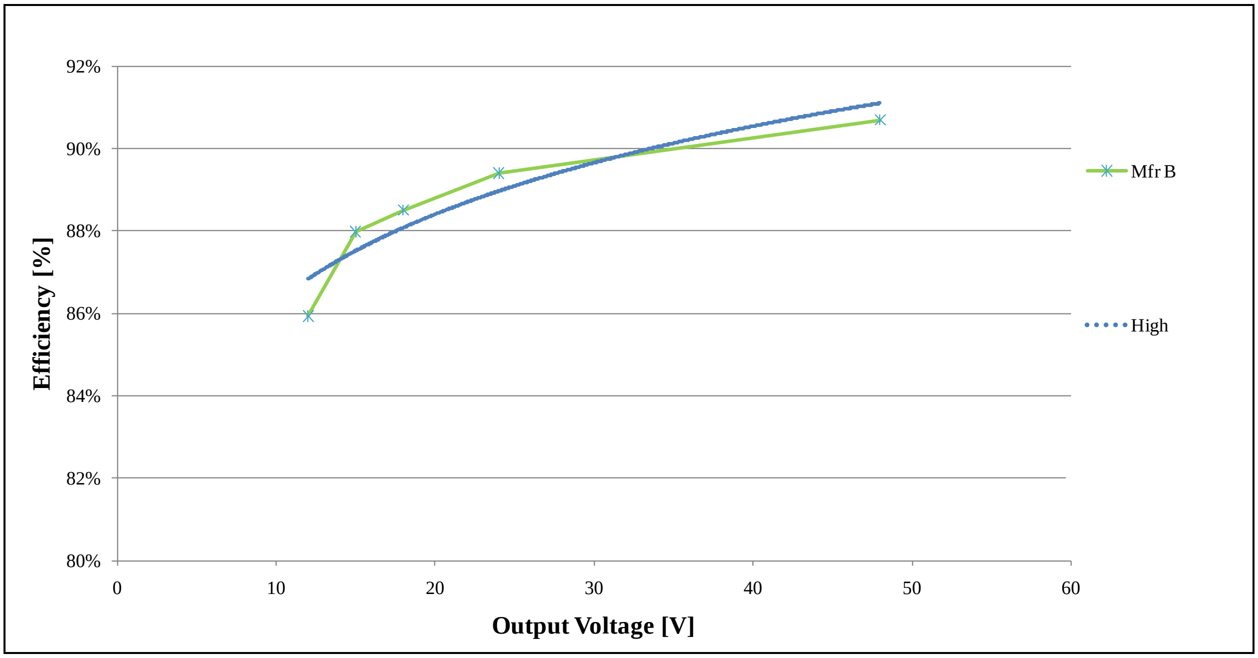


Figure 5.19 High-Efficiency Curve Used for Output Voltage Scaling

To create the lower bound for efficiency, DOE considered using Manufacturer D’s product family. However, DOE rejected Manufacturer D’s product family because it would cause the low-efficiency curve to be too close to the high-efficiency curve, which would limit the effectiveness of the scaling relationship. Instead, DOE used a combination of Manufacturer F and Manufacturer H's product families as shown in Figure 5.20. For the lower end of the range of output voltage, DOE used Manufacturer H's 2nd point and at the higher end, DOE used Manufacturer F's 3rd and 4th points. DOE did not use Manufacturer H's first point because its efficiency (84.1%) was below the EISA level. DOE did not include in its analysis any data points that did not meet EISA standards.

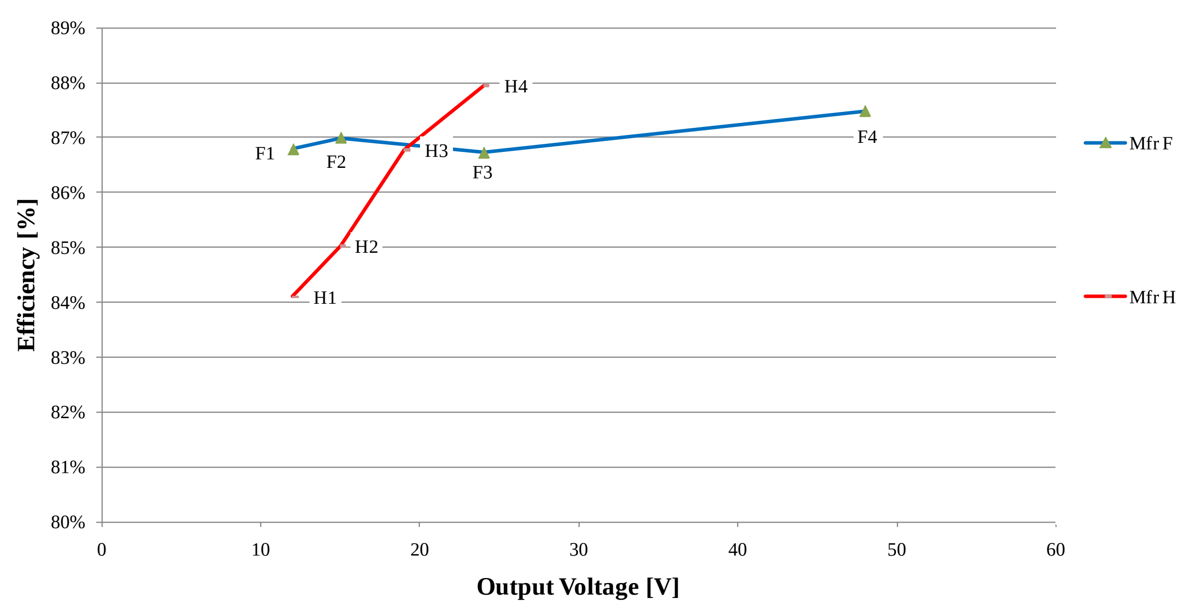


Figure 5.20 Product Families Used to Create Low-Efficiency Curve for Output Voltage Scaling

DOE created a best-fit logarithmic curve to represent the lower bound for efficiency using Manufacturer H's second data point and Manufacturer F's third and fourth data point, shown in Figure 5.21. The data points highlighted by the red squares indicate the points used by DOE to develop the line of best fit.

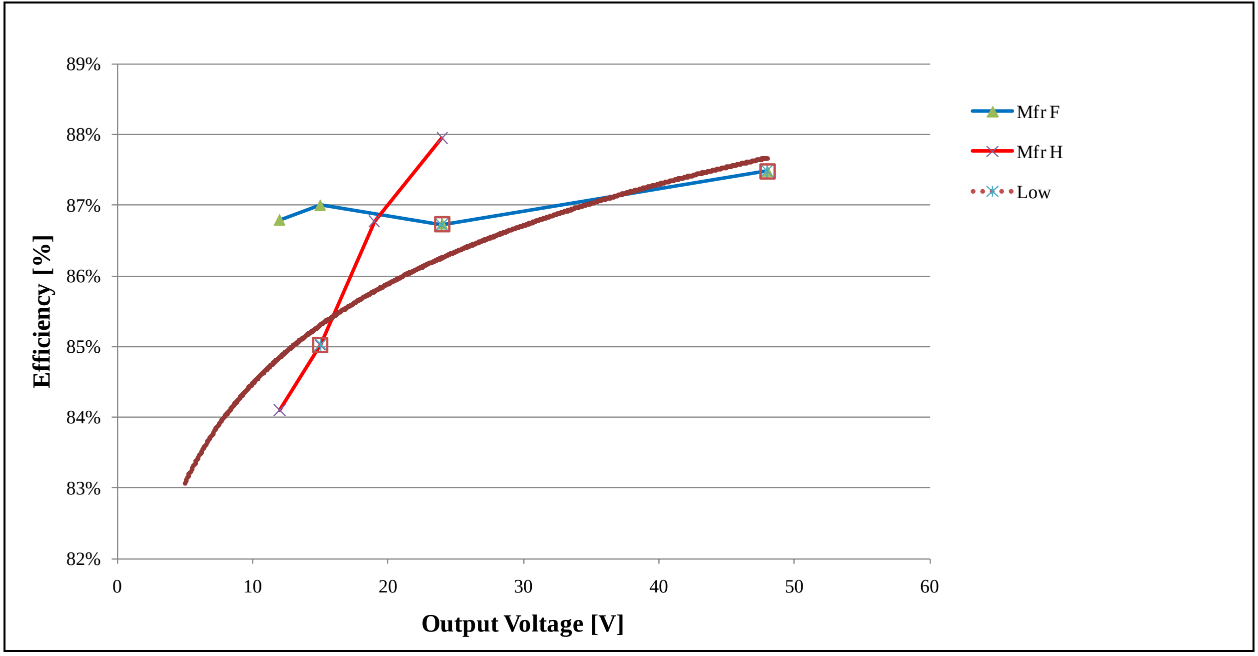


Figure 5.21 Low-Efficiency Curve Used for Output Voltage Scaling

In summary, Figure 5.22 presents the data points used to create the best fit curves, as well the upper and lower bounds for efficiency.

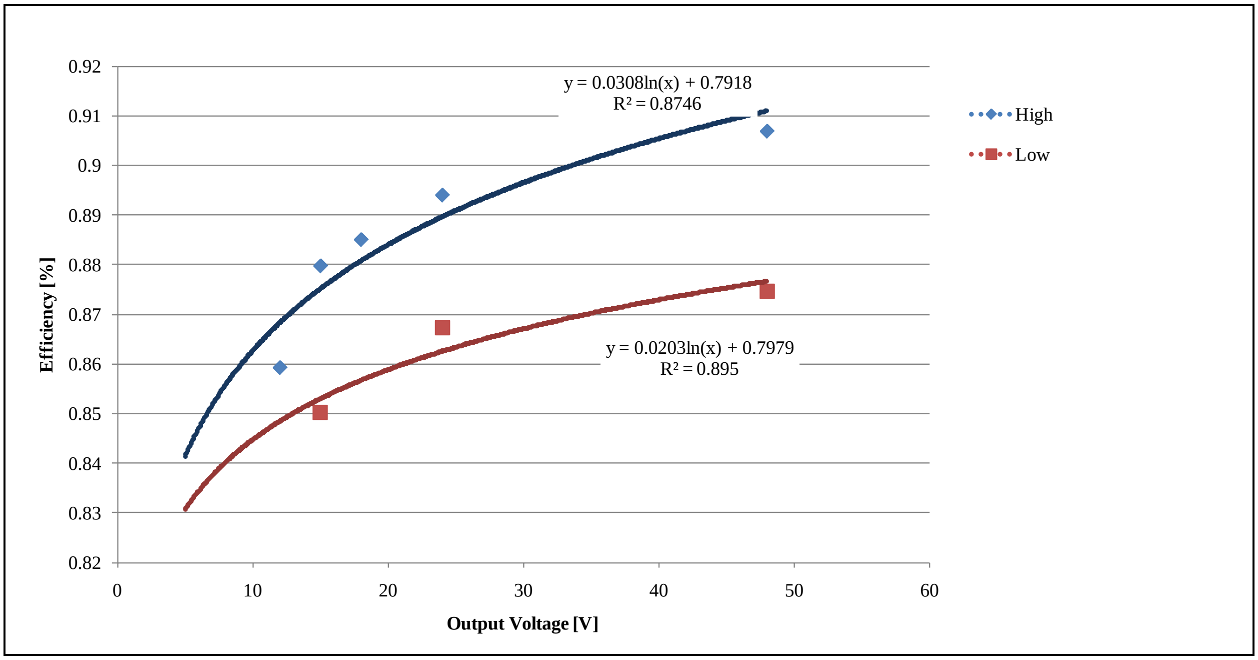


Figure 5.22 High-Efficiency and Low-Efficiency Curves for Output Voltage Scaling

Table 5-20 presents the equations for the low-efficiency curves and high-efficiency curves relating efficiency (η) to nameplate output voltage (V_{out}) for each representative unit. The results for the four representative units are shown in Figure 5.23, Figure 5.24, Figure 5.25, and Figure 5.26. Where voltage scaling was necessary, DOE scaled test unit and manufacturer data using these equations for output voltage. DOE used a similar methodology to scale output power using the EISA 2007 and Energy Star 2.0 equations as discussed in section 5.4.6.1.

Table 5-20 Curves Characterizing the Relationship between Output Voltage and Efficiency

Representative Unit	Low-Efficiency Curve	High-Efficiency Curve
18 W	$\eta = 0.0371 * \ln(V_{out}) + 0.6997$	$\eta = 0.0143 * \ln(V_{out}) + 0.8092$
60 W	$\eta = 0.0203 * \ln(V_{out}) + 0.7979$	$\eta = 0.0308 * \ln(V_{out}) + 0.7918$
120 W	$\eta = 0.0203 * \ln(V_{out}) + 0.8086$	$\eta = 0.0248 * \ln(V_{ou}t) + 0.8061$

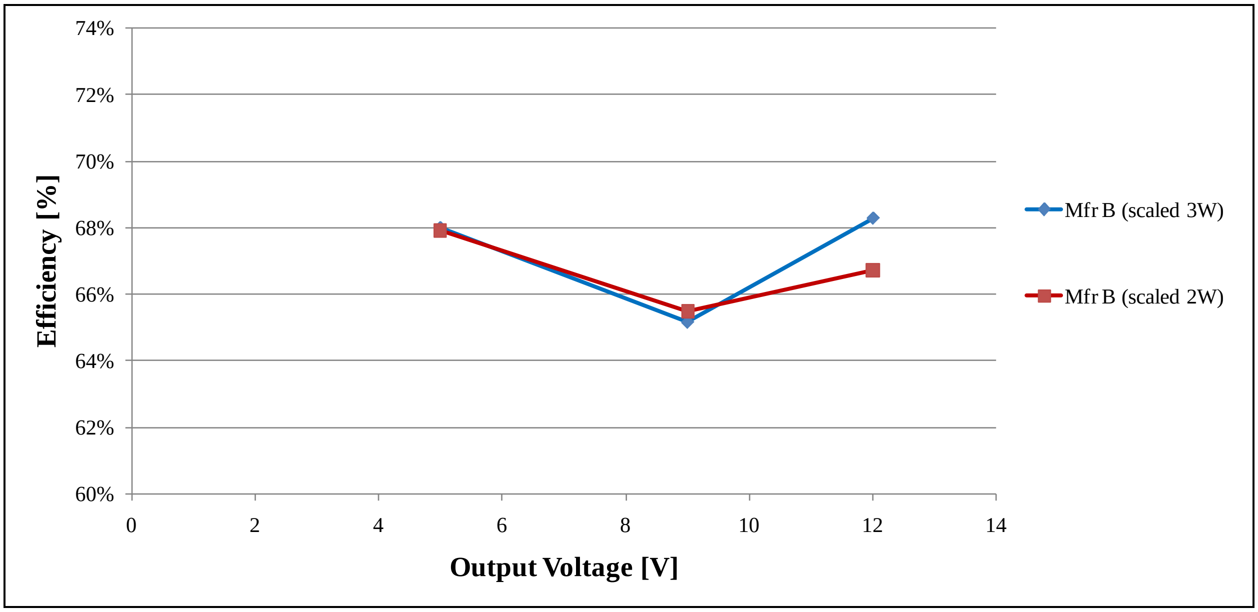


Figure 5.23 2.5-Watt EPS Product Families for Output Voltage Scaling

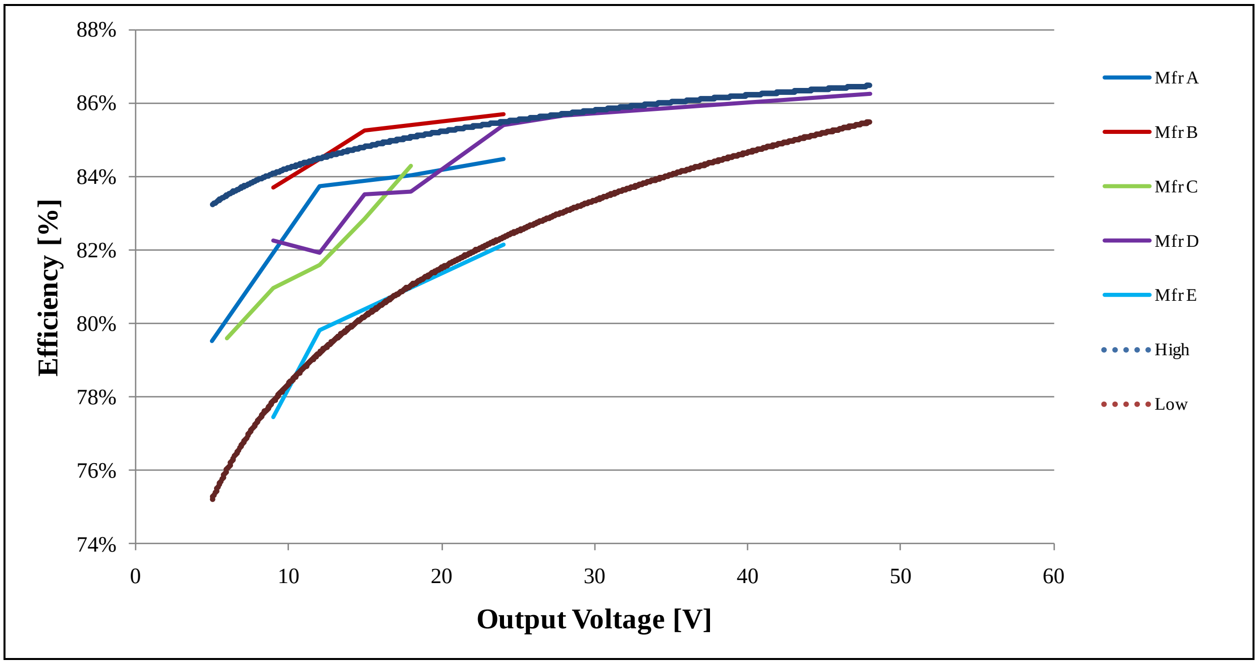


Figure 5.24 18-Watt EPS Product Families for Output Voltage Scaling

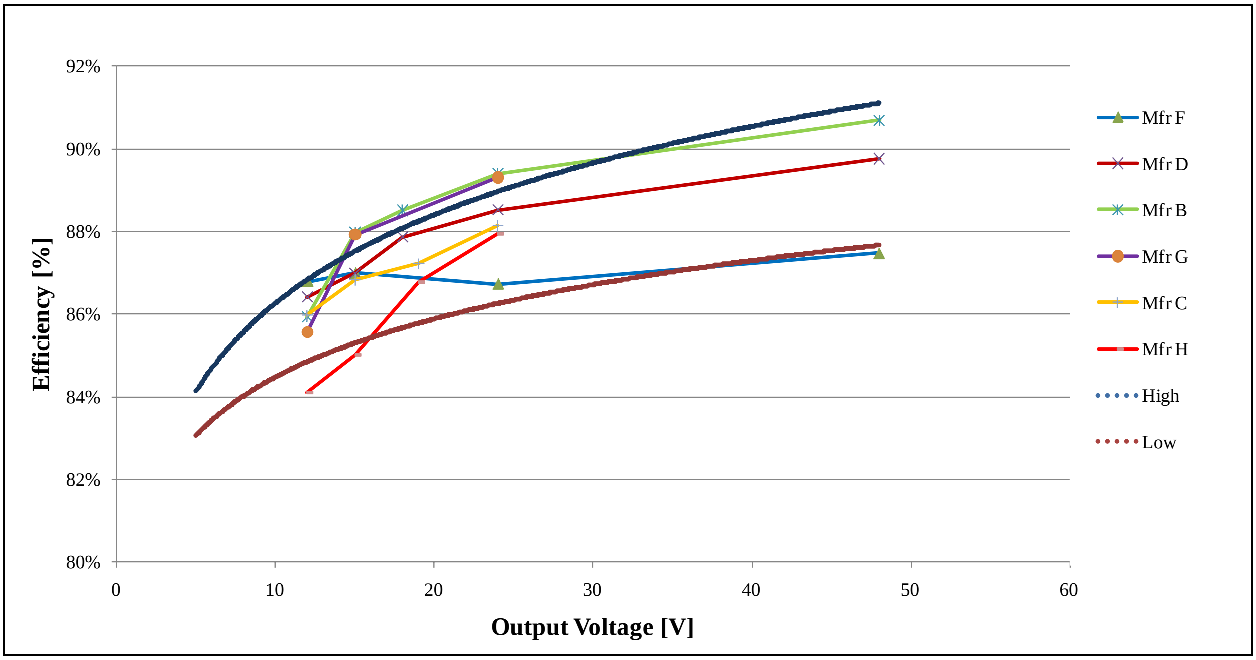


Figure 5.25 60-Watt EPS Product Families for Output Voltage Scaling

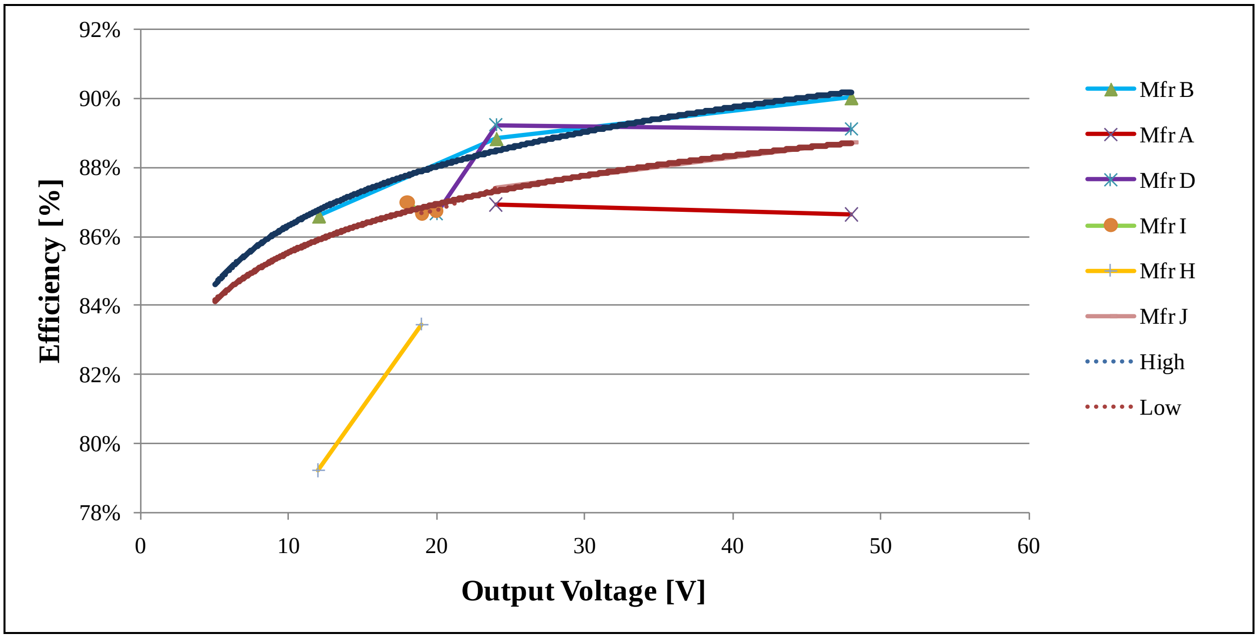


Figure 5.26 120-Watt EPS Product Families for Output Voltage Scaling

An example of an instance where output voltage scaling was necessary was with unit #999 which had a nameplate output power of 56W and voltage of 16V. Unit #999 was used as the 60W CSL 0 representative unit (see Table 5-17). Since this unit had a nameplate output voltage of 16V, it was necessary to scale it to that of an equivalent 15V unit. The original, tested efficiency of unit #999 was 86.0%, which was first scaled using output cord (see Section 5.4.6.3 for details) and output power scaling (output power scaling has no effect between 56W and 60W— see Section 5.4.6.1 for details) to 85.5%. Then, after applying the output voltage scaling, the efficiency was scaled from 85.5% to 85.4%.

5.4.6.3 Scaling Efficiency with Output Cord

The output cord of an EPS can have an appreciable impact on its measured efficiency due to resistive losses in the conductors. Based on test unit data, the output cord, which was determined to be of length 1.66 m, can cause an efficiency drop of up to 1.97 percentage points versus units with no cord. The table below shows the average and maximum efficiency drops between a unit with no output cord and a unit with a 1.66 m cord, for each of the representative units:

Table 5-21 Effects Output Cord Scaling on EPS Efficiency

Representative Unit Wattage	Average Efficiency Drop [Percentage Points]	Maximum Efficiency Drop [Percentage Points]
2.5	0.59	0.73
18	0.63	0.98
60	0.82	1.16
120	0.84	1.97

DOE considered the effect of the output cord significant in creating CSLs for the engineering analysis of product classes B, C, D, and E, based on the fact that a few percentage points separate the most and least efficient units on the market at a given output power level. Additionally, differences in cord length impact consumer utility: a longer output cord, which is less efficient, provides additional consumer utility by increasing the reach between the EPS and the end-use application.

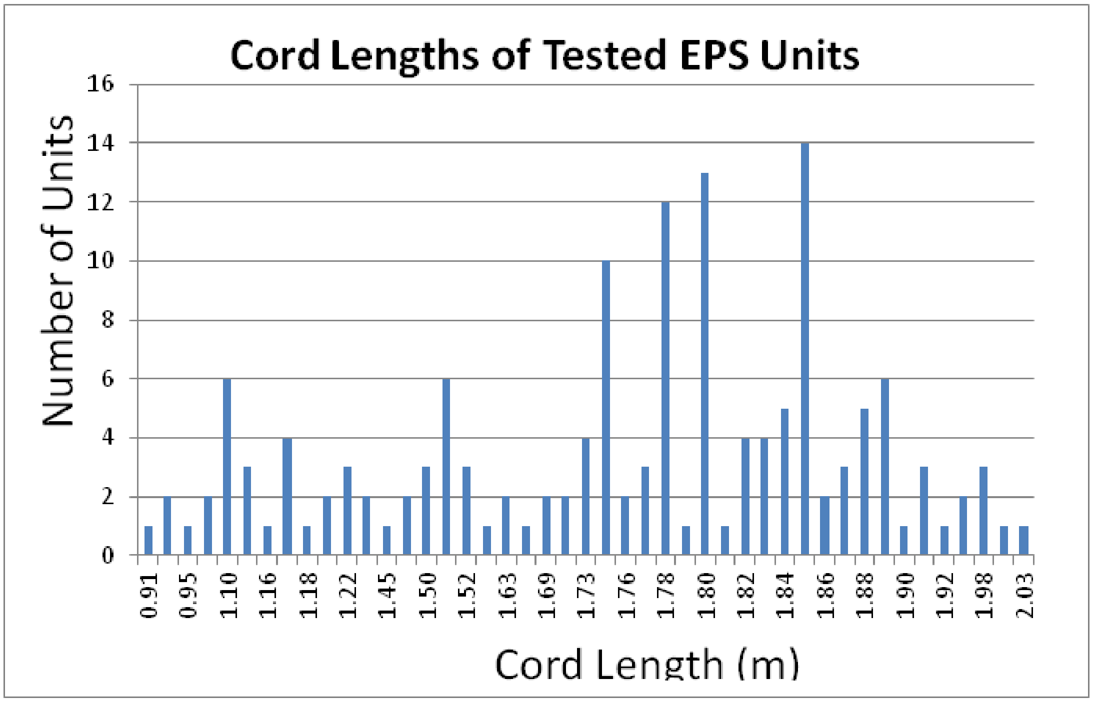


Figure 5.27 Cord Lengths of Tested EPS Units

*Data as of March 5th, 2010.

Since there are so many different cord lengths, DOE normalized tested efficiencies based on a single baseline cord length for the preliminary analysis. The 1.66 m average cord length, was derived from the individual average cord lengths in each representative unit, as shown in the table below:

Table 5-22 Average Output Cord Lengths

Representative Unit Wattage	**2.5**	**18**	**60**	**120**	**Average**
Average Cord Length [m]	1.77	1.78	1.52	1.55	**1.66**

*Data as of March 5th, 2010.

To derive the output cord efficiency scaling equation, DOE used the fact that the electrical resistance (R) of a wire depends on the resistivity (ρ), length (L), and cross sectional area (A), of the wire, in the following manner: $R = \rho LA$. Therefore, an identical EPS whose output cord length was hypothetically changed from length L, to a baseline-length L_B would have an output cord resistance of $R_{NORM} = \frac{L_B}{L} R_{CORD}$.

Secondly, the power into an EPS is partially transmitted out of the output cord end and partially consumed in the printed circuit board and the output cord components. The third fact that was used is that the power loss in the output cord is equal to the square of the current times the resistance of the cord. The second and third equations are shown below:

$$P_{IN} = P_{PCB} + P_{CORD} + P_{OUT}$$

$$P_{CORD} = I^2 R_{CORD}$$

Using these three pieces of information, the output cord efficiency scaling equation was derived. The equation for modifying the efficiency of an EPS with a certain output cord length to that with a different output cord length is shown below:

$$\eta_{NORM} = \frac{P_{OUT}}{\frac{I^2 L_B}{L} R_{CORD} + P_{IN} - I^2 R_{CORD}} = \frac{P_{OUT}}{P_{IN} + I^2 R_{CORD}\left(\frac{L_B}{L} - 1\right)}$$

Variables Defined

P_{IN}: Input power P_{PCB}: Power consumed by the EPS device in the conversion process
P_{CORD}: Power loss due to resistance in the cord
P_{OUT}: Output power
I: Output current
R_{CORD}: Resistance of a given cord
R_{NORM}: Resistance of a cord normalized for length
η_{CORD}: Efficiency of a given cord
η_{NORM}: Efficiency of a given cord, normalized for length
L_B: Baseline cord length, defined to be 1.66 m in this analysis.

One example of an instance where it was necessary to scale based on the length of the output cord was with unit # 999, which was chosen for the 60W CSL 0 representative unit (see Table 5-15). Since this unit had an output cord of length 1.09 m, it was necessary to scale its efficiency to that of a unit with a 1.66 m cord. The original, tested average active-mode efficiency of unit #999, which was 86.0%, was therefore scaled to 85.5% using the output cord scaling procedure. In general, the impact of the scaling varied depending on the deviation of the unit's cord length from the 1.66 m average and the resistance of the output cord per unit length.

Output cord scaling was used to normalize the representative unit data points; however the CSL equations do not consider output cord length. As stated previously, DOE did not include output cord length in the CSL equations to maintain simplicity. Instead, the CSL equations are developed based on the assumption that all EPS output cords are 1.66 m.

5.4.6.4 Scaling Cost by Nameplate Output Power

In interviews, manufacturers indicated that for products whose nameplate output power is close to the representative unit output power (within 10%), the cost difference is negligible, hence there is no need to scale cost by nameplate output power. However there were a few exceptions: one manufacturer provided data for a 5-watt EPS to characterize the 2.5W representative unit. In that case, the manufacturer indicated that costs should be divided in half, consistent with the difference in output power. Similarly, another manufacturer characterized the 120-watt representative unit using a 100-watt EPS; the manufacturer indicated that the costs should be scaled proportionally.

5.4.6.5 Scaling Cost by Output Cord Length

DOE scaled MSPs for test units torn down by iSuppli whose cord lengths were different from the representative units' cord length of 1.66 m. For the manufacturer data, some manufacturers noted that they did not account for cord losses in their cost-efficiency data. For those units, DOE lowered the efficiency of the units, but did not change their MSPs since the all MSPs were provided on a relative scale. Consequently, increasing all MSPs by the same amount did not affect the relative relationship between the costs.

5.4.6.6 Direct Operation EPS Markups

DOE gathered inputs on markups from manufacturer interviews. Specifically, DOE questioned manufacturers regarding typical markups for an EPS between MPC, the cost of the EPS as it leaves the factory, and MSP, the price at which the EPS is sold to an OEM. DOE aggregated the data provided by multiple manufacturers to determine that a typical markup from MPC to MSP is approximately 35.5%, and a typical markup from BOM to MSP is 62.5%. DOE used this markup to determine MSP for selected test units as well as manufacturer data. Figure 5.28 illustrates the markup chain from the original parts to the end-consumer.

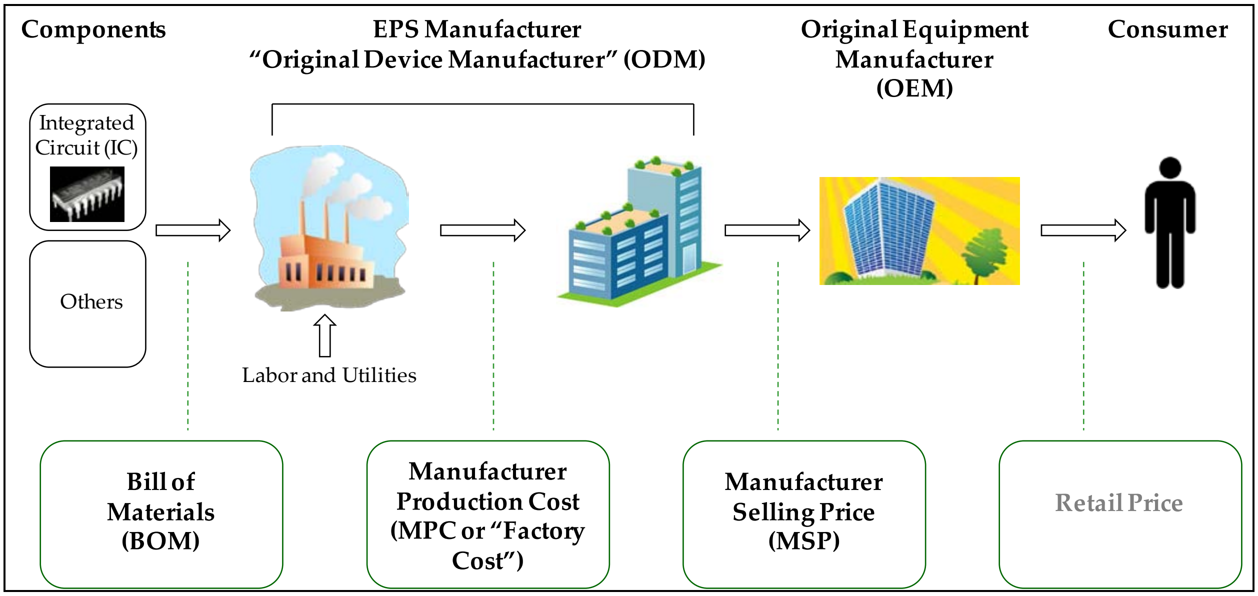


Figure 5.28 The Full Markup Chain, including the steps from BOM to MPC to MSP.

5.4.7 Direct Operation EPS Cost and Efficiency Relationships from Testing and Teardowns

For each representative unit, DOE combined the *scaled* efficiency test results with the *scaled* MSP for the three EPS test units used to characterize the baseline efficiency level (CSL 0), CSL 1, and CSL 3. As explained in section 5.4.3.2, DOE selected test units to characterize CSL 0, CSL 1, and CSL 3 such that the units' scaled efficiencies (per section 5.4.6) were equal to or slightly more efficient than the CSLs detailed in section 5.4.2 and that the units' efficiencies maintained the matched-pairs relationship. For each of these test units, iSuppli conducted teardowns to estimate MPC, as explained in section 5.4.4. DOE then scaled and marked up the test units' MPC values to MSP values.

DOE used the first eleven test units presented in Table 5-19 to characterize the CSLs for the four representative units. Before DOE used the data to generate cost-efficiency relationships, DOE normalized the data through efficiency and cost scaling steps. The scaling steps were applied in the order shown in Figure 5.16. Table 5-23 shows the details of which test units underwent which types of scaling. For details on the scaling procedures, see Section 5.4.6. For some of the test units that underwent scaling, some of the scaling had no effect. Specifically, output voltage scaling had no effect on the 2.5W representative units (see Section 5.4.6.2 for explanation), and output power scaling had no effect on the 60W and 120W representative units (see Section 5.4.6.1 for explanation). Following Table 5-19, DOE presents the test and teardown results in Table 5-24,
Table 5-25, Table 5-26, and
Table 5-27 for the 2.5W, 18W, 60W, and 120W representative units, respectively.

Table 5-23 Scaling and Markup Steps Performed on the Test Units

Rep. Unit Output Power	Test Unit #	Efficiency Scaling by Output Power	Efficiency Scaling by Output Voltage	Efficiency Scaling by Cord Length	Cost Scaling by Output Power	Cost Scaling by Cord Length	Markup to MSP
2.5W	876	✓	✓*	✓		✓	✓
	935	✓		✓		✓	✓
	996	✓		✓		✓	✓
18W	949			✓		✓	✓
	118			✓		✓	✓
	941			✓		✓	✓
60W	999	✓*	✓	✓		✓	✓
	834			✓		✓	✓
	838			✓		✓	✓
120W	854	✓*		✓		✓	✓
	951	✓*		✓		✓	✓

"✓" Indicates that the data was scaled to the representative unit values, with effects on efficiency or cost.
"✓*" Indicates that the data was scaled to the representative unit values, although the scaling had no effect.

Table 5-24 Cost and Efficiency Relationship for 2.5W EPS (Testing and Teardowns)

	CSL 0	**CSL 1**	**CSL 3**
Test Unit Efficiency [%]:	61.4	67.9	73.5
Test Unit No Load Power [W]:	0.400	0.170	0.100
CSL Description:	EISA	Energy Star 2.0	Best in Market
CSL Eff. [%], No-Load Power [W]	(58.3, 0.500)	(67.9, 0.300)	(73.2, 0.100)
Incremental MSP [$]:	0.00	0.39	-0.32
Original Application:	Cordless Phones	Generic	Mobile Phones
Test Unit #:	876	935	996

Table 5-25 Cost and Efficiency Relationship for 18W EPS (Testing and Teardowns)

	CSL 0	**CSL 1**	**CSL 3**
Test Unit Efficiency [%]:	78.9	81.4	85.4
Test Unit No Load Power [W]:	0.330	0.270	0.100
CSL Description:	EISA	Energy Star 2.0	Best in Market
CSL Eff. [%],No-Load Power [W]	(76.0, 0.500)	(80.3, 0.300)	(85.0, 0.100)
Incremental MSP [$]:	0.00	-0.12	-1.10
Original Application:	Generic	Generic	Generic
Test Unit #:	949	118	941

Table 5-26 Cost and Efficiency Relationship for 60W EPS (Testing and Teardowns)

	CSL 0	**CSL 1**	**CSL 3**
Test Unit Efficiency [%]:	85.4	87.0	88.0
Test Unit No Load Power [W]:	0.210	0.136	0.073
CSL Description:	EISA	Energy Star 2.0	Best in Market
CSL Eff. [%], No-Load Power [W]	(85.0, 0.500)	(87.0, 0.500)	(88.0, 0.210)
Incremental MSP [$]:	0.00	2.20	2.64
Original Application:	Notebook Computers	Generic	Generic
Test Unit #:	999	834	838

Table 5-27 Cost and Efficiency Relationship for 120W EPS (Testing and Teardowns)

	CSL 0	**CSL 1**	**CSL 3**
Test Unit Efficiency [%]:	86.5	88.4	88.4
Test Unit No Load Power [W]:	0.230	0.210	0.210
CSL Description:	EISA	Energy Star 2.0	Best in Market
CSL Eff. [%], No-Load Power [W]	(85.0, 0.500)	(87.0, 0.500)	(88.0, 0.210)
Incremental MSP [$]:	0.00	-4.53	-4.53
Original Application:	Notebook Computers	Notebook Computers	Notebook Computers
Test Unit #:	854	951	951

5.4.8 Direct Operation EPS Cost and Efficiency Relationships from Manufacturer Interviews

For each representative unit, DOE combined the scaled efficiency test results with the MSP for the three EPS test units used to characterize the baseline efficiency level (CSL 0), CSL 1, and CSL 3. The CSL values for CSL 4 (Max-Tech) came from manufacturer interviews.
Table 5-29,
Table 5-30, Table 5-31, and
Table 5-32 list data for each CSL for each representative unit.

Similar to the test units, the manufacturer data underwent a number of the efficiency and cost scaling steps. The scaling steps were applied in the order shown in Figure 5.16. Table 5-28 shows the details of which manufacturer representative units underwent which types of scaling. Though most of the individual manufacturer data was not scaled, Table 5-28 indicates scaling wherever data for at least one manufacturer was scaled. Individual manufacturer data characteristics cannot be revealed due to non-disclosure agreements (NDAs) with participating manufacturers. Thus, if the data used contained even a single manufacturer whose data required a certain type of scaling, Table 5-28 lists that scaling was required for the entire aggregated manufacturer data set. For details on the scaling procedures, see Section 5.4.6. Following Table 5-28, DOE presents the aggregated manufacturer results in
Table 5-29,
Table 5-30, Table 5-31, and
Table 5-32, for the 2.5W, 18W, 60W, and 120W representative units, respectively.

Table 5-28 Scaling and Markup Steps Performed on the Aggregated Manufacturer Data

Rep. Unit Output Power	**Efficiency Scaling by Output Power**	**Efficiency Scaling by Output Voltage**	**Efficiency Scaling by Cord Length**	**Cost Scaling by Output Power**	**Cost Scaling by Cord Length**	**Markup to MSP**
2.5W	✓		✓	✓	✓	✓
18W	✓*	✓	✓		✓	✓
60W	✓*		✓		✓	✓
120W	✓*	✓	✓	✓	✓	✓

"✓" Indicates that the data was scaled to the representative unit values, with effects on efficiency or cost.

"✓*" Indicates that the data was scaled to the representative unit values, although the scaling had no effect.

Table 5-29 Cost and Efficiency Relationship for 2.5W EPS (Manufacturer Interviews)

	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Mfr Unit Efficiency [%]:	58.3	67.9	71.0	73.5	74.8
Mfr Unit No Load Power [W]:	0.500	0.300	0.130	0.100	0.039
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best-in-Market	Max Tech
CSL Eff. [%], No-Load Power [W]	(58.3, 0.500)	(67.9, 0.300)	(70.9, 0.200)	(73.2, 0.100)	(74.8, 0.039)
Incremental MSP [$]:	0.00	0.15	0.33	0.45	0.52
Test Unit #:	N/A	N/A	N/A	996	N/A

Table 5-30 Cost and Efficiency Relationship for 18W EPS (Manufacturer Interviews)

	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Mfr Unit Efficiency [%]:	76.0	80.3	83.0	85.4	91.1
Mfr Unit No Load Power [W]:	0.500	0.300	0.200	0.100	0.039
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best-in-Market	Max Tech
CSL Eff. [%],No-Load Power [W]	(76.0, 0.500)	(80.3, 0.300)	(83.0, 0.200)	(85.0, 0.100)	(91.1, 0.039)
Incremental MSP [$]:	0.00	0.00	0.17	0.64	2.89
Test Unit #:	N/A	N/A	N/A	941	N/A

Table 5-31 Cost and Efficiency Relationship for 60W EPS (Manufacturer Interviews)

	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Mfr Unit Efficiency [%]:	85.0	87.0	87.0	88.0	92.2
Mfr Unit No Load Power [W]:	0.500	0.500	0.200	0.073	0.050
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best-in-Market	Max Tech
CSL Eff. [%], No-Load Power [W]	(85.0, 0.500)	(87.0, 0.500)	(87.0, 0.230)	(88.0, 0.210)	(92.2, 0.089)
Incremental MSP [$]:	0.00	0.00	0.82	1.29	2.73
Test Unit #:	N/A	N/A	N/A	838	N/A

Table 5-32 Cost and Efficiency Relationship for 120W EPS (Manufacturer Interviews)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Mfr Unit Efficiency [%]:	85.0	87.0	88.0	88.4	93.5
Mfr Unit No Load Power [W]:	0.500	0.500	0.230	0.210	0.089
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best-in-Market	Max Tech
CSL Eff. [%], No-Load Power [W]	(85.0, 0.500)	(87.0, 0.500)	(87.0, 0.230)	(88.0, 0.210)	(92.2, 0.089)
Incremental MSP [$]:	0.00	0.00	0.31	0.45	6.41
Test Unit #:	N/A	N/A	N/A	951	N/A

5.4.9 Summary of Results for Direct Operation EPSs

Sections 5.4.7and 5.4.8 present engineering analysis cost-efficiency results that DOE derived from test and teardown results as well as manufacturer interviews, respectively. Figure 5.30 through Figure 5.37 present results from manufacturer interviews in terms of incremental MSP versus average efficiency and incremental MSP versus no-load power consumption for each representative unit. The label "Incremental MSP" in these figures refers to the MSP increase above the baseline (CSL 0), which is normalized to $0, whereas "Absolute MSP" represents the price at which an OEM sells the EPS to a retailer. These graphs describe the cost-efficiency relationship for EPSs, under the assumption that all other factors are held constant. To that end, DOE normalized all representative unit data to the representative unit criteria listed in Table 5-3.

In summary, for each representative unit, the manufacturer data for cost versus efficiency and cost versus no-load power data showed a trend of increasing MSPs with higher CSLs, meaning that it costs more to manufacture more efficient EPSs. DOE's SMEs agreed that, all other factors being held constant, the cost-efficiency curves should be upwards sloping, whereby more efficient EPSs correspond to higher MSPs. However, the cost-efficiency relationship produced from the EPS test and teardown data occasionally showed the opposite trend. In many cases for the test and teardown curves, the CSL 3 best-in-market unit was the cheapest, and the CSL 0 unit was the most expensive. Note that the testing and teardown results are presented only for CSL 0, CSL 1, and CSL 3 (CSL 4 had no test unit to characterize it because it was the max-tech level, and CSL 2 was an intermediate level that was chosen after the testing and teardown analysis was complete).

For three of the four test and teardown representative units, the costs decreased between CSL 1 and CSL 3. During manufacturer interviews conducted after the preliminary analysis, Navigant sought comment on the discrepancy between the cost-efficiency curves using manufacturer data and those using teardown data. Manufacturers consistently suggested two possible contributors to the negative cost-efficiency slope of the teardown data (1) the more efficient units required smaller heatsinks or excluded them all together; and (2) the price for achieving a specific efficiency drops each year with decreases in component costs so it is possible that the EPSs used in the cost-efficiency teardown curves were designed in different years.

Manufacturers stated that heatsinking can add significant cost to the final BOM of an EPS, especially at lower output powers. Heatsinks are traditionally made of finned metal and used to dissipate excess heat from components during normal operation. Without the heatsinks, components can malfunction due to overheating. Often they are combined with a thermal compound that decreases the thermal resistance between the heatsink and the associated component allowing the heat to pass from the component more easily. EPSs with higher efficiencies tend to require smaller and/or fewer heatsinks because less of the power passing through the EPS is lost as heat, which could reduce the overall cost of the EPS. After reviewing the costs from iSuppli for the units used in generating the test and teardown cost-efficiency curves, DOE was unable to validate this claim with any consistency, but did see this trend in at least one representative unit.

DOE feels that the design time associated with each of the tested EPSs contributed more heavily to the negative sloping test and teardown cost-efficiency curves. Manufacturers stated that the overall trend of cost versus efficiency is an increase in cost with an increase in efficiency, but the price to meet a specific efficiency with the same design comes down each year as a result of decreasing component MSPs, illustrated in Figure 5.29. The EPSs DOE selected to be torn down by iSuppli were all purchased in the fall of 2009, but were not necessarily designed or released at the same time. Therefore, DOE believes the cost estimates may have crossed several years of design and did not accurately reflect the cost-efficiency relationship of EPSs on the market. Hence, DOE has chosen to use manufacturer data only in the cost-efficiency analysis for all the representative units in product class B. Additionally, only the manufacturer data was used in the UEC, LCC, and NIA analyses for product classes B, C, D, and E. However, the test data for EPSs at CSL 0, CSL 1, and CSL 3 was used to characterize the CSLs for each representative unit. The results for the individual representative units follow.

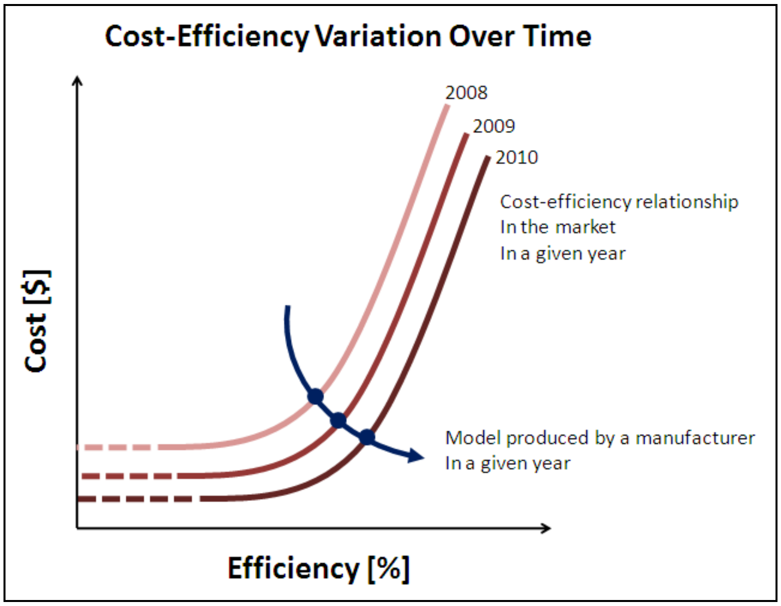


Figure 5.29 Cost-Efficiency Variation in the EPS Market Over Time

The 2.5W representative unit has manufacturer curves that are slightly different from the curves of the other representative units. The manufacturer curves in both Figure 5.30 and Figure

5.31 are upwards sloping across increasing CSLs, with the greatest increase in MSP occurring from CSL 1 to CSL 2. This is not the case for the other representative units, which are flat from CSL 0 to CSL 1 before sloping upwards. The reason the 2.5W cost-efficiency curve differs from the remaining curves is because some manufacturers are still producing linear EPSs for low power applications. During interviews, manufacturers stated that low power linear EPSs are still a cost-effective option at the lower efficiencies and were capable of meeting CSL 1 with an associated cost. The final cost-efficiency curve incorporated linear EPSs by normalizing the data for EPSs using switched-mode technology and then shifting the curve to account for the lower efficiency linear EPSs. For all the other representative units, manufacturers used switched-mode technologies, which are already being manufactured at or above CSL 1 (Energy Star). Hence, the incremental MSP to achieve CSL 1 was normalized to $0 for these units.

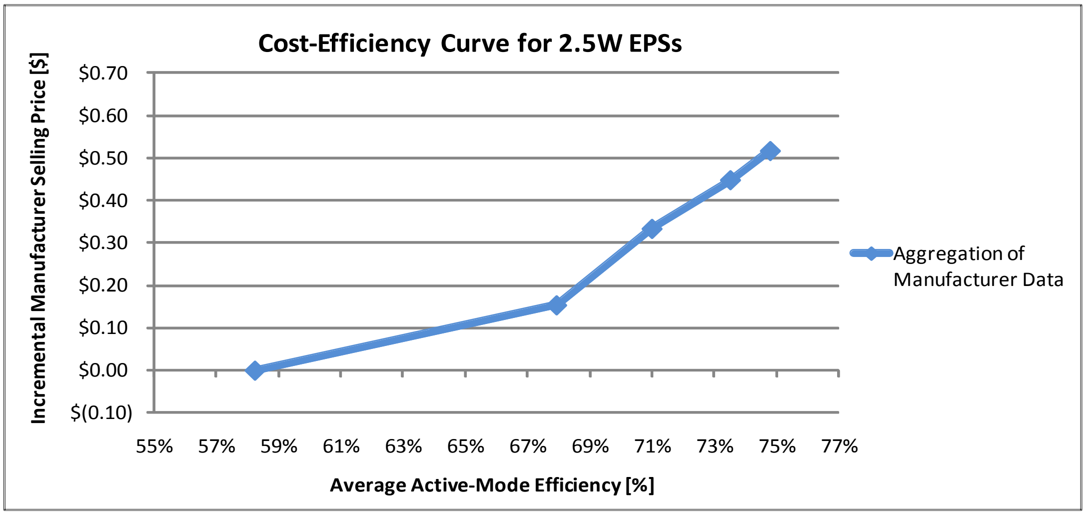


Figure 5.30 2.5W Incremental MSP vs. Efficiency Curve based on Manufacturer Data

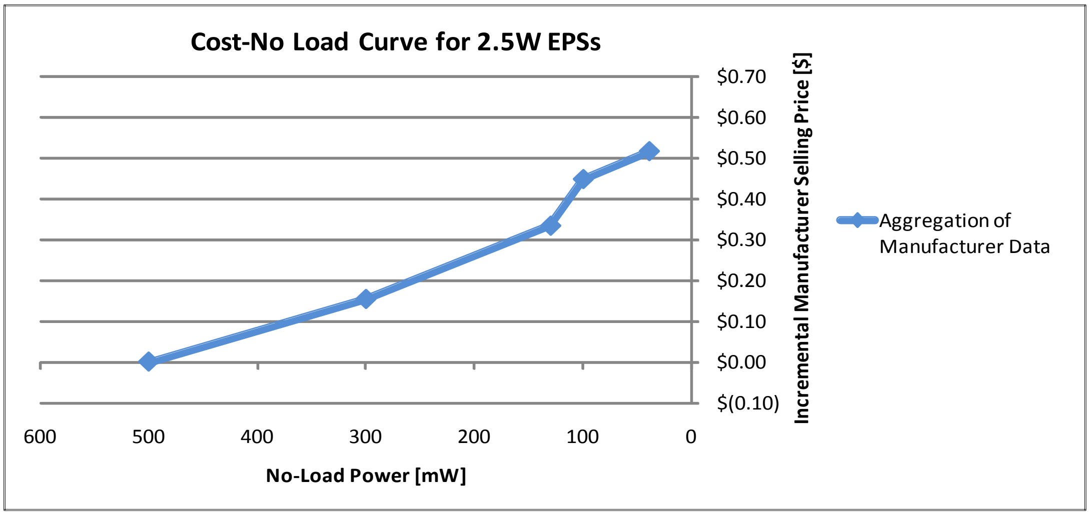


Figure 5.31 2.5W Incremental MSP vs. No-load Power Curve based on Manufacturer Data

The manufacturer curves in Figure 5.32 and Figure 5.33 are non-decreasing, with the greatest increases in MSP occurring from CSL 2 to CSL 3 and CSL 3 to CSL 4. The graph shows zero increase in MSP from CSL 0 to CSL 1 because the majority of EPSs for the 18W representative unit are already being manufactured at CSL 1.

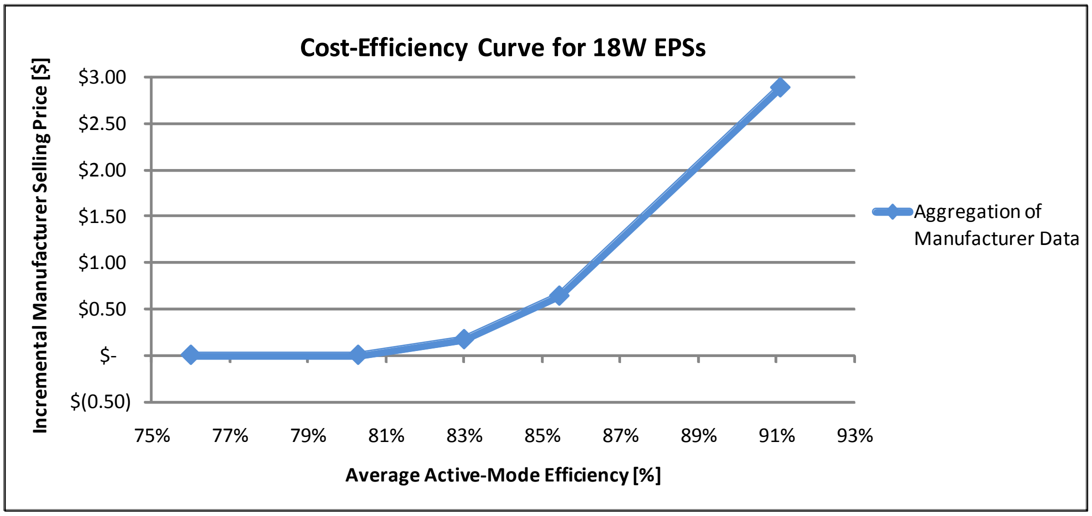


Figure 5.32 18W Incremental MSP vs. Efficiency Curve based on Manufacturer Data

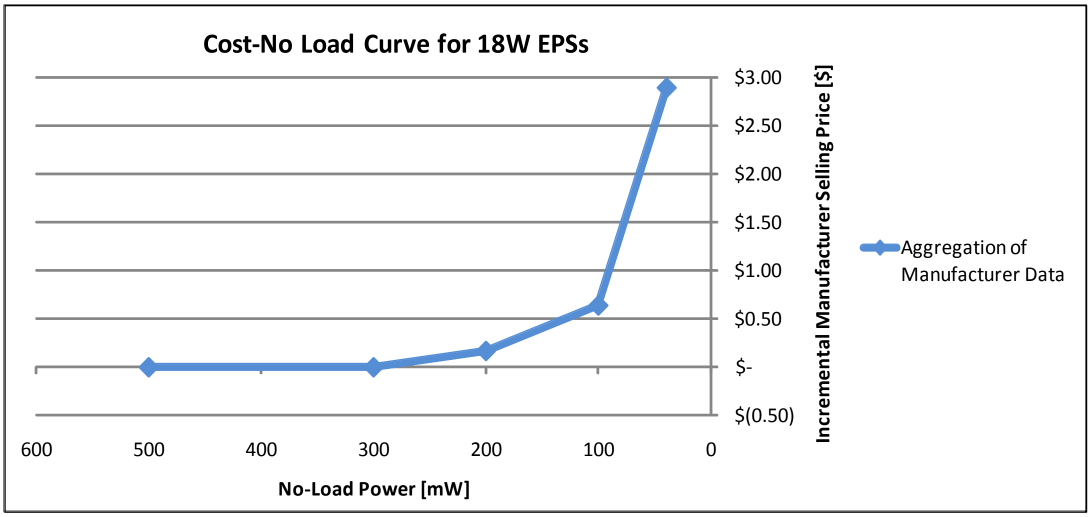


Figure 5.33 18W Incremental MSP vs. No-load Power Curve based on Manufacturer Data

The manufacturer curves in Figure 5.34 and Figure 5.35 have the greatest increase in MSP from CSL 3 to CSL 4. The graph shows zero increase in MSP from CSL 0 to CSL 1 because the majority of EPSs for the 60W representative unit are already being manufactured at CSL 1.

The sharp rise in cost from CSL 1 to CSL 2 in Figure 5.34 results from manufacturers only improving in the no-load power metric and not the efficiency metric from CSL 1 to CSL 2, and hence the vertical increase in cost on the efficiency plot (Figure 5.34) is explained by referring to the no-load power plot (Figure 5.35).

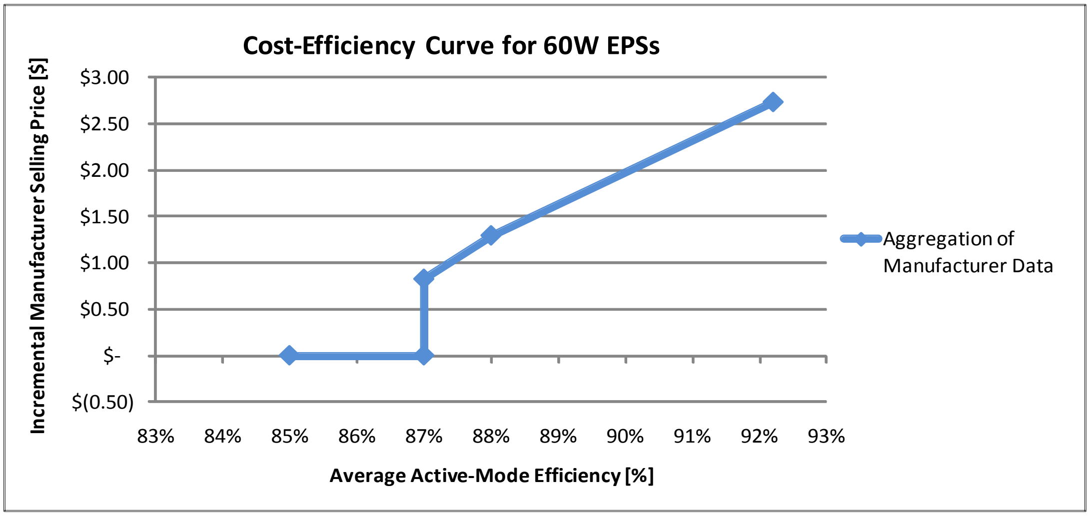


Figure 5.34 60W Incremental MSP vs. Efficiency Curve based on Manufacturer Data

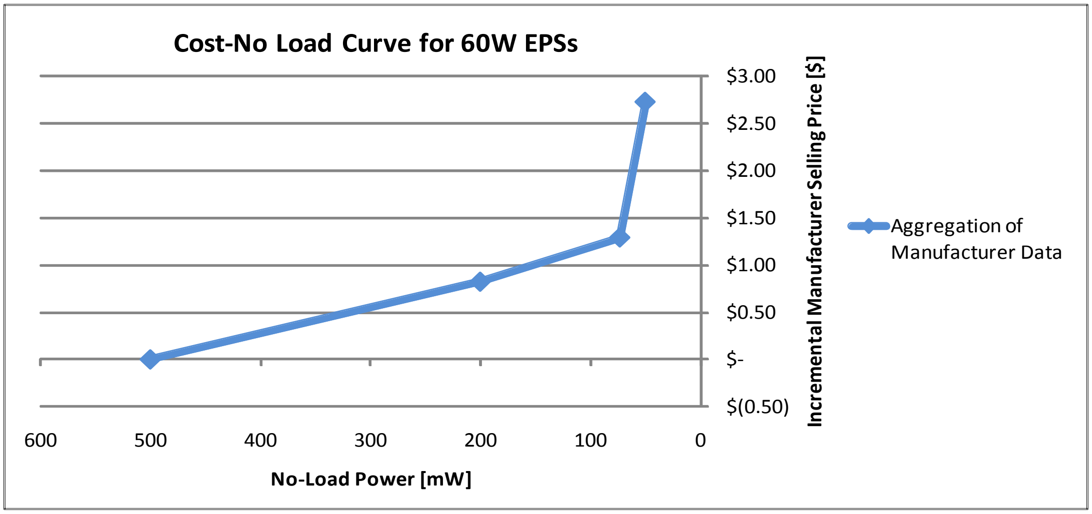


Figure 5.35 60W Incremental MSP vs. No-load Power Curve based on Manufacturer Data

The manufacturer curves in both Figure 5.36 and Figure 5.37 are non-decreasing across increasing CSLs. The 120W representative unit had the largest increase from the best unit available on the market to the maximum technologically feasible unit because manufacturers reported that, of the four representative units, the 120W unit could achieve the highest theoretically efficiency. To achieve this efficiency, however, would most likely require a topology change. For these reasons, there is a dramatic cost increase in Figure 5.36 and Figure 5.37 from CSL 3 to CSL 4.

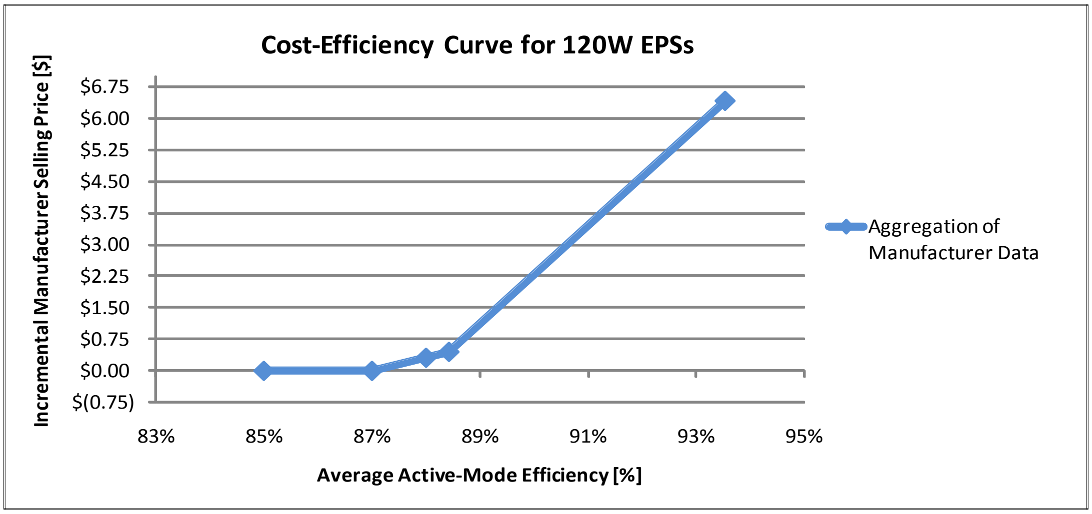


Figure 5.36 120W Incremental MSP vs. Efficiency Curve based on Manufacturer Data

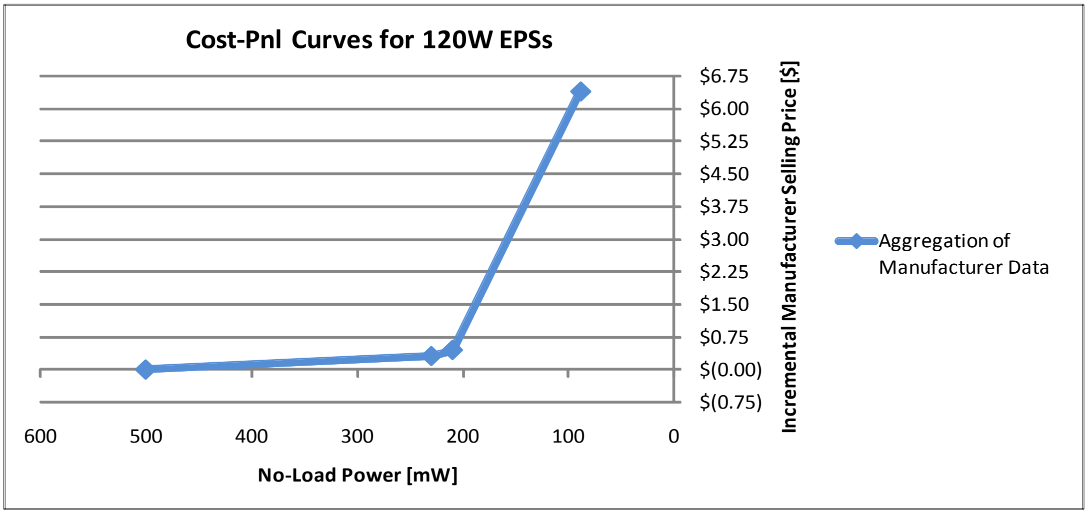


Figure 5.37 120W Incremental MSP vs. No-load Power Curve based on Manufacturer Data

5.4.10 Direct Operation EPS CSL Equations for Product Classes Based on the Representative Units

DOE identified and selected four representative units within the representative product class B on which to concentrate its analytical effort. DOE evaluated the representative units at five CSLs based on four sources: the EISA 2007 standard, the Energy Star 2.0 specification, test unit data, and manufacturer data. The following sections discuss how DOE created CSL equations for all direct operation product classes based on the analysis of its representative unit data.

5.4.10.1 Deriving CSL Equations for Product Class B from Representative Units

In its testing, DOE gathered data about individual EPS representative units from product classes B, C, D, and E. While these units provided insight pertaining to specific efficiency and no-load power values, DOE needed to create CSL equations to account for all ratings. To that end, DOE created four pairs of equations to define each CSL relating average efficiency to nameplate output power and no-load mode power consumption to nameplate output power as specified in 5.4.2:

- The equations for CSL 0 are derived directly from the EISA standard with the output power divisions for the efficiency equations shifted to 49 watts rather than 51 watts as specified.
- The equations for CSL 1 are derived directly from the Energy Star 2.0 specification for AC/DC basic voltage units with the output power divisions for no-load requirements shifted to 49 watts rather than 50 watts as specified.
- The equations for CSL 2 were created by curve-fitting the data points used to characterize the intermediate efficiency level, CSL 2 (see section 5.4.2 for details on how the points were selected).
- The equations for CSL 3 were created by curve-fitting BIM test unit data points.
- The equations for CSL 4 were created by curve-fitting data points from manufacturer interviews.

The process of creating CSL 2, CSL 3 and CSL 4 curves is described here in further detail. DOE derived CSL 2 by fitting equations to the efficiency values of the four intermediate level data points, at their respective output power values of 2.5W, 18W, 60W, and 120W (see equations in Table 5-9). For all its curve-fitting, DOE used the simplest possible equation form that was general enough to encompass all the CSL equations found in the EISA and Energy Star 2.0 CSLs. This equation was of the form $Y=a*\ln(P_{out}) + b*P_{out} + c$, for each of the nameplate output power segments, where Y indicates either the efficiency or no load-power requirement; P_{out} indicates the nameplate output power; and a, b, and c indicate the specific parameters defined in the respective CSLs.

Since even this general form of the equation could not pass through all points exactly, DOE ensured that the equations met three conditions. First, the distance to each point was minimized. Second, the equation did not exceed the tested efficiencies. Third, DOE further restricted the parameter choice in order to ensure that the CSL curves adhered to a matched pairs approach. This means that the CSL curves yielded both non-decreasing (usually higher) efficiency values and non-increasing (usually lower) no-load power values when moving from lower to higher CSLs, across all output power levels. For the fitted CSL 2 equation the maximum difference between any data point and the equation was less than 0.5 percentage points.

The CSL 2 no-load power equation was based on fitting the same equation forms on the same nameplate output power segments as was done for CSL 1, for the four intermediate level no-load power values at 2.5W, 18W, 60W, and 120W, without going below the chosen values (see equations in

Table 5-10). Specifically,
Table 5-8 shows that CSL 1 no-load power equations had one constant value up to a nameplate output power of 49 watts, and another constant value above 49 watts. Likewise, DOE based the CSL 2 equations for no-load power in

Table 5-10 on the maximum no-load power among the two CSL 2 lower power representative unit data points (2.5W and 18W) and the two CSL 2 higher power representative units data points (60W and 120W). The maximum of the lower power representative units was used for the first segment of nameplate output power, of up to 49 watts, and the maximum of the higher power representative units was used for the higher output power segment.

The CSL 3 and CSL 4 efficiency and no-load power specifications were created using the same reasoning as CSL 2. Instead of using the four intermediate level data points, the CSL 3 curves were fit to the BIM data points at 2.5W, 18W, 60W, and 120W (see equations for average efficiency in Table 5-11 and no-load power in

Table 5-12). Similarly, instead of using the four intermediate level data points, the CSL 4 curves were fit to the CSL 4 data points at 2.5W, 18W, 60W, and 120W, which were based on manufacturer interviews (see equations for average efficiency in Table 5-13 and no-load power in Table 5-14).

5.4.10.2 Deriving CSL Equations for Product Classes C, D, and E

After developing the CSLs for product class B, DOE developed separate CSL equations for low voltage and AC/AC units. As noted in Section 5.4.2, Energy Star 2.0 has four product classes, including low voltage and AC/AC product classes, each with its own set of equations. DOE leveraged these existing Energy Star 2.0 equations when creating low voltage and AC/AC CSLs for product classes C, D, and E.

For the low voltage units in product classes C and E, different CSL equations from those of product class B are necessary because low-voltage EPSs have lower efficiency, as detailed in section 5.4.6.2. Similarly, DOE believes that the AC/AC units of product classes D and E require different CSL equations for no-load power based on the Energy Star 2.0 specifications. Given that DOE is proposing to use two separate metrics for the EPS standards, four equations were used to characterize the CSLs in each direct operation product class: the CSL equations for basic voltage (V_{BASIC}), AC/DC no-load power (P_{NL}_DC), the low voltage equation for efficiency (V_{LOW}), and the AC/AC equation for no-load power (P_{NL}_AC). Table 5-33 shows the efficiency equations, and Table 5-34 shows the no-load power equations used for each of the four product classes.

Table 5-33 Average Active-Mode Efficiency CSL Equations for Product Classes B, C, D, and E.

	Basic Voltage		Low Voltage	
AC/DC	**B**	Eff: V_{BASIC}	**C**	Eff: V_{LOW}
AC/AC	**D**	Eff: V_{BASIC}	**E**	Eff: V_{LOW}

Table 5-34 No-Load Power CSL Equations for Product Classes B, C, D, and E.

	Basic Voltage		Low Voltage	
AC/DC	**B**	No Load: P_{NL}_DC	**C**	No Load: P_{NL}_DC
AC/AC	**D**	No Load: P_{NL}_AC	**E**	No Load: P_{NL}_AC

The V_{LOW} efficiency equations were created using different methods depending on the CSL. Though DOE had developed its own output voltage scaling method for scaling representative unit data points, it was not used for product class scaling because it was only designed for the cost and efficiency analysis of the four specific representative units in product class B (see Section 5.4.6.2 for additional reasons and details).

For CSL 0, the V_{LOW} equation is identical to the basic-voltage CSL 0 equation because all units in the market already meet the EISA standard. For CSL 1, the V_{LOW} equation is equivalent to the Energy Star 2.0 low-voltage equation.

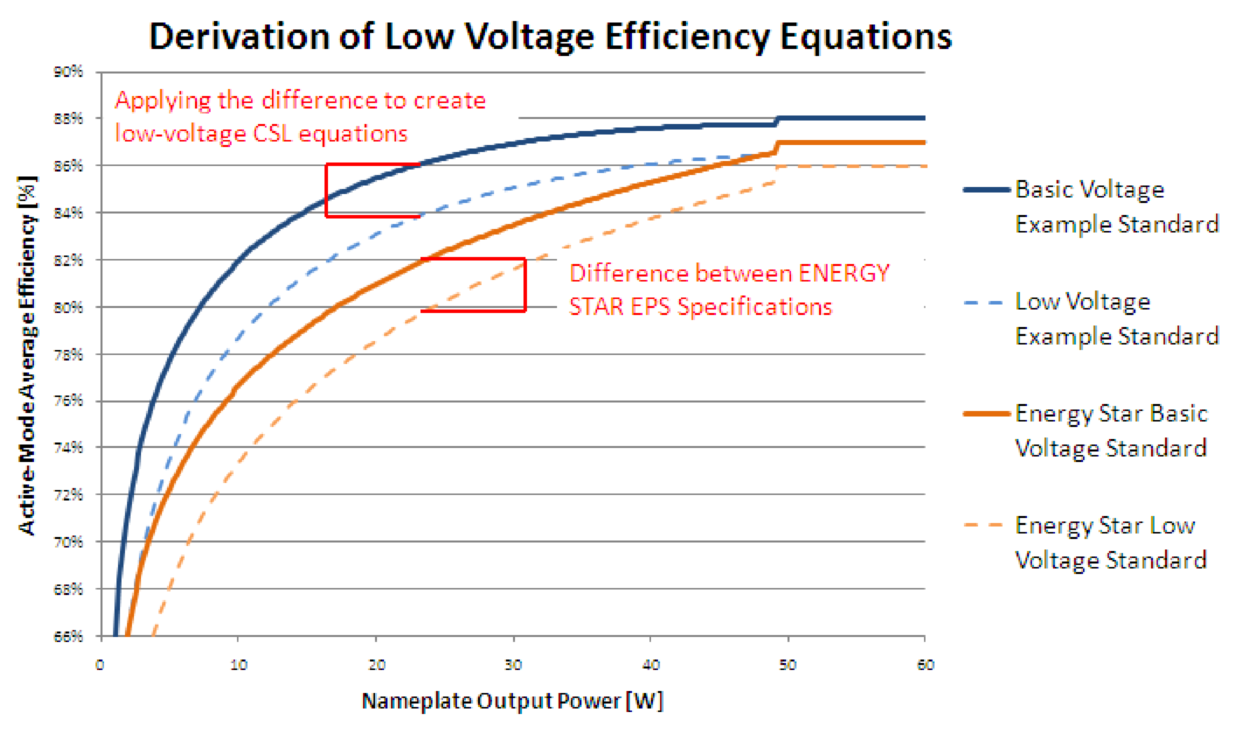


Figure 5.38 Derivation of Low Voltage Average Active-Mode Efficiency Equations

*The curves presented in the plot are for illustrative purposes only.

As shown in Figure 5.38, the V_{LOW} curves for CSL 2, CSL 3, and CSL 4 were created by using their respective CSL 2, CSL 3, and CSL 4 V_{BASIC} efficiency curves, and altering all equation parameters by the difference in the coefficients between the CSL 1 V_{BASIC} and V_{LOW} equations. This had the effect of shifting the CSL 2, CSL 3, and CSL 3 V_{LOW} curves downwards from their corresponding V_{BASIC} CSL 2, CSL 3, and CSL 4 curves, by a similar amount as the shift between the CSL 1 (Energy Star 2.0) V_{BASIC} and V_{LOW} curves. The V_{LOW} CSLs are shown the Table 5-35.

Table 5-35 The Low-Voltage Product Classes' (C, E) Active-Mode Efficiency Equations

CSL	Nameplate Output Power (P_{out})	Minimum Average Efficiency in Active Mode *(expressed as a decimal)*
0	Identical to Basic Voltage CSL 0	Identical to Basic Voltage CSL 0
1	0 to ≤ 1 watt	$\geq 0.497 \times \text{Pout} + 0.067$
	> 1 to ≤ 49 watts	$\geq 0.075 \times \ln(\text{Pout}) + 0.561$
	> 49 watts	≥ 0.860
2	0 to ≤ 1 watt	$\geq 0.507 \times \text{Pout} + 0.077$
	> 1 to ≤ 49 watts	$\geq 0.0825 \times \ln(\text{Pout}) - 0.0011 \times \text{Pout} + 0.586$
	> 49 watts	≥ 0.860
3	0 to ≤ 1 watt	$\geq 0.517 \times \text{Pout} + 0.087$
	> 1 to ≤ 49 watts	$\geq 0.0834 \times \ln(\text{Pout}) - 0.0014 \times \text{Pout} + 0.609$
	> 49 watts	≥ 0.870
4	0 to ≤ 1 watt	$\geq 0.537 \times \text{Pout} + 0.097$
	> 1 to ≤ 49 watts	$\geq 0.1017 \times \ln(\text{Pout}) - 0.00196 \times \text{Pout} + 0.609$
	> 49 watts	≥ 0.912

The equation for CSL 0 P_{NL}_AC is equivalent to the EISA standard, since all EPSs meet this level. However, the division between higher power and lower power EPS no-load standards was moved to 49 watts from 51 watts as specified by EISA for consistency with the Energy Star 2.0 efficiency specifications and the higher CSLs.

The equation for CSL 1 P_{NL}_AC is equivalent to the corresponding ENERGY STAR 2.0 Specification for AC/AC units. Unlike the AC/DC units, the specification establishes one no-load level for all nameplate output powers less than or equal to 250 watts.

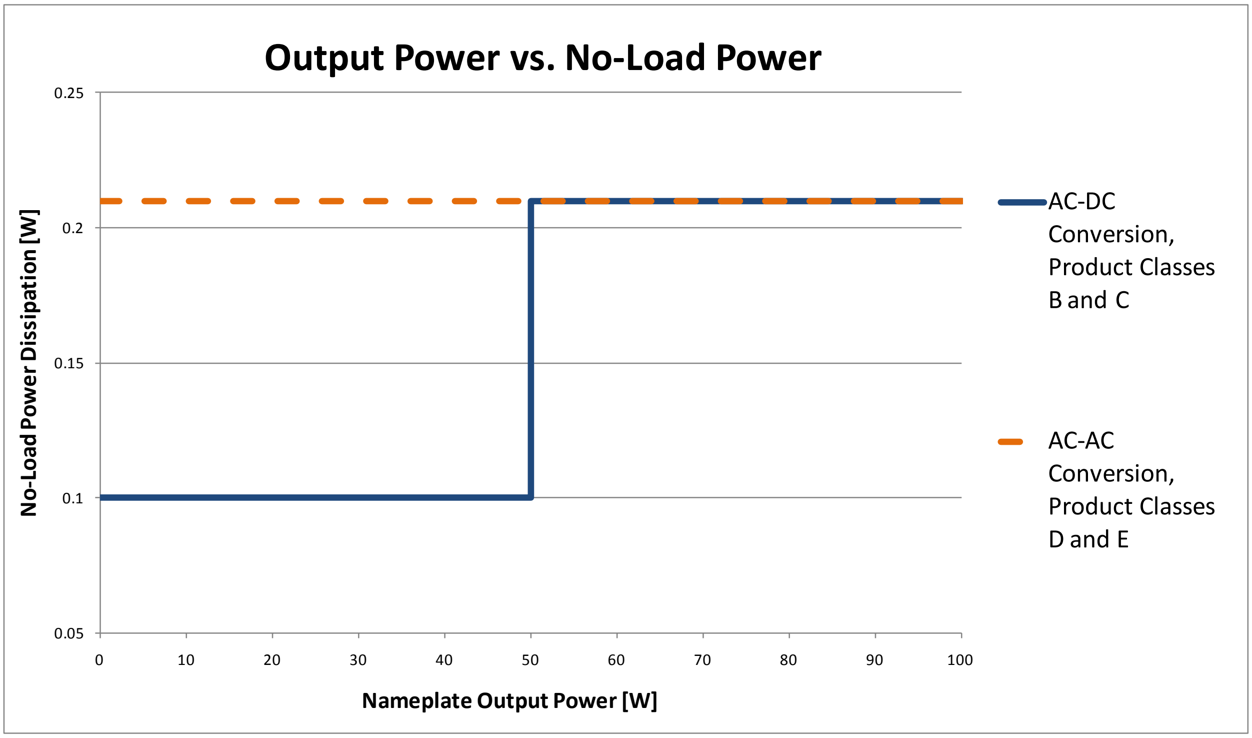


Figure 5.39 Derivation of AC/AC No-Load Power Equations

*The curves presented in the plot are for illustrative purposes only.

To create AC P_{NL} curves for CSL 2, CSL 3, and CSL 4, DOE used the same approach as was adopted in the CSL 0 and CSL 1 P_{NL}_AC curves, in which a constant no-load power limit was set for both the CSL 0 and CSL 1 P_{NL}_AC curves. Specifically, the P_{NL}_AC levels were chosen using the maximum allowable no-load power values across all nameplate output powers for the corresponding P_{NL}_DC graphs as exemplified by Figure 5.39. The P_{NL}_AC CSLs are shown in Table 5-36.

Table 5-36 AC/AC Product Classes' (D and E) Maximum Allowable No-Load Power Equations

CSL	Nameplate Output Power (P_{out})	Maximum Power in No-Load
0	0 to ≤ 250watt	≤ 0.500 watts
1	0 to ≤ 250watt	≤ 0.500 watts
2	0 to ≤ 250watt	≤ 0.230 watts
3	0 to ≤ 250watt	≤ 0.210 watts
4	0 to ≤ 250watt	≤ 0.089 watts

5.5 MULTIPLE-VOLTAGE AND HIGH POWER EXTERNAL POWER SUPPLY ENGINEERING ANALYSIS

In this section DOE discusses how it developed the EPS engineering analysis for multiple-voltage and high power EPSs in the BCEPS rulemaking. First, DOE describes which EPS representative units it analyzed. Next, DOE discusses how it created CSLs for the EPSs in the two product classes. Finally, DOE describes how it applied the EPS determination analysis that it published on May 14 2010, to develop its engineering analysis for the NOPR (75 FR 27170.)

DOE based the EPS engineering analysis for multiple-voltage and high power EPSs on the analysis from the determination analysis regarding EPSs outside the scope of EISA standards, as well as the analysis developed for direct operation EPSs.

5.5.1 Multiple-Voltage and High Power EPS Representative Product Classes and Representative Units

In this section DOE presents its selection of EPS representative units for high power and multiple-voltage EPSs based on the product classes presented in chapter 3. As noted previously, DOE based the high power and multiple-voltage EPS product classes on the product classes presented in the determination analysis as well as the product classes developed for direct operation EPSs.

5.5.1.1 Representative Units for Multiple-Voltage EPSs

In the preliminary analysis, DOE presented two representative product classes for multiple-voltage EPSs based on two consumer products that existed in the market: multi-function printing devices and video game consoles. DOE divided the two product classes by nameplate output power (≤100 watts and >100 watts) based on a market survey of multiple-voltage EPSs conducted during the determination analysis. DOE has since confirmed that multiple-voltage EPSs are no longer in production for multi-function devices and can no longer be purchased. Therefore, DOE has eliminated the product class divisions of multiple-voltage EPSs and now classifies all multiple-voltage EPSs under product class X for all nameplate output powers. Since a single application constitutes the majority of shipments in the representative product class, DOE elected to use that application and its characteristics to define its representative unit. This is shown in

Table 5-38.

Table 5-37 Multiple-Voltage EPS Product Class

Nameplate Output Power	Product Class
All Output Powers	X

Table 5-38 Multiple-Voltage EPS Representative Units

Nameplate Output Power [W]	Nameplate Output Voltage [V]	Second Nameplate Output Voltage [V]	Example Application
203	5	12	Video Game

5.5.1.2 Representative Units for High-Power EPSs

DOE chose only one product class for high-power EPSs because only one application exists that requires a high power EPS (shown in Table 5-39). Product class H consists of 345 watt EPSs for ham radios based on a market survey conducted during the determination analysis. DOE found EPSs for ham radios with nameplate output power ranging from 276 watts to 786 watts, but selected 345 watts as the representative unit because it was the most popular (9 units available) and is in the middle of the output power range for all units. Since a single application constitutes the majority of shipments in this product class, DOE elected to use that application to define the attributes of the representative unit shown in

Table 5-40.

Table 5-39 High Power EPS Product Class

Nameplate Output Power	Product Class
> 250 watts	H

Table 5-40 High Power EPS Representative Units

Nameplate Output Power [W]	Nameplate Output Voltage [V]	Example Application
345	13.8	Amateur Radio

5.5.2 Multiple-Voltage and High Power EPS Candidate Standard Levels

In this section DOE presents its selection of CSLs for multiple-voltage and high power EPSs and how it developed the CSL equations for the NOPR. DOE based the CSLs for these EPSs on a combination of the CSLs from the determination analysis and CSLs developed for product classes B, C, D, and E.

5.5.2.1 Candidate Standard Levels for Multiple-Voltage EPSs

DOE developed CSLs for multiple-voltage EPSs based on those presented in section 3.7.1.1 of the determination analysis TSD. Specifically, multiple-voltage EPSs are distinct from other types of EPSs both in that their underlying technology is different and that there are no established standard levels in their market. Consequently, DOE structured the CSLs for multiple-voltage EPSs based on products available in the market and the theoretical maximum technologically feasible level described by manufacturers, as shown in Table 5-41.

Table 5-41 Multiple-Voltage EPS Candidate Standard Levels of Efficiency

CSL	Reference	Basis
0	Market Bottom	Test data of the least efficient unit in the market
1	Mid Market	Test data of the typical unit in the market
2	Best-in-Market	Manufacturer’s data
3	Max Tech	Maximum technologically feasible efficiency

In the determination analysis DOE defined the efficiency values for each CSL based on test data and manufacturer data. Both the baseline and CSL 1 were developed directly from test units DOE found on the market. The higher efficiency CSLs were generated from manufacturer interviews where Navigant, on behalf of DOE, received incremental cost estimates for the efficiency levels of CSL 2 and CSL 3. The full details on the development of the CSLs and their associated costs can found in Section 3.7.1.1 of the TSD to the Notice of Proposed Determination (NOPD) that DOE published on November 3, 2009. 74 FR 56928. DOE believes the absence of any standards implemented for multiple-voltage EPSs since the determination analysis coupled with the fact that only one application exists for product class X make the CSLs proposed in the determination analysis valid for multiple-voltage EPSs in the NOPR.

Table 5-42 203W Representative Unit Candidate Standard Levels of Efficiency

CSL	Reference	Minimum Active-Mode Efficiency (%)	Maximum No-Load Power Consumption (W)
0	Market Bottom	82.4	12.33
1	Mid-Market	86.4	0.4
2	Best-in-Market	86.4	0.3
3	Max Tech	88.5	0.3

In contrast to Class A EPSs, whose minimum average efficiency and maximum no-load power consumption requirements are functions of nameplate output power, DOE analyzed multiple-voltage EPS efficiency and no-load power at a single, discrete output power. DOE believes this approach is appropriate because although product class X spans a range of nameplate output powers, it has only one significant application and therefore warrants a more narrow analysis.

5.5.2.2 Candidate Standard Levels of Efficiency for High-Power EPSs

DOE developed CSLs for high-power EPSs based on those presented in the determination analysis. Specifically, high-power EPSs are distinct from other types of EPSs both in that their underlying technology is different and that there are no established standard levels in their market. Consequently, DOE structured the CSLs for high-power EPSs based on products available in the market, the theoretical maximum technologically feasible level described by manufacturers, and scaled efficiencies from the 120W representative unit in product class B as shown in Table 5-43.

Table 5-43 High-Power EPS Candidate Standard Levels of Efficiency

CSL	Reference	Basis
0	Market Baseline	Test data of a low-efficiency unit in the market
1	Low Market	Test data of a high-efficiency unit in the market
2	Mid-Market	Manufacturers’ theoretical maximum efficiency
3	Scaled Best-in-Market	Scaled from 120W EPS CSL 3
4	Scaled Max Tech	Scaled from 120W EPS CSL 4

In the determination analysis DOE defined the efficiency values for each CSL based on test data and manufacturer data. CSL 0 corresponds to a line frequency EPSs. DOE tested two line frequency EPSs: EPS #401 (62.4% efficient, 15.43 watts no-load power) and EPS #404

(50.7% efficient, 12.6 watts no-load power). DOE used EPS #401 as the sole basis for CSL 0 because that unit was tested and torn down for analysis. Similarly, DOE based CSL 1 on the tested values of a switched-mode EPS #402 (81.3% efficient, 6.01 watts no-load power) because the unit was costed by iSuppli which allows the cost for the CSL to be related to an exact data point. CSL 2 came from interviews with a designer and distributor of high-power EPSs. Specifically, the high-power EPS designer indicated that the higher efficiency of CSL 2 could be achieved by using an IC with a more efficient switching algorithm and replacing rectifying diodes with a synchronous rectification circuit.

For the NOPR, DOE was advised by its SMEs that high power EPSs could reach higher efficiencies than those proposed for CSL 2 and CSL 3 in the determination analysis. Specifically, they felt that the efficiencies of the 120W EPS CSLs could be applied to the high power EPSs because the achievable efficiency of an EPS tends to remain constant above output powers of 50 watts. Therefore, DOE applied the voltage scaling methods described in Section 5.4.6.2 to CSL 3 and CSL 4 of the 120W representative unit in order to characterize the higher efficiency CSLs for high power EPSs. Voltage scaling was necessary in this case because the 120W CSLs were generated using a 19V representative unit while 345W EPS representative unit had a nameplate output voltage of 13.8V. The no-load metric for CSL 3 and CSL 4 was chosen by assuming that three 120W EPSs could theoretically be connected to deliver 345 watts to a load. The associated no-load values for CSL 3 and CSL 4 are therefore three times greater than the no-loads used for the equivalent 120W CSLs.

Table 5-44 345W Representative Unit EPS Candidate Standard Levels of Efficiency

CSL	Reference	Minimum Active-Mode Efficiency (%)	Maximum No-Load Power Consumption (W)
0	Market Bottom	62.4	15.43
1	Low End Market	81.3	6.01
2	Mid-Market	84.6	0.5
3	Scaled Best-in-Market	87.5	0.5
4	Scaled Max Tech	92.0	0.266

In contrast to Class A EPSs, whose minimum average efficiency and maximum no-load power consumption requirements are functions of nameplate output power, DOE analyzed multiple-voltage EPS efficiency and no-load power at a single, discrete output power. DOE believes this approach is appropriate because although product class H spans a range of nameplate output powers, achievable efficiencies tend to remain constant in EPSs with high output powers. Therefore, DOE can extend its analysis of 345 watt EPSs to all EPSs with nameplate output powers greater than 250 watts.

5.5.3 Multiple-Voltage and High Power EPS Cost-Efficiency Relationships

In this section DOE presents its methodology to develop cost-efficiency curves for multiple-voltage and high power EPSs. DOE developed cost-efficiency curves based on the data used to generate cost-efficiency curves in the determination analysis as well as the data used to generate cost-efficiency curves for direct operation EPSs in the NOPR.

To develop the NOPR, DOE used the same scaling and analysis techniques for both EPS product classes. Thus, DOE revised the data from the determination analysis for the NOPR. Specifically, in developing the engineering analysis for product classes B, C, D, and E, DOE refined the scaling methodologies it used in the engineering analysis for multiple-voltage and high power EPSs in the determination analysis. In addition, DOE evaluated EPSs based on the full costs of all materials, as opposed to the determination analysis which evaluated EPSs based on the efficiency-related materials cost. DOE believes that its refined scaling methods have enhanced robustness and that the full cost of an EPS is a more appropriate basis for evaluation because of the inter-relatedness of EPS components. In the following subsections DOE explains how it used data from the determination analysis. In all cases, DOE applied the updated scaling and analysis techniques to the data.

5.5.3.1 Cost-Efficiency Relationship for Multiple-Voltage EPSs

DOE developed cost-efficiency curves for multiple-voltage EPSs based on testing and tearing down EPSs as well as interviewing manufacturers. DOE first outlined this methodology in the determination analysis and followed a similar approach in the NOPR. However, as stated previously, DOE chose to use the MSP to evaluate the cost-efficiency relationship of multiple-voltage EPSs. Additionally, the costs are presented in Table 5-45 as incremental MSPs for consistency with the cost-efficiency analysis of the direct operation EPSs.

Table 5-45 Cost and Efficiency Relationship for 203W EPS

	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**
Mfr Unit Efficiency [%]:	82.4	86.4	86.4	88.5
Mfr Unit No Load Power [W]:	12.33	0.400	0.300	0.300
CSL Description:	Market Baseline	Mid-Market	Best-in-Market	Max Tech
Incremental MSP [$]:	0.00	2.45	2.66	7.71
Test Unit #:	#203	#213	N/A	N/A

DOE calculated the MSPs by applying the same markup used in the direct operation EPS engineering analysis to the costs generated by iSuppli for the units that were torn down in order to characterize CSL 0 and CSL 1. The remaining CSL costs were supplied during manufacturer interviews as incremental MPCs and marked up to MSPs for the cost-efficiency curve. Finally, all the data was normalized so that CSL 0 corresponds to a cost of $0 as was done in the engineering analysis for direct operation EPSs.

5.5.3.2 Cost-Efficiency Relationship for High-Power EPSs

DOE developed cost-efficiency curves for multiple-voltage EPSs based on testing and tearing down EPSs as well as interviewing manufacturers. DOE first outlined this methodology in the determination analysis and followed a similar approach in the NOPR. However, as stated previously, DOE chose to use the MSP to evaluate the cost-efficiency relationship of high power EPSs. Additionally, the costs are presented in Table 5-46 as absolute MSPs because of the counter-intuitive nature of the curve. The cost-efficiency curve for high power EPSs shows decreasing costs with increases in efficiency because of a technology shift. Rather than utilize negative costs in the engineering analysis, MIA, and LCC, DOE has chosen to use the MSP rather than the incremental MSP.

Table 5-46 Cost and Efficiency Relationship for 345W EPS

	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
Mfr Unit Efficiency [%]:	62.4	81.3	84.6	87.5	92.0
Mfr Unit No Load Power [W]:	15.43	6.01	0.500	0.500	0.266
CSL Description:	Market Bottom	Low End Market	Mid-Market	Scaled Best-in-Market	Scaled Max Tech
MSP [$]:	132.68	104.52	104.52	107.30	143.92
Test Unit #:	#401	#402	N/A	N/A	N/A

For high power EPSs, DOE was able to obtain retail prices for the linear and switched-mode units used to characterize CSL 0 and CSL 1 respectively. High power EPSs are unique from EPSs in the direct operation product classes and product class X because they are sold as standalone products through specialized distributors. Therefore, DOE derived the MSPs for these units by dividing the retail price by the markups used in the LCC analysis, which calculates the retail price based on an MSP input for all the other EPS product classes. This methodology is a departure from the efficiency related materials cost approach used in the determination analysis, but DOE believes it is a more robust characterization of the cost-efficiency relationship for high power EPSs.

The relationship for cost and efficiency for high power EPSs is also unique because the cost for the baseline unit is higher than the costs for all the CSLs other than max-tech. This is because linear power supplies are still sold for high power ham radios, which are more expensive and less efficient than the switched-mode EPSs used to characterize the higher efficiency CSLs. Ham radio enthusiasts believe that the linear EPSs generate less transient noise than their switched-mode counterparts and are willing to pay more for a cleaner transmission signal. Thus, high power linear EPSs are still being manufactured despite lower-cost alternatives. Since the presence of the linear EPSs creates a negative sloping trend from the baseline to CSL 1, DOE believes presenting the nominal MSP is more appropriate in this instance.

5.5.4 Summary of Results for Multiple-Voltage and High Power EPSs

Section 5.5.3 presents cost-efficiency results that DOE derived from test and teardown data as well as manufacturer interviews. Figure 5.40 through Figure 5.43 present results in terms of incremental MSP versus average efficiency and incremental MSP versus no-load power consumption for each representative unit. The label “Incremental MSP” in these figures refers to the MSP above the baseline CSL 0 while “MSP” refers to the price at which manufacturers sell the EPS to distributors. “MSP” is applied to the 345W representative unit’s cost-efficiency curve as discussed in 5.5.3.2. These graphs describe the cost-efficiency relationship for multiple-voltage and high power EPSs, under the assumption that all other factors are held constant. To that end, DOE normalized the 203W multiple-voltage EPS representative unit data to the representative unit parameters listed in Table 5-38.

5.5.4.1 Summary of Results for Multiple-Voltage EPSs

The manufacturer curves in

Figure 5.40 and Figure 5.41 are non-decreasing, with the greatest increases in MSP occurring from CSL 2 to CSL 3. The small increase in cost from CSL 1 to CSL 2 is due to an improvement in the no-load power metric without an associated active-mode efficiency improvement. Manufacturers provided a cost increase associated with lowering the no-load power from 400mW to 300mW in order to meet European Union standby power requirements, hence the vertical jump in the efficiency plot.

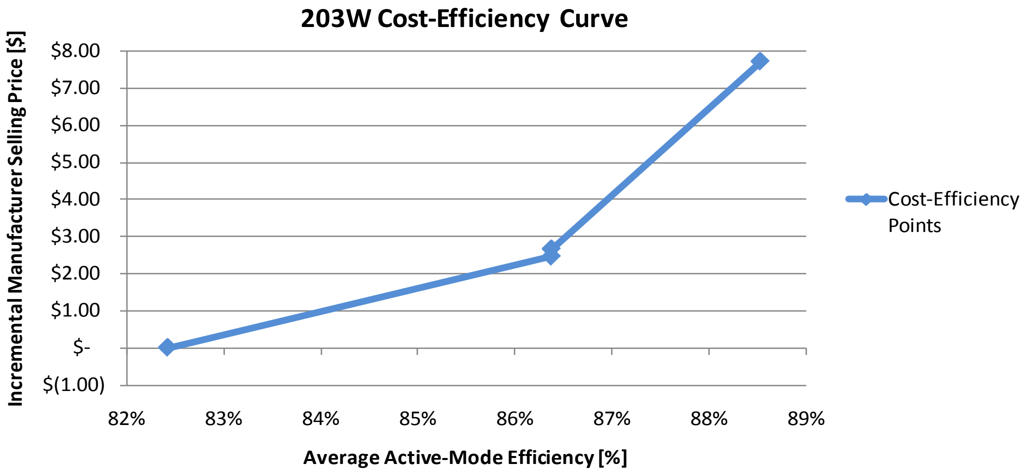


Figure 5.40 203W Incremental MSP vs. Efficiency

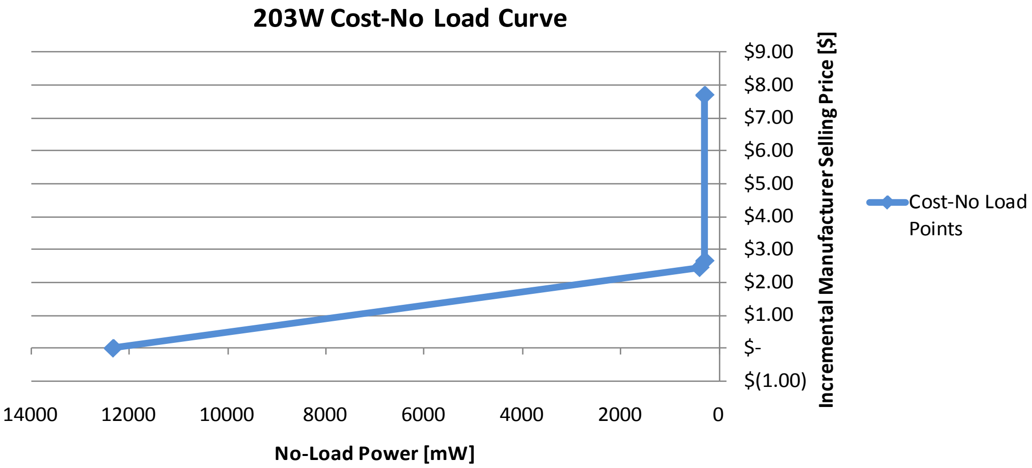


Figure 5.41 203W Incremental MSP vs. No-load Power

5.5.4.2 Summary of Results for High Power EPSs

The manufacturer curves in Figure 5.42 and Figure 5.43 show the greatest increase in MSP occurring from CSL 2 to CSL 3. As mentioned previously, there is a decrease in cost from CSL 0 to CSL 1 because of a technology change between the units torn down to characterize the CSLs. Additionally, since the analysis of the switched-mode EPSs was based largely on the 120W cost-efficiency curve, the curve is flat from CSL 1 to CSL 2. DOE generated this relationship under the assumption that three 120W EPSs could theoretically deliver the same power to a load and thus would carry the same cost-efficiency relationship as long as a 3X multiplier was applied to the costs of the 120W units.

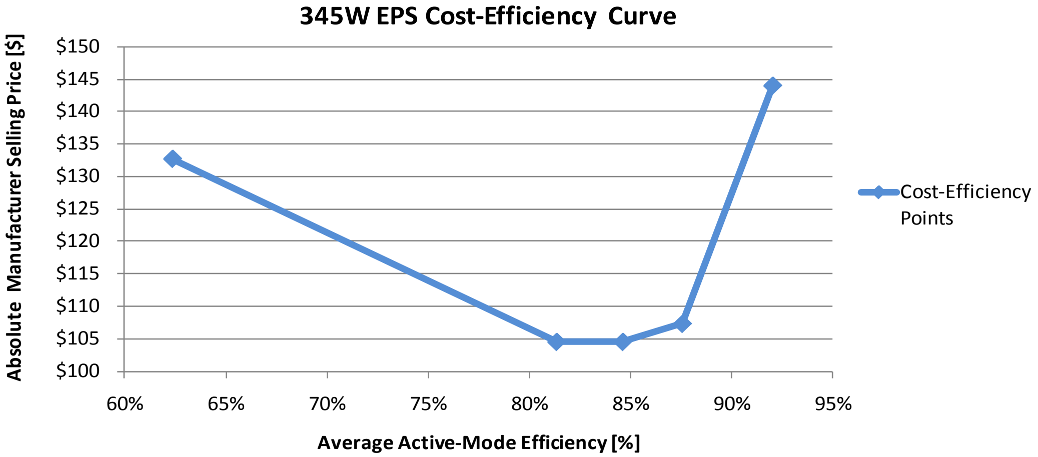


Figure 5.42 345W Incremental MSP vs. Efficiency

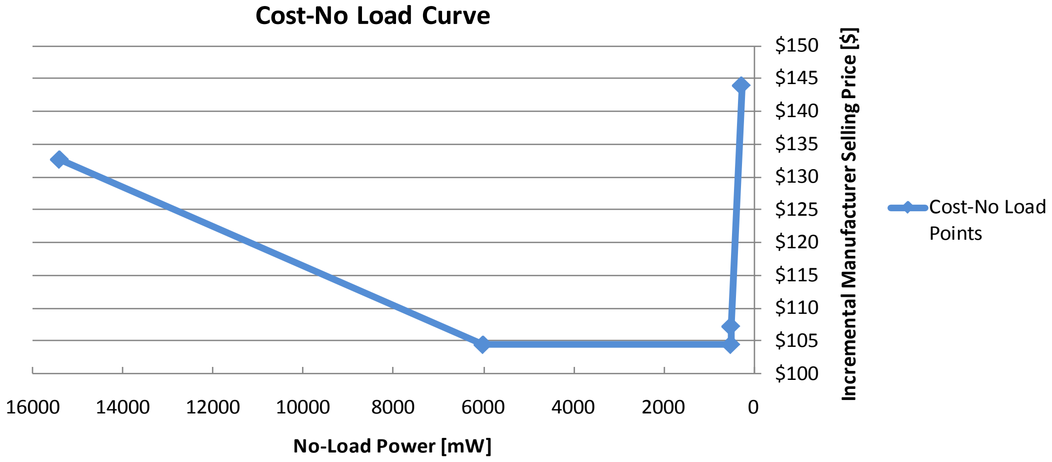


Figure 5.43 345W Incremental MSP vs. No-load Power

5.5.5 Creating CSL Equations for Multiple-Voltage and High Power EPSs

DOE focused its analytical efforts on two representative units for multiple-voltage and high power EPSs. DOE evaluated these units at four CSLs for multiple-voltage EPSs and five

CSLs for high power EPSs using two sources: test unit data and manufacturer data. The following sections discuss how DOE used the representative unit CSLs to generate the CSL equations for multiple-voltage and high power EPSs.

5.5.5.1 Deriving CSL Equations for Multiple-Voltage EPSs

The determination analysis contemplated setting a single efficiency level across all output powers for multiple-voltage EPSs. DOE has since revised its approach and believes that adopting the Energy Star 2.0 low-voltage standard for AC-DC EPSs would accurately describe the multiple-voltage EPS market. The Energy Star 2.0 low-voltage standard meets the proposed standard efficiency level for the 203W representative unit while accounting for efficiency variations over nameplate output power as shown in Figure 5.44. This could become important for future products with lower output power ratings than the single application for multiple-voltage EPSs available on the market today. This approach would also be consistent with the CSL standard equations for direct-operation EPSs.

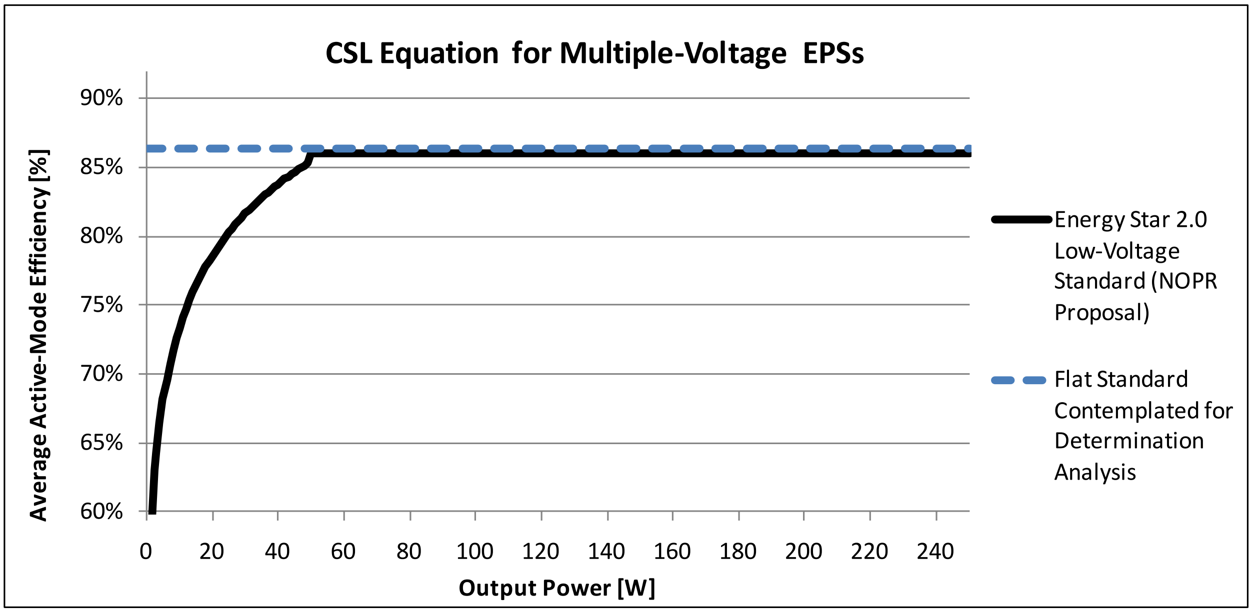


Figure 5.44 CSL Equation for Multiple-Voltage EPSs

5.5.5.2 Deriving CSL Equations for High Power EPSs

For the NOPR, DOE is proposing to set a single efficiency standard for high power EPSs for two reasons. First, only one consumer application exists for high power EPSs. Second, efficiency tends to remain constant for EPSs above 49 watts. Therefore, applying a constant CSL for all output powers above 250 watts is valid for high power EPSs.

5.6 INDIRECT OPERATION EXTERNAL POWER SUPPLY ENGINEERING ANALYSIS

DOE created product class N for EPSs that indirectly power consumer applications. EPSs in product class N must charge a battery as an intermediary before the consumer product will operate as intended. DOE believes these EPSs are a part of the battery charging system in these cases and are therefore analyzed as part of the BC engineering analysis. As the energy savings for these products will come from the BC standards, there was no EPS engineering analysis conducted for product class N. Under this proposal, the EPSs in these battery charging systems would be subject to the same EISA 2007 standards that they are already meeting. DOE also notes that the EPSs in this product class are only Class A EPSs as defined by EISA 2007.

5.7 BATTERY CHARGER ENGINEERING ANALYSIS

The battery charger engineering analysis estimates the cost associated with increasing the efficiency of a representative BC. When developing the engineering analysis for battery chargers, DOE selected representative units for each product class. For each representative unit, DOE tested a number of different products. After examining the test results, DOE selected CSLs that equated to discrete levels of improved BC performance in terms of energy consumption. Subsequently, for each CSL, DOE used either teardown data or information gained from manufacturer interviews to generate costs corresponding to each representative unit. Finally, for each product class DOE developed scaling relationships based on additional test results and generated unit energy consumption (UEC) equations that are functions of battery energy. This was used as a measure of efficiency where higher UECs mean low BC efficiencies.

A general discussion of the analytical methods used for each of the product classes follows, including a discussion of the selection of representative units (section 5.7.1), a description of the efficiency metrics, including a description of the calculation of unit energy consumption (section 5.7.2), an evaluation of efficiencies in the market and development of CSLs (section 5.7.3), and an evaluation of the associated costs through teardowns (section 5.7.4) and manufacturer interviews (section 5.7.5). Subsequently, section 5.7.6 describes the markups applied to the efficiency-related production costs to arrive at manufacturer selling prices for use in later analyses. Sections 5.7.7 through 5.7.16 describe the application of the above methods to and the detailed engineering results of each of the product classes. Finally, section 5.7.17 describes how results from the analysis of the representative units were extrapolated to the remainder of BCs covered within each product class.

5.7.1 BC Representative Units

DOE focused its engineering analysis for each BC product class on one representative unit, an idealized BC typical of those used with high-volume applications found in the product class. Because results from the analysis of these representative units were later extended to additional BCs, DOE selected them from high-volume and/or high-energy-consumption applications, as determined by the market survey. Nonetheless, the analysis of these BCs is pertinent to all the applications in the product class under the assumption that all BCs with the same battery voltage and energy provide similar utility to the user, regardless of their actual end-use product.

DOE evaluated the data from the market survey and, for each product class, identified common battery voltage and energy combinations. DOE then selected the representative units to correspond to the combinations of battery voltage and energy that also incorporated a wide variety of applications. By selecting representative unit characteristics (battery voltage and energy) common to BCs for several applications, DOE (1) extended the applicability of the analysis across a larger portion of BCs and (2) increased the variety of efficiencies used in its analysis.

To elaborate, the primary benefit of focusing on battery voltage and energy pairings that were typical of popular BC products across a variety of applications was the wider applicability of the resultant analysis. By treating the BC component of multiple applications as an interchangeable component and analyzing not only—for example—cellular telephone BCs, but also those for cordless telephones and digital cameras, DOE ensured that the BC representative unit is representative of all applications for BCs with the representative-unit battery voltage and energy.

As an added benefit, evaluating BCs for multiple applications will also result in a greater variety of costs and efficiencies represented in the analysis. Just as the end-use product applications vary in cost and size, so do their BCs. Now, because these two characteristics of a BC impact its efficiency,[b] the efficiency of BCs tends to stratify by application. By analyzing multiple applications, DOE therefore ensured that its analysis takes into account the full variety of efficiencies in the market.

Figure 5.45 shows the characteristics of the BC representative units superimposed over the results of the market survey, previously presented in Figure 5.3. The figure illustrates how the representative units compare to the data obtained through the market survey. Additional information regarding the representative units is compiled in Table 5-47. In addition to the battery energy and voltage, the table also displays typical production volumes for a single BC model in each product class. These volumes were used only in the teardown portion of the engineering analysis, where they were used to calculate how the fixed costs of manufacturing equipment and non-recurring engineering costs would be amortized over the total number of BCs in a production run, and their impact on the unit price.

---

[b] Efficiency has a real impact on the minimum size of electronic components, as the components' ability to dissipate heat is constrained by their available surface area. The smaller the component, the less surface area it has. Therefore, requirements on size and weight often motivate more efficient designs.

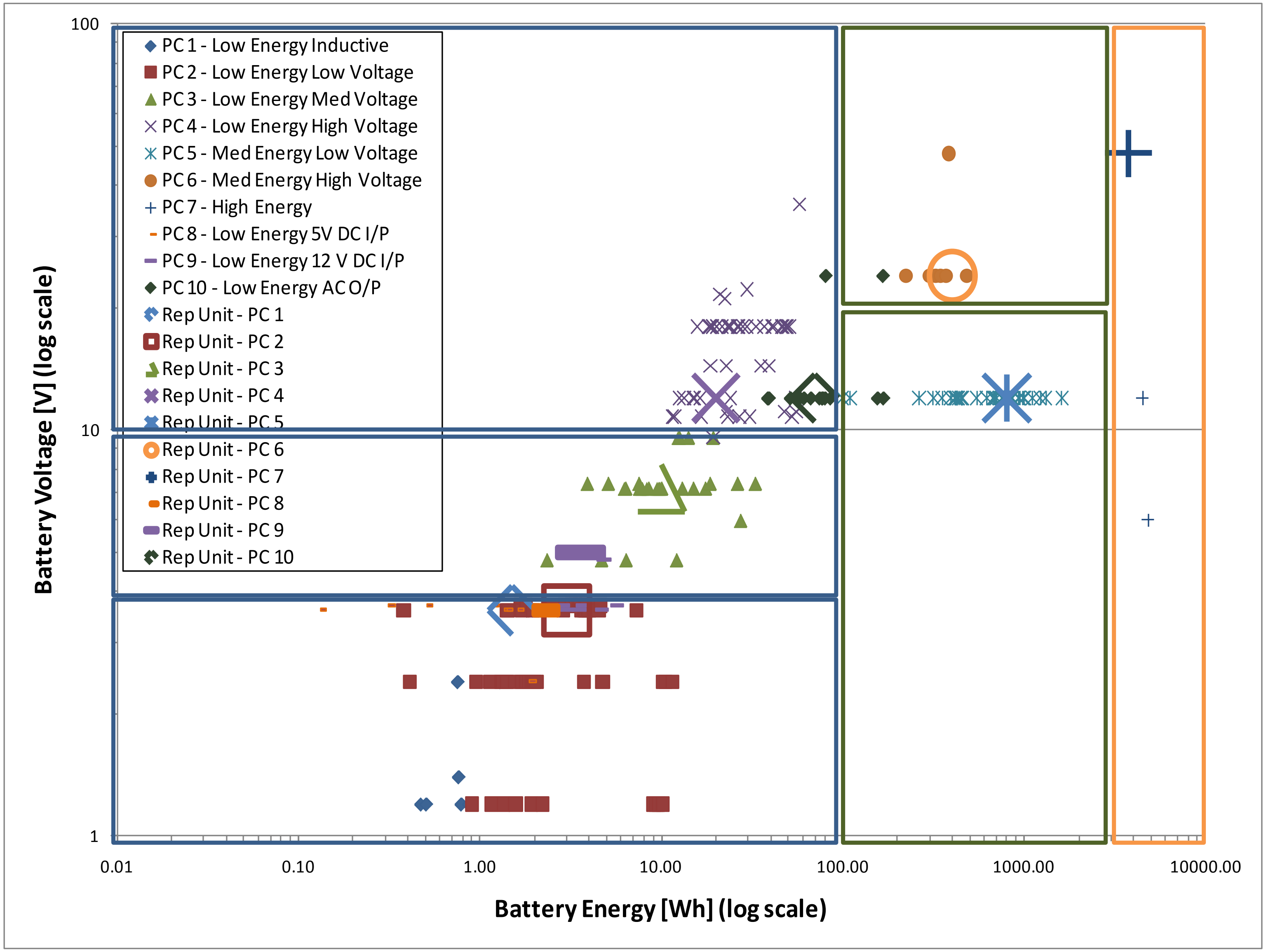


Figure 5.45 Battery Charger Representative Units relative to Market Survey

Table 5-47 Representative Units for each Battery Charger Product Class

Product Class	**Description**	**Battery Voltage *(V)***	**Battery Energy *(Wh)***	**Annual Production Volume *(K units)***	**Lifespan Production Volume *(K units)***	**Typical Applications**
1	Low Energy, Inductive	3.6	1.5	500	2000	Toothbrushes
2	Low Energy, Low Voltage	3.6	3	480	1600	Cellular and Cordless Phones
3	Low Energy, Med. Voltage	7.2	10	400	1380	Power Tools. Portable DVD Players
4	Low Energy, High Voltage	12	20	640	2180	Notebook Computers, Power Tools
5	Med. Energy, Low Voltage	12	800	50	500	Marine Chargers, Wheelchairs
6	Med. Energy, High Voltage	24	400	50	500	Lawn Mowers
7	High Energy	48	3750	150	1460	Golf Carts
8	Low Energy, 5V DC Input	3.6	2	600	2000	Portable Music and Media Players
9	Low Energy, 12V DC Input	5	3.6	480	1600	GPS
10	Low Energy, AC Output	12	70	1000	5000	Uninterruptible Power Supplies

5.7.2 BC Efficiency Metric

In the preliminary analysis, DOE recommended the use of a single metric called unit energy consumption (UEC) to illustrate the improved performance of BCs. UEC was intended to represent an annualized amount of the non-useful energy consumed by a BC in all modes of operation. Non-useful energy is all of the energy consumed by a BC that is not transferred and stored in a battery as a result of charging, or in other words, the losses. In order to calculate UEC, DOE must also make assumptions about time spent in each mode of operation. The collective assumption about time spent in each mode of operation is referred to as a usage profile and is addressed in detail in TSD chapter 7.

5.7.2.1 Calculation of Unit Energy Consumption

As discussed previously, UEC is a calculation intended to give the total annual amount of energy lost by a BC from the time spent in each mode of operation. For the preliminary analysis, the various performance parameters were combined with the usage profile parameters and used to calculate UEC with the following equation:

$$UEC = 365\left(n(E_{24} - P_m(24 - t_c) - E_{batt}) + \left(P_m\left(t_{a\&m} - (t_c n)\right)\right) + (P_{sb}t_{sb}) + \left(P_{off}t_{off}\right)\right)$$

Where

E_{24} = 24-hour energy
E_{batt} = Measured battery energy
P_m = Maintenance mode power
P_{sb} = Standby mode power
P_{off} = Off mode power
t_c = Time to completely charge a fully discharged battery
n = *Number of charges per day*
$t_{a\&m}$ = *Time per day spent in active and maintenance mode*
t_{sb} = *Time per day spent in standby mode*
t_{off} = *Time per day spent in off mode*[c]

When broken down and examined in segments, it becomes evident how this equation gives a value for energy consumed in each mode of operation per day and ultimately, energy consumption per year.

Active (or Charge) Mode Energy per Day

$$n(E_{24} - P_m(24 - t_c) - E_{batt}) = E_{Active\ Mode}/day$$

In the first portion of the equation, shown above, DOE combines the assumed number of charges per day, 24-hour energy, maintenance mode power, charge time, and measured battery

---

[c] Those values shown in *italics* are parameters assumed in the usage profile and change for each product class. The other values should be determined according to Appendix Y to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Battery Chargers.

energy to calculate the active mode energy losses per day. To get this value, 24-hour energy is reduced by the measured battery energy (the useful energy inherently included in a 24-hour energy measurement) and the maintenance mode power times the quantity of 24 minus charge time. 24 minus charge time gives the time spent in maintenance mode, which, when multiplied by maintenance mode power yields maintenance mode energy. Thus, maintenance mode energy and the value of the energy transferred to the battery during charging are both subtracted from 24-hour energy, leaving a quantity theoretically equivalent to the amount of energy required to fully charge a depleted battery. Finally, this number is multiplied by the assumed number of charges per day resulting in a value for active mode energy per day.

Maintenance Mode Energy per Day

$$\left(P_m\left(t_{a\&m} - (t_c n)\right)\right) = E_{Maintenance\ Mode}\ /day$$

In the second segment of DOE's equation, shown above, maintenance mode power, time spent in active and maintenance mode per day, charge time, and the assumed number of charges per day are combined to obtain maintenance mode energy per day. The product of charge time and number of chargers per day is subtracted from the time per day spent in active and maintenance mode. The resulting quantity is an estimate of time spent in maintenance mode per day, which, when multiplied by the measured value of maintenance mode power yields the energy consumed per day in maintenance mode.

Standby (or No-Battery) Mode Energy per Day

$$(P_{sb} t_{sb}) = E_{Standby\ Mode}\ /day$$

In the third part of DOE's UEC equation, shown above, the measured value of standby mode power is multiplied by the estimated time in standby mode per day, which results in a value of energy consumed per day in standby mode.

Off-Mode Energy per Day

$$(P_{off} t_{off}) = E_{No\_Battery\ Mode}\ /day$$

In the final part of DOE's UEC equation, shown above, the measured value of off-mode power is multiplied by the estimated time in off-mode per day, which results in a value of energy consumed per day in off-mode.

Finally, to obtain UEC, the values found through the aforementioned calculations are added together. The resulting sum is equivalent to an estimate of the average energy consumed by a BC per day. That value is then multiplied by 365, the number of days in a year, and the end result is a value of energy consumed per year.

Modifications to Equation for Unit Energy Consumption

On April 2, 2010, DOE published its NOPR on active mode test procedures for BCs and EPSs. 75 FR 16958. In that notice, DOE proposed shortening the charge and maintenance mode test procedure in scenarios when a technician could determine that a BC had entered maintenance mode. 75 FR 16970. However, during its testing of BCs, DOE observed complications that arise from trying to determine the charge time for some devices, which could in turn affect the accuracy of the UEC calculation. DOE also received comments opposed to the proposed shortened test procedure and ultimately decided that the duration of the charge test must not be shortened and instead must remain a minimum of 24 hours (the original duration). 76 FR 31750. The test is longer if it is known (*i.e.* because of an indicator on the BC) or it can be determined from manufacturer information that fully charging the associated battery will take longer than 19 hours.[d]

This revision to the test procedure is important because it underscores the potential issues with trying to determine exactly when a BC has entered maintenance mode, or in other words, occasionally it is difficult to determine charge time. Therefore, since charge time is a part of the calculation that DOE presented in the preliminary analysis, DOE rewrote its equation for UEC. The new equation, which was presented to manufacturers during interviews, is mathematically equivalent to the equation presented in the preliminary analysis. When the terms in the preliminary analysis UEC equation are multiplied out, those terms containing a factor of charge time cancel each other out and drop out of the equation. What is left can be factored and rewritten as done below. This means that even though the new equation looks different from the equation presented for the preliminary analysis, the value that is obtained is exactly the same and represents the exact same value of unit energy consumption.

$$UEC = 365\left(n(E_{24} - E_{batt}) + \left(P_m\left(t_{a\&m} - (24n)\right)\right) + (P_{sb}t_{sb}) + \left(P_{off}t_{off}\right)\right)$$

In the BC active mode test procedure NOPR, DOE had also proposed capping the measurement of 24-hour energy at the 24 hour mark of the test. However, this could result in inaccuracies because that measurement will not include the full amount of energy used to charge a battery if the charge time is longer than 24 hours. Therefore, in its final rule, DOE reversed its decision and now energy is measured for the entire duration of the charge and maintenance mode test, which includes a minimum of 5 hours in maintenance mode. 76 FR 31750. Therefore, to account for tests that last longer than 24 hours, DOE has made additional modifications to its equation for UEC.

The modifications to the UEC calculation do not alter the value obtained when the charge and maintenance mode test is completed within 24 hours. However, when the test does exceed 24 hours, the energy lost during charging is scaled back to a 24 hour, or per day, cycle by multiplying that energy by the ratio of 24 to the duration of the charge and maintenance mode test. In the equation below, t_{cd}, represents the duration of the charge and maintenance mode test and is a value that the test procedure requires technicians to determine.

There is one more alteration that DOE made to the equation which is the subtraction of 5 hours of maintenance mode energy from the 24-hour energy measurement. DOE does this

---

[d] The charge mode test must include at least a five hour period where the unit being tested is known to be in maintenance mode. Thus, if a device takes longer than 19 hours to charge, or is expected to take longer than 19 hours to charge, the entire duration of the charge mode test will exceed 24 hours in total time after the five hour period of maintenance mode time is added. 76 FR 31750 (BCEPS TP Final Rule)

because the charge and maintenance mode test includes a minimum of 5 hours of maintenance mode time. Consequently, in the second portion of the equation below, DOE reduces the amount of time subtracted from the assumed time in active and maintenance mode time per day. In other words, the second portion of the equation, which is an approximation of maintenance mode energy, is reduced by 5 hours. This alteration is needed in those instances when the charge and maintenance mode test exceeds 24 hours, because the duration of the test minus 5 hours is an approximation of charge time, which can be used to determine what portion of the time spent in active and maintenance mode is dedicated to maintenance mode. The primary equation that manufacturers will use to determine their product's unit energy consumption and whether or not their device complies with DOE's standards is below.

$$UEC = 365\left(n(E_{24} - 5P_m - E_{batt})\frac{24}{t_{cd}} + \left(P_m\left(t_{a\&m} - (t_{cd} - 5)n\right)\right) + (P_{sb}t_{sb}) + \left(P_{off}t_{off}\right)\right)$$

Where, t_{cd} = Charge test duration (usually 24 hours)

5.7.2.2 Secondary Calculation of UEC

For some battery chargers the equation described previously is not appropriate and an alternative calculation is necessary. For some products, the charge time could be extremely long. If, in these cases the charge test duration (as determined according to section 5.2 of Appendix Y to Subpart B of Part 430) minus 5 hours is multiplied by the number of charges per day (n) is greater than the time assumed in active and maintenance mode (*i.e.* $n(t_{cd} - 5) > t_{a\&m}$) an alternative equation must be used. That is because if the number of charges per day multiplied by the time it takes to charge (when $t_{cd} > 24$, charge test duration less 5 hours), or in other words, the charge time per day is longer than the assumption for time in charge mode and maintenance mode per day an inconsistency is generated between the product being tested and DOE's assumptions. This can be corrected by using an alternative equation, which is shown below.

$$UEC = 365\left(n(E_{24} - 5P_m - E_{batt})\frac{24}{(t_{cd} - 5)} + (P_{sb}t_{sb}) + \left(P_{off}t_{off}\right)\right)$$

5.7.3 BC Candidate Standard Levels of Efficiency

After selecting its representative units, DOE examined the impacts on cost of improving the efficiency of each of the representative units presented in section 5.7.1 to evaluate the impact and assess the viability of potential energy efficiency standards. As described in the technology assessment and screening analysis, TSD chapters 3 and 4 respectively, the technology options for improving efficiency are many. Each incremental technology improvement increases the BC efficiency along a continuum. The engineering analysis develops cost estimates for several discrete CSLs along that continuum.

CSLs are often based on (1) efficiencies available in the market; (2) other voluntary specifications or mandatory standards that cause manufacturers to develop products at particular efficiency levels; and (3) the maximum technologically feasible level.[e]

There are no current energy conservation standards for BCs, and the ENERGY STAR efficiency[1] level may not be widely applicable.[f] Therefore, DOE based the CSLs for its BC analysis on the efficiencies attainable through the design options presented previously, and as seen in commercially available units. DOE selected commercially available BCs at the representative-unit battery voltage and energy from the high-volume applications identified in the market survey. DOE then tested these in accordance with the proposed DOE BC test procedure. For each representative unit, DOE then selected CSLs to correspond to the efficiency of BC models that were comparable to each other in most respects, but differed significantly in UEC (*i.e.* efficiency).

In general, for each representative unit, DOE chose the baseline (CSL 0) unit to be the one with the highest calculated unit energy consumption, and the best-in-market (CSL 2) to be the one with the lowest. Generally, DOE also included an intermediate level (CSL 1) to provide additional resolution to the analysis.[g]

Unlike the previous CSLs, CSL 3 was not based on an evaluation of the efficiency of BC units in the market, since BCs with maximum technologically feasible efficiency are not commercially available due to their high cost. Where possible, Navigant, obtained manufacturer estimates of max-tech costs and efficiencies. In some cases, manufacturers were unable to offer any insight into efficiencies beyond the best currently available in the market. With the technical insight of subject matter experts, an independent estimate of the efficiency of a max-tech unit was also developed by DOE through extrapolation of its analysis of the best-in-market unit by estimating the impacts of adding any remaining energy efficiency design options to said unit.

The CSLs in Table 5-48 are presented in terms of unit energy consumption, with higher CSLs corresponding to lower energy consumption. To generate these numbers DOE assumed a class-average usage profile. However, to minimize the sensitivity of the CSL units to the particular usage profile selected for a given product class, DOE based its CSLs on the successive BC units that show efficiency improvement in all of the modes—*i.e.*, active, maintenance, no-battery, and off modes. Thus, although the results of the analysis may change depending on the usage profile selected, the ordering of the CSLs will not. The BC model corresponding to the baseline CSL will continue to consume more energy than that corresponding to the next higher CSL, and so on, regardless of the usage profile. These CSLs are summarized for each representative unit in Table 5-48, below, while the usage profiles used to calculate energy consumption at each CSL are shown in Table 5-49.

---

[e] The “max-tech” level represents the most efficient design that is commercialized or has been demonstrated in a prototype with materials or technologies available today. “Max-tech” is not constrained by economic justification, and typically is the most expensive design option combination considered in the engineering analysis.

[f] The ENERGY STAR level for BCs was not adopted as a CSL because the ENERGY STAR BC guidelines do not consider energy consumption in active mode.

[g] An alternative approach would have set CSL 1 at the best-in-market unit. The approach would have been used in the absence of an intermediate, improved-efficiency unit. However, DOE decided against this approach to ensure naming consistency.

Table 5-48 Unit Energy Consumption of Battery Charger Representative Units at each CSL

	Unit Energy Consumption by Representative Unit *kWh/year*									
CSL	**1** **Low Energy, Inductive** **1.5 Wh, 3.6 V**	**2** **Low Energy, Low Voltage** **3 Wh, 3.6 V**	**3** **Low Energy, Med Voltage** **10 Wh, 7.2 V**	**4** **Low Energy, High Voltage** **20 Wh, 12 V**	**5** **Med. Energy, Low Voltage** **800 Wh, 12 V**	**6** **Med. Energy, High Voltage** **400 Wh, 24 V**	**7** **High Energy** **3750 Wh, 48 V**	**8** **Low Voltage DC Input** **2 Wh, 3.6 V**	**9** **High Voltage DC Input** **3.6 Wh, 5 V**	**10** **Low Energy, AC Output** **70 Wh, 12 V**
0	8.7	8.7	11.9	37.7	84.6	120.6	255.1	0.9	0.8	19.3
1	6.1	6.5	4.7	9.9	56.1	81.7	191.7	0.7	0.3	6.1
2	3.0	2.9	0.8	4.6	29.3	38.3	131.4	0.2	0.1	4.0
3	1.3	1.0	0.7	3.0	15.4	16.8	-	0.2	-	1.5
4	-	0.8	-	-	-	-	-	-	-	-

Table 5-49 Usage Profiles for Battery Charger Representative Units

Product Class	**Description**	**Time Per Day Spent in Each Mode**					**Number of Full Charges Per Day**
		Active and Maintenance *hr*	**No-Battery** *hr*	**Unplugged** *hr*	**Off** *hr*	**Total** *hr*	
1	**Low Energy, Inductive**	20.7	0.1	3.2	0.0	24.0	0.15
2	**Low Energy, Low Voltage**	8.8	4.6	10.6	0.0	24.0	0.54
3	**Low Energy, Med Voltage**	6.9	0.3	16.8	0.0	24.0	0.10
4	**Low Energy, High Voltage**	16.4	0.9	6.7	0.0	24.0	0.49
5	**Med Energy, Low Voltage**	6.3	1.1	16.6	0.0	24.0	0.11
6	**Med Energy, High Voltage**	17.2	6.8	0.0	0.0	24.0	0.34
7	**High Energy**	8.1	7.3	8.6	0.0	24.0	0.32
8	**Low Voltage DC Input**	6.3	7.0	10.7	0.0	24.0	0.54
9	**High Voltage DC Input**	1.1	0.0	22.9	0.0	24.0	0.14
10	**Low Energy, AC Output**	24.0	0.0	0.0	0.0	24.0	0.00

5.7.4 BC Teardown Analysis

As mentioned in the discussion above, the CSLs used in the BC engineering analysis were based on the efficiencies of BCs available in the market. Following testing, the units corresponding to each commercially available CSL were disassembled to (1) evaluate the presence of energy efficiency design options and (2) estimate the materials cost. The disassemblies were performed by DOE's subject-matter experts and included an examination of the general design of the BC as well as an evaluation of the presence of any of the technology options discussed in chapter 3.

After the BC units corresponding to the CSLs were evaluated, they were torn down by iSuppli, another DOE contractor and industry expert. For most BCs, the teardowns were comparable to those conducted for EPSs, described in section 5.4.4.

Teardowns were done differently for BCs embedded inside complex consumer electronic products such as camcorders and notebook computers. Because the BC constitutes a small portion of the circuitry of these products, DOE did not evaluate the entirety of the products' cost. Rather, iSuppli identified the subset of components in each product enclosure responsible for battery charging, including the battery, charge regulator, and any related power converters and voltage regulators.

In general, any component in the product and enclosure can be categorized as (1) intended solely for battery charging functions, such as the battery itself; (2) intended solely for non-battery charging functions, such as a user-interface component; and (3) intended for both battery charging and non-battery charging functions; such as a power supply. For the engineering analysis, iSuppli included in the BC bill-of-materials components in categories 1 and 3, the latter because of their crucial role in the battery charging process. Nonetheless, this choice was not always appropriate and cases where dual-purpose components such as microcontrollers unnecessarily inflated the cost of the BC are noted in the subsequent sections. The results of these teardowns were used as the primary source for the manufacturer selling prices (MSPs).

In addition to the tests and teardowns conducted for the preliminary analysis, DOE incorporated more than 100 new tests and 13 new teardowns from all product classes.

5.7.5 BC Manufacturer Interviews

For the preliminary analysis, Navigant interviewed several BC manufacturers on behalf of the U.S. Department of Energy (DOE). Of these, some manufactured the BCs directly, while others were original equipment manufacturers (OEMs) of battery-operated products. The purpose was to obtain data on the possible efficiencies and resultant costs of consumer BCs. In October, November, and December of 2010, Navigant conducted additional interviews for the NOPR, some with the same manufacturers and some with new manufacturers. These interviews served dual purposes for the NOPR analyses. First, it gave manufacturers the opportunity to provide comments on the preliminary analysis engineering analysis results under a non-disclosure agreement with Navigant. Although Navigant could not share the particulars of these discussions with DOE, it could generalize the comments received and make adjustments to its engineering analysis for the NOPR. Second, these interviews allowed Navigant and DOE to obtain inputs and comments for the manufacturer impact analysis, which is discussed in detail in TSD chapter 12.

Prior to the interview, each manufacturer was sent a questionnaire (included as Appendix 12A) to guide the discussion. To ensure consistency between manufacturers, the survey specified the parameters of each BC representative unit under consideration, previously presented in section 5.7.1.

5.7.5.1 Manufacturer Responses

For each representative unit, the interviewers asked manufacturers to describe the technological improvements and associated costs necessary to meet each of the CSLs presented in section 5.7.3. These CSLs were also presented in a disaggregated form (*i.e.*, energy consumption by mode, rather than combined into a weighted unit energy consumption) to help the respondents.

Nonetheless, in many cases, manufacturers were unable to provide information in terms of the representative unit, and responded instead with information on other popular models with which they were more familiar. The discrepancies between the representative units and the manufacturers' popular units do not seem as significant. In general, manufacturers did not expect the energy consumption of a BC to vary due to small variations in battery voltage and energy—especially at the higher battery energies where there is a diminishing impact of fixed losses at higher output power.

As mentioned in the previous section, DOE attempted to obtain teardown results for all of its product classes, however, it had problems obtaining useful and accurate teardown results for two of its products class. The problematic classes were product class 1, mainly electric toothbrushes, and product class 10, uninterruptible power supplies. For these two product classes, DOE relied heavily on the outcomes of its manufacturer interviews and the cost versus efficiency data provided by manufacturers showed economically justifiable levels all the way up to the max-tech level. Therefore, DOE continued to use the manufacturer data for cost and efficiency for these two product classes. The method DOE used to aggregate cost-efficiency data obtained from different manufacturers, and for each CSL is described in detail below.

5.7.5.2 Aggregation of Manufacturer Responses

After collecting information from manufacturers on the mode-specific energy consumption and cost of battery chargers, Navigant used the following process to calculate aggregate manufacturer cost-efficiency data at each CSL:

1. Calculate the unit energy consumption for each manufacturer design;
2. Perform a regression analysis of each manufacturer's data using a $1/x$ basis function, resulting in a cost-efficiency curve for each manufacturer defined for every UEC;
3. Translate each manufacturer curve to obtain incremental costs from the baseline;

4. Average all the manufacturers' incremental costs at each CSL, resulting in an incremental aggregate cost-efficiency curve;

5. Translate the aggregate curve to equal the teardown results at the baseline UEC, resulting in an absolute incremental cost-efficiency curve; and

6. Finally, decompose the aggregated UECs at each CSL to estimate performance in each mode for a typical manufacturer unit (used for comparison with teardown results and for calculating application-specific energy consumption used in the LCC analysis).

Each of these steps is described in the sections that follow.

Calculate the UEC for Each Manufacturer-Supplied Design

Navigant used the shipment-weighted average usage profile for each product class to calculate the unit energy consumption of each BC when used with the typical mix of applications for the product class. The derivation of the application-specific usage profiles, the resultant product class-average usage profiles, and the calculation of the UEC are all described in Chapter 7 of the TSD; nonetheless, these procedures were used within the engineering analysis prior to reporting manufacturer's cost-efficiency data as a necessary step in the aggregation procedure.

Regression Analysis to Calculate Manufacturer Costs across all UECs

However, the resulting shipment-weighted UECs did not necessarily coincide with the UECs specified at each CSL; therefore, it was not possible to simply average the costs provided by the manufacturers at each CSL to obtain an aggregate cost-efficiency curve. Instead, Navigant performed a regression analysis of the manufacturer cost-efficiency data, to obtain a best-fit cost-efficiency curve for each manufacturer.

According to the manufacturer interviews, large improvements in energy efficiency could initially be made at relatively little cost. For example, manufacturers reported that improved transformer steel could decrease the energy consumption of low-energy, low-voltage chargers by 20 percent for a $0.25 increase in selling price. However, further improvements would offer diminishing returns until the maximum-technologically achievable efficiency, beyond which no further improvements could be possible given currently available technology. An ideal charger with zero losses in active, maintenance, or no-battery modes, but with a low cost, inefficient battery, could be assumed to have an infinite selling price.

Navigant modeled this apparent relationship between cost and efficiency as a $^1\!/_x$ curve of the form presented in Eq. 1, below:

$$MSP = \frac{1}{m \cdot (UEC - b)} + a \,,$$

Eq. 1

Where:

MSP is the manufacturer's selling price;
UEC is the unit energy consumption;
m is a parameter controlling the concavity of the curve;
a is a parameter corresponding to the flatness of the curve at the lower efficiencies; and
b is a parameter corresponding to the energy consumption of the ideal charger.

Curves of this form were fitted to the MSP-versus-shipment-weighted-UEC data for each manufacturer; the *a* variable, above, was adjusted as necessary to maximize the coefficient of determination *(*R^2 value). This process is illustrated in Figure 5.46.

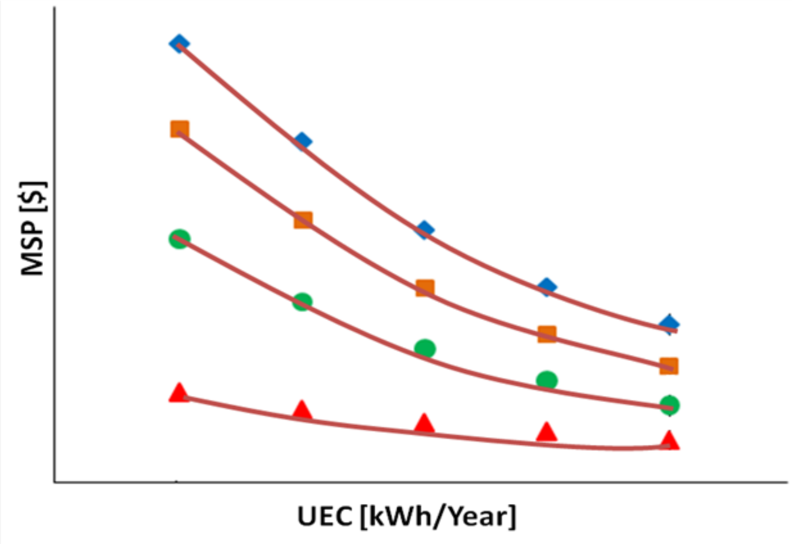


Figure 5.46 Regression of Manufacturer Cost-Efficiency Data

Translate Curves to Obtain Incremental Costs from the Baseline

After calculating the manufacturer best-fit-curves, Navigant translated each one by subtracting the cost at the baseline CSL. As illustrated in Figure 5.47, the cost translation process shifts the absolute system costs of each manufacturer's products so that the cost of the baseline system is consistent across all manufacturers. By ensuring that all manufacturers share a common baseline system cost, DOE was able to compare manufacturers' data points directly while maintaining each manufacturer's incremental costs as efficiency increases, allowing for a direct analysis of the cost of efficiency improvements regardless of baseline costs (which may vary depending on the size of the manufacturer).

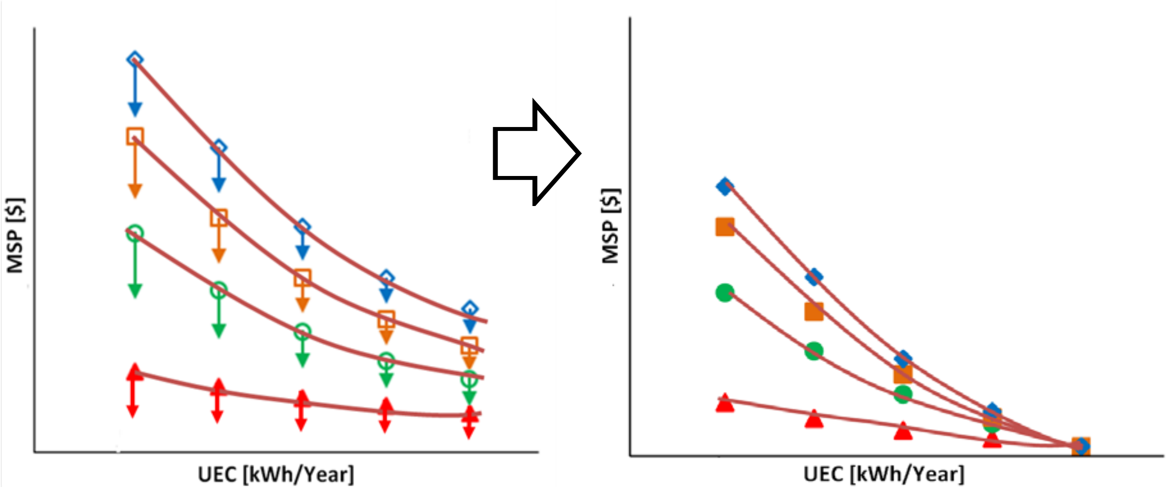


Figure 5.47 Translation of Curves to obtain Incremental Costs from the Baseline

Average the Incremental Costs at Each CSL

The last step of the procedure produced cost-efficiency relationships with a common baseline for each manufacturer across all UECs. Next, DOE aggregated these responses by calculating the cost for each manufacturer at each CSL and averaging them, such that the baseline aggregate cost was the average of the manufacturer costs at the baseline CSL 0 (equal to zero from the last step), the aggregate cost at CSL 1 was the average of the manufacturer costs at CSL 1, and so on. This process is illustrated in Figure 5.48.

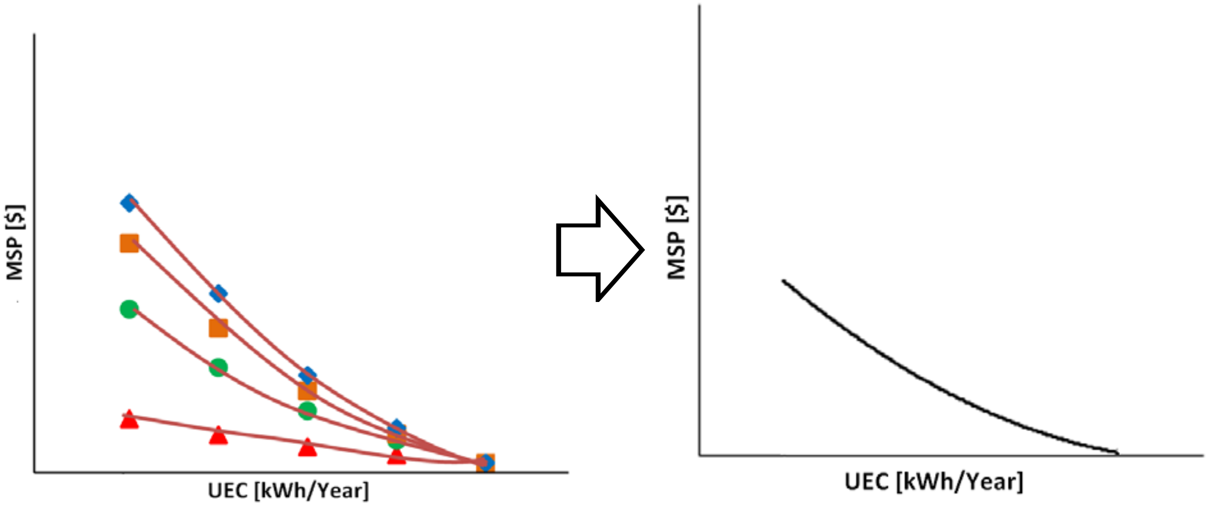


Figure 5.48 Aggregation of Translated Manufacturer Curves

Translate Curves to Obtain Absolute Costs from Teardown Baseline

Finally, to allow easier comparison between manufacturer and teardown results and more meaningful interpretation of analysis results as a portion of total unit costs, Navigant translated the aggregate manufacturer curves such that the manufacturers’ MSPs at baseline efficiency corresponded to the lowest teardown MSP. This process is illustrated in Figure 5.49.

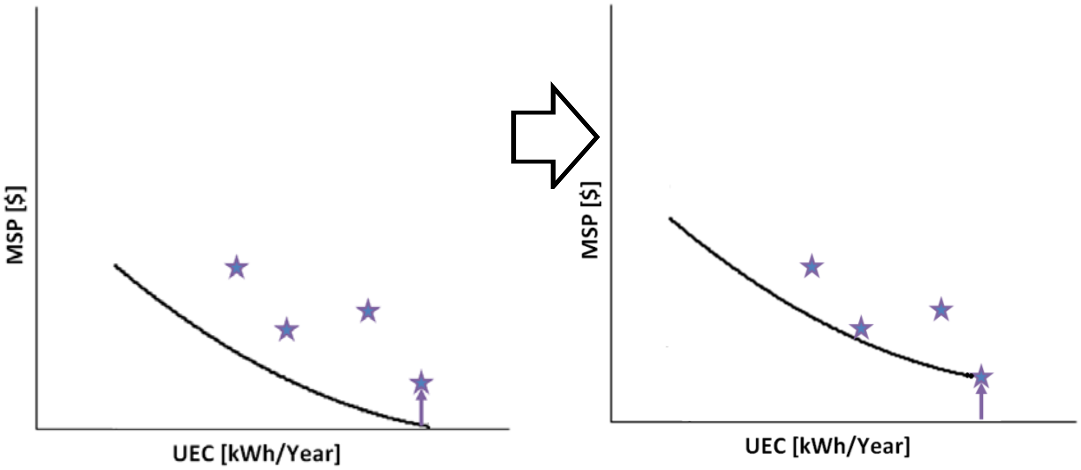


Figure 5.49 Translation of Curves to obtain Absolute Costs from Teardown Baseline

Decompose the aggregate UECs at each CSL to Estimate Mode-Specific Performance

Finally, DOE decomposed the aggregate UEC at each CSL into mode-specific performance figures. As an illustration, a UEC of 10 kWh per year for a given representative unit was decomposed into an estimated active-mode efficiency of 50 percent, maintenance mode power of 2 watts, and no-battery mode power of 1 watt. These mode-specific estimates were calculated taking into account the original manufacturer responses, which were also provided in terms of mode-specific performance, and were used to provide a more direct comparison to DOE test results and for use in the downstream LCC analysis.

Rather than weighting the original manufacturer responses to calculate the UEC, followed by decomposing the aggregate UEC into mode-specific performance, Navigant could have also aggregated the mode-specific responses directly. However, doing so would have treated the performance in each mode as independent; by first calculating the UEC, DOE takes into account the fact that manufacturers will tend to optimize performance in one mode over that in another, depending on the usage of the product.

5.7.6 BC Cost Model

DOE gathered inputs on markups for BCs from manufacturer interviews. Specifically, DOE questioned manufacturers regarding typical markups for a BC manufacturer, or original device manufacturer (ODM), between bill-of-materials (BOM) cost, *i.e.*, what they pay for the BC components, and manufacturer selling price (MSP), *i.e.*, the price at which they sell the BC to an original equipment manufacturer (OEM). This MSP is alternatively known as the OEM's "assembly price" or "factory price."

The analysis focused on the cost of BC components directly related to efficiency—*i.e.*, the electronics, and excluded the packaging, cord, and cosmetic touches which may vary from product and depends greatly on the application, and whether or not the BC is integrated into a product or packaged separately. Therefore, the resultant MSP was an electronics MSP.

In addition to ignoring packaging costs, DOE further simplified the analysis by standardizing how BC production and non-production markups would be calculated across the

ODM and OEM, both of which may participate in the manufacturing of the BC. As further explanation, the four possible arrangements for BC production are illustrated in Figure 5.50, below.

1. The OEM manufactures both the end-use product and all BC components.
2. The OEM manufactures the end-use product, but purchases all BC components from an ODM or ODMs.
3. The OEM manufactures the end-use product, including any BC components embedded in the end-use product, while purchasing remaining BC components from an ODM or ODMs.
4. The OEM manufactures nothing; instead it purchases the end-use product and all BC components from an ODM or ODMs.

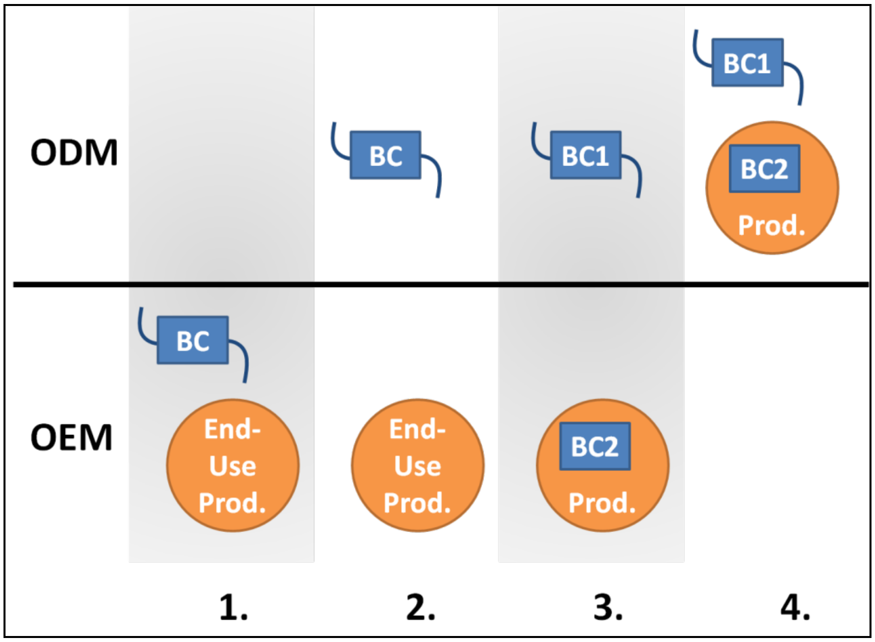


Figure 5.50 Possible Batter Charger and End-Use Product Manufacturing Arrangements

Which of the above arrangements applies to a particular BC will influence how the various production and non-production markups are calculated. The behavior of the OEM can further influence the markup. Some OEMs indicated that they pass through the cost of the BC, while others claimed to mark it up the same amount as the rest of the battery-operated product.

Rather than attempt to take into account all the manufacturing relationships revealed during the interviews, DOE’s analysis assumes a standard BC manufacturing markup, regardless of who manufactures the BC—whether it is the OEM or ODM. This markup is an average of those provided by manufacturers and accounts for the production and non-production costs, as well as profit associated with electronics assembly.

Although this markup, presented in Table 5-50, varies by product class, it is independent of application, as the same factories typically manufacture BCs for a host of different applications. The large variations in the markup can be explained by the nature of the product sold. In general, the lower-energy units are manufactured in larger numbers and rely on somewhat generic EPSs for power conversion. In contrast, the higher-energy units are manufactured in smaller numbers, and the same manufacturer typically manufactures the power conversion and higher-value charge-control portions of the BC. DOE multiplied these product-class specific markups by the BOM cost to arrive at an MSP for each unit.

Table 5-50 Average Markup applied to the BOM for each Product Class

PC	Description	Average BC Manufacturer Markup
1	**Low Energy, Inductive**	1.2
2	**Low Energy, Low Voltage**	1.2
3	**Low Energy, Med Voltage**	1.2
4	**Low Energy, High Voltage**	1.5
5	**Med Energy, Low Voltage**	2.1
6	**Med Energy, High Voltage**	2.1
7	**High Energy**	2.1
8	**Low Energy, 5V DC Input**	1.2
9	**Low Energy, 12V DC Input**	1.2
10	**Low Energy, AC Output**	1.6

5.7.7 Product Class 1: Low Energy, Inductive (Manufacturer Interview Data)

The low-energy, inductively charged product class includes BCs with a cradle that couples inductively to the end-use product enclosure. These consist of a rectifier/low-pass filter, the battery, and the end-use product (an electric toothbrush). This product class includes all inductively-coupled BCs with a battery voltage less than 4 volts and a battery energy less than 100 Wh, though in actuality DOE has only found models with batteries with a voltage of 1.2 to 3.6 volts and energy of 0.5 to 1.8 Wh.

Despite the low shipments and low per-unit energy consumption in this product class, DOE decided to explicitly analyze it due to potential differences in design between inductively-coupled chargers and other classes of BCs. Although DOE interviewed manufacturers of inductively-coupled battery chargers and tested several toothbrushes from different manufacturers, it was unable to perform product teardowns. DOE found that when it attempted to have electric toothbrushes torn down, most products contained potting which was manufacturers' way of further water-proofing the internal electronics. Unfortunately, when this potting was removed, so too were any identifying markings that iSuppli needed to estimate a cost for the components. This prevented DOE from obtaining cost data for the respective efficiency levels tested. Hence, DOE analyzed this product class with manufacturers' data for cost and efficiency.

5.7.7.1 Units Analyzed

The results of DOE tests of low-energy inductive BCs are plotted in Figure 5.51. These test results also include the results of tests conducted by Ecos Consulting and submitted to DOE by Pacific Gas & Electric. As can be seen, there is substantial disparity between the baseline, intermediate, and best-in-market units. In addition to the factor-of-two difference in battery energy between the intermediate unit at approximately 0.9 Wh and the best-in-market at 1.8 Wh, there is also a difference in voltage (not pictured) with batteries ranging from 1.2 to 3.6 volts. Selecting a common point of comparison was not possible.

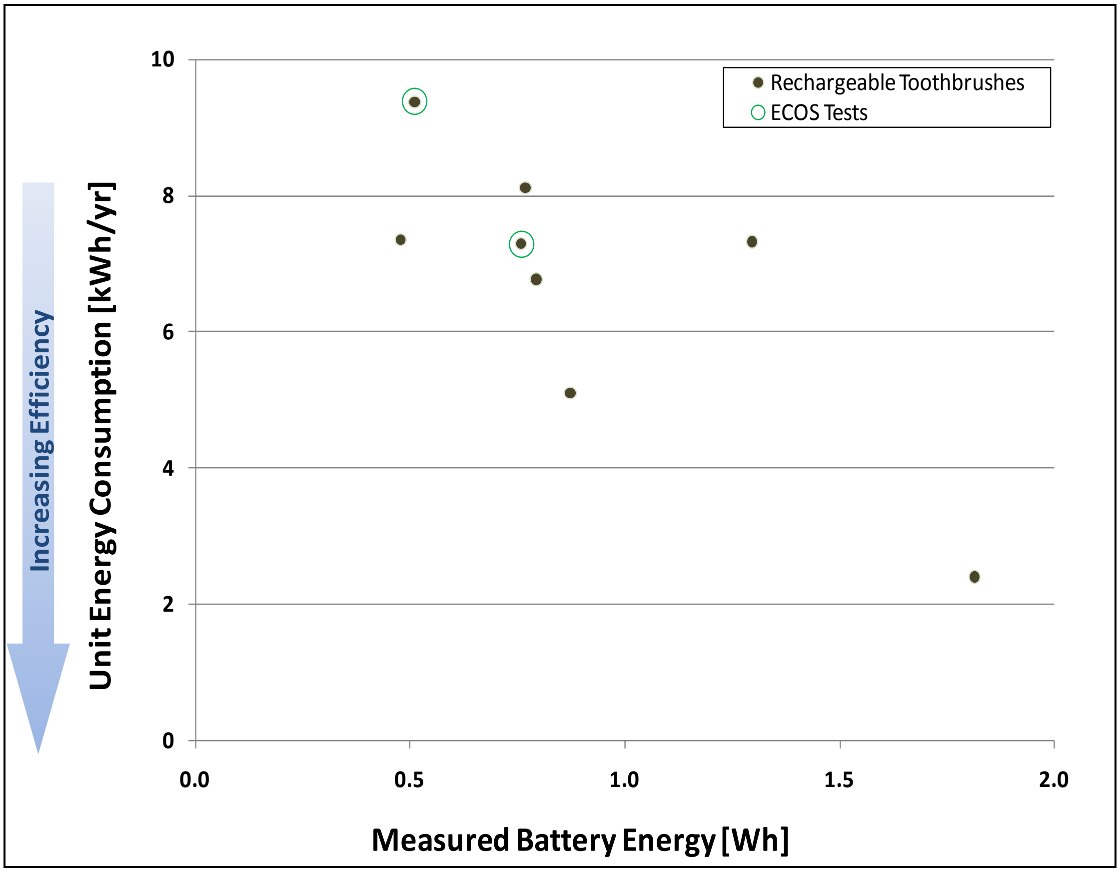


Figure 5.51 Test Results for Product Class 1: Low Energy, Inductive

Therefore DOE turned to the manufacturers of these products. The manufacturers provided information on units meeting the baseline through best-in-market CSLs for this product class. The estimated performance characteristics of a representative unit based on an aggregate of the manufacturer data is presented in Table 5-51, while the design options required to reach these levels of performance are described in sections 5.7.7.2 through 5.7.7.5.

Table 5-51 Manufacturer Performance Data for Product Class 1 Representative Unit

CSL	Application	Rated Battery Energy *Wh*	Est. Charge Test Duration *h*	Est. 24-Hour Energy *Wh*	Est. 24-Hour Energy Efficiency *%*	Est. Maint. Power *W*	Est. No-Battery Power *W*	UEC *kWh/yr*
0	Toothbrush	1.5	24	26.7	6	1.2	0.5	8.7
1	Toothbrush	1.5	24	19.3	8	0.8	0.4	6.1
2	Toothbrush	1.5	24	10.8	14	0.4	0.2	3.0
3	Toothbrush	1.5	24	5.9	25	0.2	0.1	1.3

5.7.7.2 CSL 0—Baseline (UEC of 8.7 kWh/yr)

The baseline unit represents BCs intended to inductively charge nickel-cadmium batteries. Although many of these were designed as long as 10 years ago, they continue to be sold in the market albeit at the lower price points.

BCs for electric toothbrushes make up the majority of the units tested at the baseline CSL. As such it is composed of two enclosures: a charging stand that connects directly to AC mains and serves as the transmitter in the inductive link, followed by a receiver and charge controller in the handle of the toothbrush. Because of the inductive connection—which transfers power through magnetic coupling between transmitter and receiver coils when they are in close proximity—both enclosures are sealed, allowing them to be used in a wet environment.

What distinguishes the baseline units from units at the other CSLs is the slow charge rate and lack of termination. The charge acceptance of a nickel cell decreases as the battery approaches full charge, resulting in less charge in the cell for each unit of charge delivered by the BC. Because it spends more time in this inefficient region of cell operation, the slow baseline unit accumulates significant active-mode losses.

These active-mode losses are compounded by the lack of termination. Rather than turn off the current to the battery after a full charge, the baseline unit continues to provide a small but not insignificant current, resulting in an input power around 1 watt in active and maintenance modes. No-battery power is less than 0.5 watts, while the resultant unit energy consumption is less than 8.7 kWh.

5.7.7.3 CSL 1—Improved (UEC of 6.1 kWh/yr)

Manufacturers have been able to improve the performance of the baseline charger by substituting in energy-saving components and making other incremental improvements to the design. Although many are still nickel-chemistry trickle chargers, units meeting CSL 1 save energy over the baseline by using more efficient sub-circuits and components, such as lower-loss biasing of the input stage or higher-efficiency Schottky diodes in the inductive receiver. Schottky diodes have half the forward voltage drop of conventional silicon *pn*-junction diodes, resulting in half the losses.

The above improvement in biasing circuitry would reduce unit energy consumption and place these units into CSL 1. Specifically, the improvements in the biasing circuitry would reduce the no-battery power to less than 0.5 watts. This, combined with the component improvements, yields input power less than 0.75 watts in active and maintenance modes, resulting in a unit energy consumption less than 6.1 kWh.

5.7.7.4 CSL 2—Best-in-Market (UEC of 3 kWh/yr)

Currently, the best-in-market models in this product class ship with lithium-ion toothbrushes. Even though lithium-ion cells have a nominal voltage of 3.6 volts (as opposed to 1.2 volts for the nickel cells described previously), the manufacturers considered the utility and design of the lithium-ion best-in market unit to be comparable to the nickel units at the lower CSLs.

Specifically, one can redesign the CSL 0 or CSL 1 units to meet CSL 2; however, it may require improvements in all three modes of operation: active, maintenance, and no-battery. Active-mode efficiency can be increased by improving the inductive coupling between the transmitter and receiver by placing a resonant capacitor in series with the receiver coil or by inserting additional ferrite material (which channels the magnetic field) in the charging stand. Such improvements result in a 5 percentage-point higher active mode efficiency over a typical CSL 1 unit.

However, according to manufacturers, the biggest gains can be made in the non-active modes. Because it charges a lithium-ion battery, which cannot tolerate a continuous trickle current, the best-in-market unit terminates following a full charge. Possible further improvements include reducing the clock speed of the microcontroller or dimming the informational LEDs located in the toothbrush handle. In total, these result in decreased input power during maintenance mode below 0.5 watts, while decreasing the no-battery power to 0.2 watts. The resulting unit energy consumption is less than 3 kWh per year.

5.7.7.5 CSL 3—Max-Tech (UEC of 1.3 kWh/yr)

During interviews, manufacturers also discussed potential efficiency improvements beyond the best-in-market level. According to manufacturers, technology options exist that can decrease energy consumption in all three modes of operation.

First, manufacturers recommended improving the coupling between the toothbrush handle and charger base through the addition of an extra coil, which could increase the proportion of power transferred to the handle through resonance. Additionally, manufacturers suggested slowing the microcontroller clock and dimming the status indicators (LEDs or LCD backlights), which would decrease energy consumption in both active and maintenance modes. Even with these improvements, the inductive connection would limit the overall system efficiency in active mode to 25 percent. These design options, along with incremental improvements in the charging base, can be expected to decrease the unit energy consumption below 1.3 kWh per year.

5.7.7.6 Estimate of Manufacturer Selling Price

Because of an inability to perform meaningful teardowns, the MSPs for this product class were based on the manufacturer interviews, and are pictured in Figure 5.52 and detailed in Table 5-52.

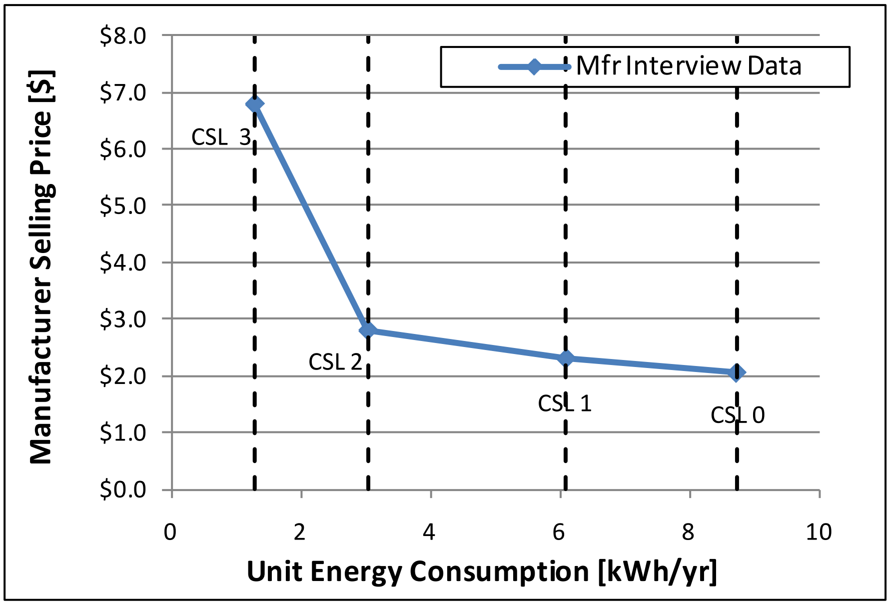


Figure 5.52 MSP vs. UEC for Product Class 1

Table 5-52 CSL Descriptions for Product Class 1

CSL	UEC *kWh/yr*	MSP from Manufacturer Interviews *$*
0	8.7	2.05
1	6.1	2.30
2	3.0	2.80
3	1.3	6.80

5.7.8 Product Class 2: Low Energy, Low Voltage (Test and Teardown Data)

The low-energy, low-voltage product class includes BCs for batteries below 4 volts and below 100 Wh. It represents the low end of battery energy, and includes BCs for telephony, personal care, and portable entertainment applications.

BCs in this product class charge batteries composed of lithium-ion, nickel-cadmium, or nickel-metal hydride cells. Because the nominal voltage of a lithium-ion cell is 3.6 volts, there are no BCs for lithium-ion batteries in the lower portion of the voltage range; instead in this range DOE found BCs for nickel-based batteries with one or two cells (nickel cells have a nominal voltage of 1.2 volts). At or above 3.6 volts, either battery chemistry can be used; however, applications that are smaller, lighter, or more expensive tend to use lithium-ion batteries, while the remainder use nickel batteries.

5.7.8.1 Units Analyzed

DOE tested 23 units for this product class; their unit energy consumption, assuming a shipment-weighted product class-average usage profile, is pictured in Figure 5.53. For comparison, the figure also includes the results of tests conducted by Ecos Consulting[2]. Of these, DOE chose five units for further evaluation and teardowns based on their test results and internal design. Detailed information regarding these five units is presented in Table 5-53.

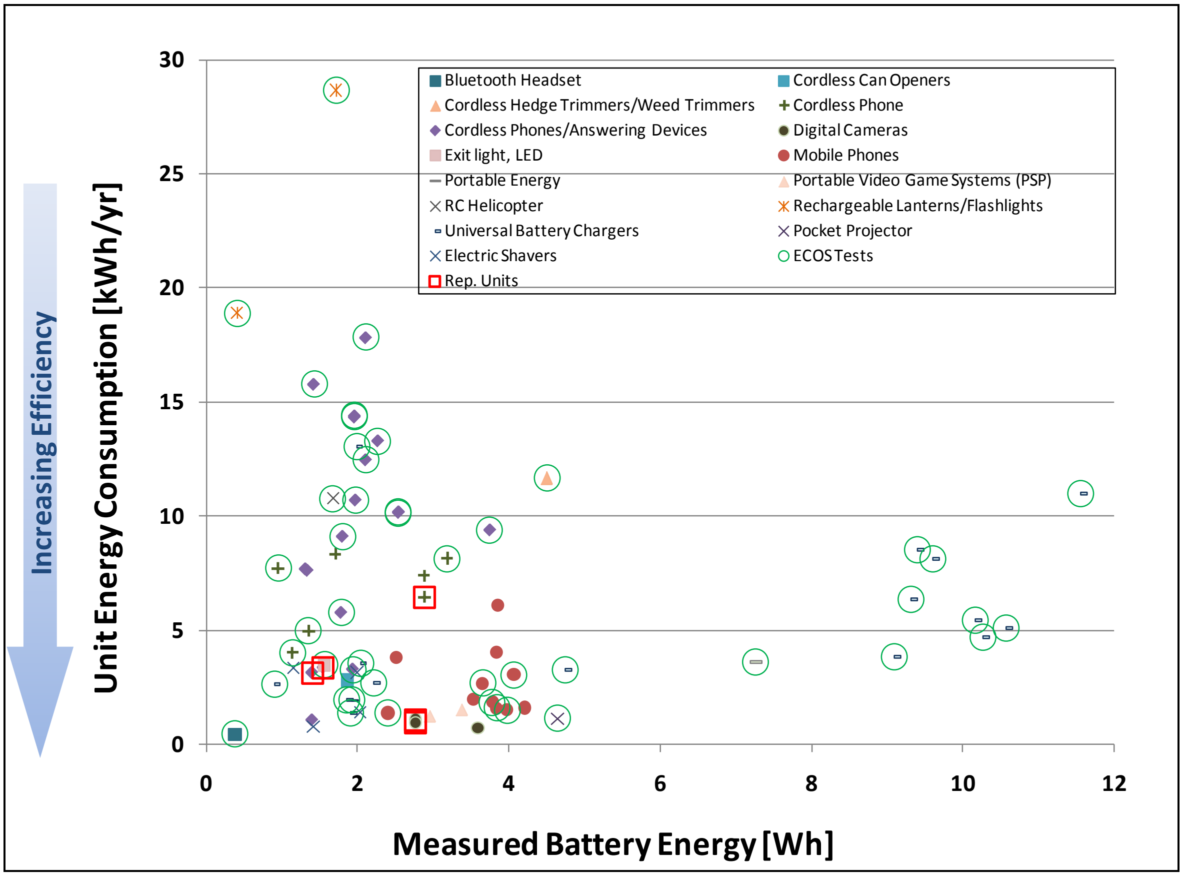


Figure 5.53 Test Results for Product Class 2: Low Energy, Low Voltage

As can be seen in Figure 5.53 the majority of the products tested in this product class have battery energy less than 5 Wh, with the exception of the cluster of Ecos test points at approximately 10 Wh. These correspond to tests of universal battery chargers for standard-sized AA or AAA batteries, performed with the highest number of batteries these units could charge (typically 4). However, Ecos also tested these same units with the smallest allowable number of batteries, whereupon the measured battery energy ranged from 0.9 to 2.2 Wh—within the main cluster of battery energies. Therefore, DOE focused its analysis on units at approximately 3 Wh to make its analysis applicable to the widest range of BCs in this class, including the universal battery chargers.

From these, DOE selected several units for further analysis based on their measured energy consumption, detailed in Table 5-53. These units were selected to span a wide range of efficiencies available in the market. The only BCs that lie outside this efficiency distribution are the Ecos test units with unit energy consumption above 10 kWh per year.

In its test results database, Ecos lists these all as cordless phones/answering devices, and despite a thorough search, DOE was unable to find any cordless phones with energy consumption at those levels. This discrepancy between the lowest-efficiency units tested by DOE versus Ecos may be due to the vintage of the units tested by Ecos (2007, prior to the efficiency impacts of EISA 2007) and the potential energy consumption of answering machine features. In either case, establishing the baseline CSL at the energy consumption of a current BC (with an EISA-compliant EPS) unburdened by any additional non-battery charging functionality, is the preferred approach.

Table 5-53 Manufacturer Performance Data for Product Class 2 Representative Unit

CSL	**Application**	**Battery Energy** *Wh*	**Charge Test Duration** *h*	**24-Hour Energy** *Wh*	**24 Hour Energy Efficiency** *%*	**Maint. Power** *W*	**No-Battery Power** *W*	**UEC** *kWh/yr*
0	Power Tool	3.0	27	46.5	6	1.8	0.7	8.7
1	Cordless Phone	2.9	26	36.9	8	1.4	0.3	6.5
2	Cordless Phone/ Answering Device	1.5	24	19.7	8	0.5	0.1	2.9
3	Digital Camera	2.8	24	8.2	34	0.1	0.1	1.0
4	Mobile Phone	3.0	24	6.9	43	0.04	0.1	0.8

5.7.8.2 CSL 0—Baseline (UEC of 8.7 kWh/yr)

As mentioned above DOE did not tear down any products at the baseline CSL, due to a lack of product with this efficiency at the representative unit battery voltage and energy. For the later analyses (life-cycle cost and national impacts analyses), DOE therefore used the results from the manufacturer interview results for this CSL as the baseline unit.

Although manufacturers discussed the full range of efficiency for this product class, chargers at the baseline efficiency in practice are limited to infrequently charged applications used around the home, such as cordless telephones and handheld vacuum cleaners. The least efficient chargers in this class are slow, which makes them useful primarily for applications that are used infrequently and otherwise left for long periods in maintenance mode. Because they have to dissipate more heat, the less-efficient baseline chargers are also typically more bulky than chargers at higher CSLs, again relegating them to those same applications, which need not be portable.

The baseline charger typically consists of a trickle charger for a nickel battery. The power conversion is performed by a line-frequency transformer followed by a half-wave or bridge rectifier. The impedance of the transformer windings typically performs charge control.

As in the case of the inductive baseline unit, the slow charge rate results in large recombination losses in the battery. Active-mode efficiency (including the battery) can be as low as 10 percent, though typically varies between 30 and 60 percent. Maintenance mode power, due to the constant trickle current, is around 2 watts, while no-battery power—driven primarily by magnetization losses in the transformer—can be as high as 1 watt. This performance results in a unit energy consumption below 8.7 kWh.

5.7.8.3 CSL 1—Improved (UEC of 6.5 kWh/yr)

Disassembly of the CSL 1 unit for this product class revealed a line-frequency design (the baseline topology described by manufacturers), though with certain efficiency improvements, likely prompted by the mandatory EPS efficiency standards put in place by EISA 2007. For instance, the charger wall adapter uses higher-grade transformer steel, resulting in a particularly low no-load power (0.29 watts), which results in the equally low no-battery power listed in Table 5-53.

Furthermore, the rectifier is composed of four 1N5818 power Schottky diodes. With roughly half the forward voltage drop, and consequently half the losses, of conventional silicon diodes, these Schottkies contribute to the unit's improved efficiency in active mode, especially in relation to some of the units tested by Ecos Consulting in 2007. As no dedicated charge control components were found, the transformer inductor windings are assumed to perform this function.

As can be seen in Figure 5.54(b), the initial portion of the input power waveform during charge mode displays the decaying exponential characteristic typical of line-frequency slow chargers. This characteristic is due to the relationship between charger output current and battery voltage. In this type of charger, the current is proportional to the battery voltage per Eq. 5.2.

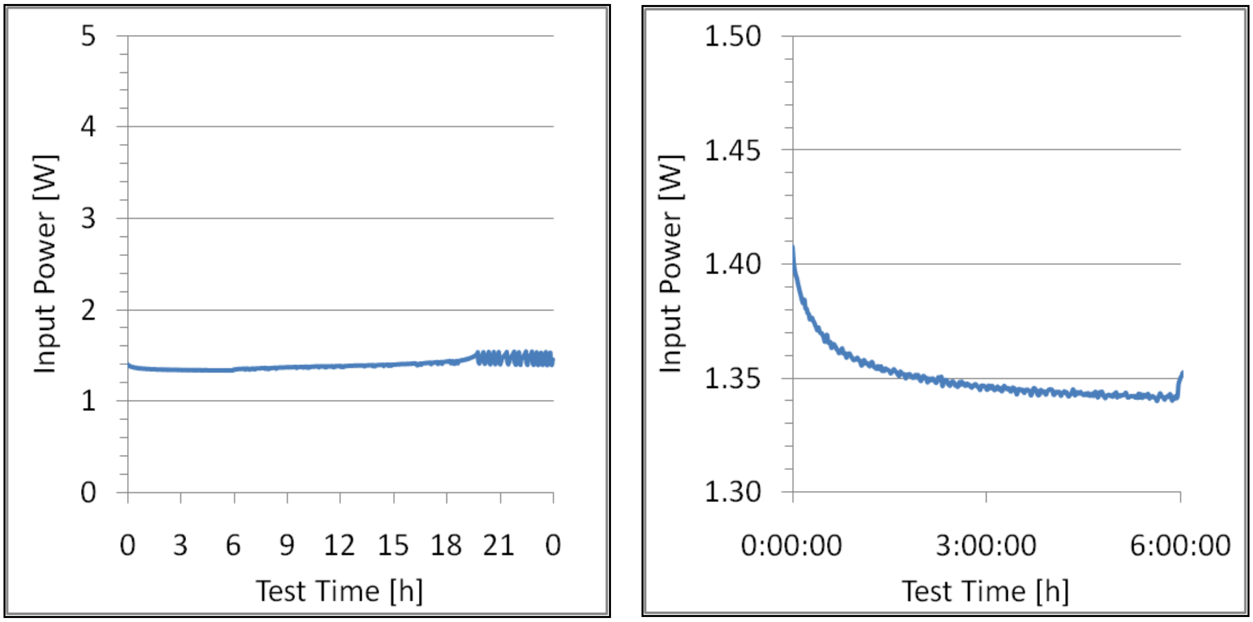
$$I = \frac{V_{OUT} - V_{BATT}}{R_{OUT}},$$

Eq. 5.2

Where:

I is the charge current;
V_{OUT} is the charger output voltage;
V_{BATT} is the battery voltage; and
R_{OUT} is the output impedance of the charger, typically due to the transformer windings, which performs charge control.

As the battery recharges, its voltage increases, decreasing the charge current and slowing the rate of charge, resulting in an exponential input power characteristic. Even though the input power for this charger is fairly low, the long charge time, and in particular the time spent at high state-of-charge, a shortcoming cited by manufacturers during interviews, contributes to the active mode losses in this charger.



(a) (b)

Figure 5.54 Input Power Waveform during Charge and Maintenance Modes

In Figure 5.54 the full 24-hour plot (a) shows some increased activity in maintenance, possibly associated with phone operation, while the six-hour fragment (b) shows the exponential characteristic typical of slow chargers.

5.7.8.4 CSL 2—Intermediate (UEC of 2.9 kWh/yr)

For product class 2, DOE originally had a large gap between the improved efficiency level and the best-in-market efficiency level. As a result, DOE added a CSL for an intermediate efficiency level. For this CSL, DOE evaluated two cordless phone units, which yielded an average UEC of 2.9 kWh/yr, which, consequently, is the CSL 2 limit for this product class. Their individual test results are shown in Table 5-53. These two units have a simple line frequency design as was seen in units that reached the CSL 1 efficiency level. In addition, the units evaluated have unregulated voltage and did not have an integrated circuit controller. The 60 Hz transformer in one of the cordless phones, was constructed with low-cost EI375 laminations. These units also have four Schottky diodes and a 2200 uF capacitor. A picture of the top and the bottom circuits of one of the units are given below in Figure 5.55. The input power consumed over the duration of the charge test is given in Figure 5.56.

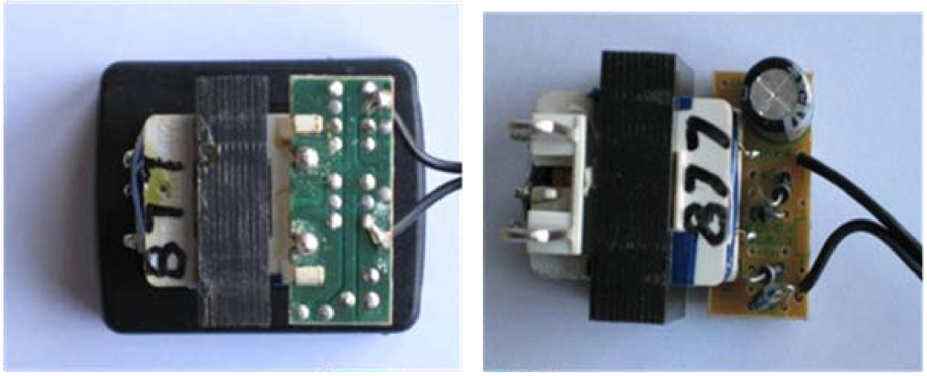


Figure 5.55 Top and Bottom of a Cordless Phone Charger Circuit

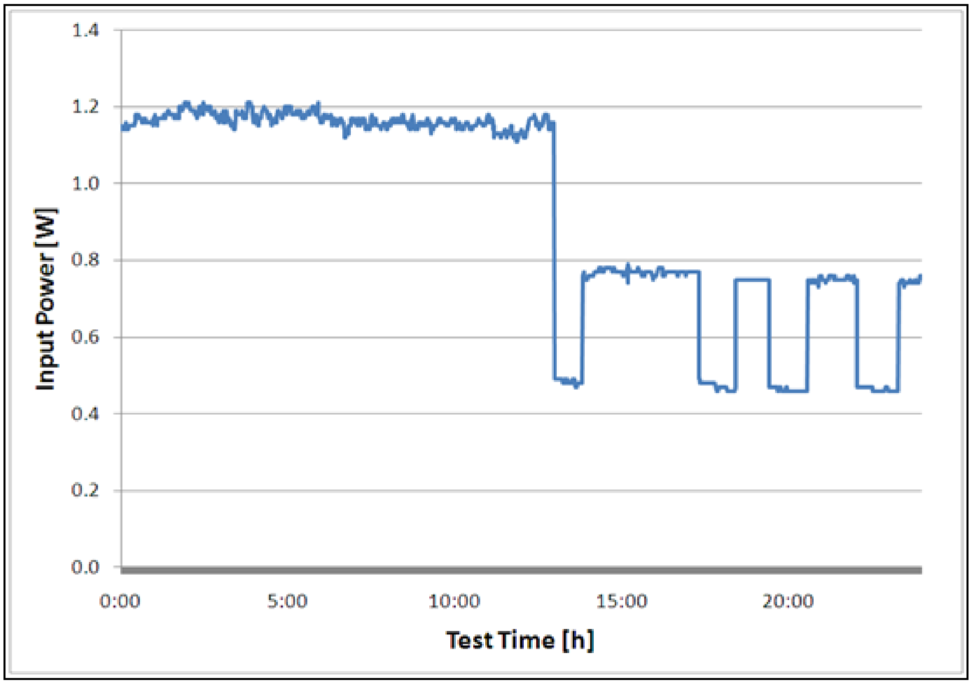


Figure 5.56 Input Power Waveform during Charge and Maintenance Modes

This unit could be further designed for better performance, with better core material to reduce no-load power consumption. In addition two diodes would be adequate instead of four, if a center-tapped secondary winding is used, and hence reducing its diode losses and costs.

5.7.8.5 CSL 3—Best-in-Market (UEC of 1 kWh/yr)

To decrease the energy consumption of the intermediate unit, a manufacturer needs to move to a switched-mode power supply, which is one of the efficiency improvements in the digital camera chargers at CSL 3, the performance of which is detailed in Table 5-53.

The two digital cameras differ both in physical form and internal construction. The first charger listed in Table 5-53, which is slightly less efficient, charges an internal lithium-ion battery and is therefore composed of two enclosures connected by a USB cable—a wall adapter and additional electronics inside the camera body. The more efficient unit charges an external lithium-ion battery, and has both power supply and charge control circuitry integrated into a single enclosure that plugs directly into mains. The best-in-market CSL can therefore be met by chargers for both external as well as internal batteries, cable losses notwithstanding. Furthermore, the CSL can also be met by chargers for other applications—one of the other units at CSL 3 torn down by DOE was a video game charger, though that particular unit has been excluded from the analysis because a microcontroller that was used for both battery charging and other functions inflated its cost past the point where it was comparable to the other chargers.

An interesting difference between the two camera chargers lies in their choice of power supply topology. As can be seen in Figure 5.57, the switched-mode power supply for the slightly-less efficient charger does not have an integrated controller (IC), relying instead on a ringing-choke converter (RCC) topology, which nonetheless manages to achieve an active mode efficiency of 75 percent when tested according to the EPS test procedure. The power converter circuit of the other charger features a flyback design; its efficiency independent of the battery is unknown because of the inability of the EPS test procedure to test chargers that connect directly to an external battery.

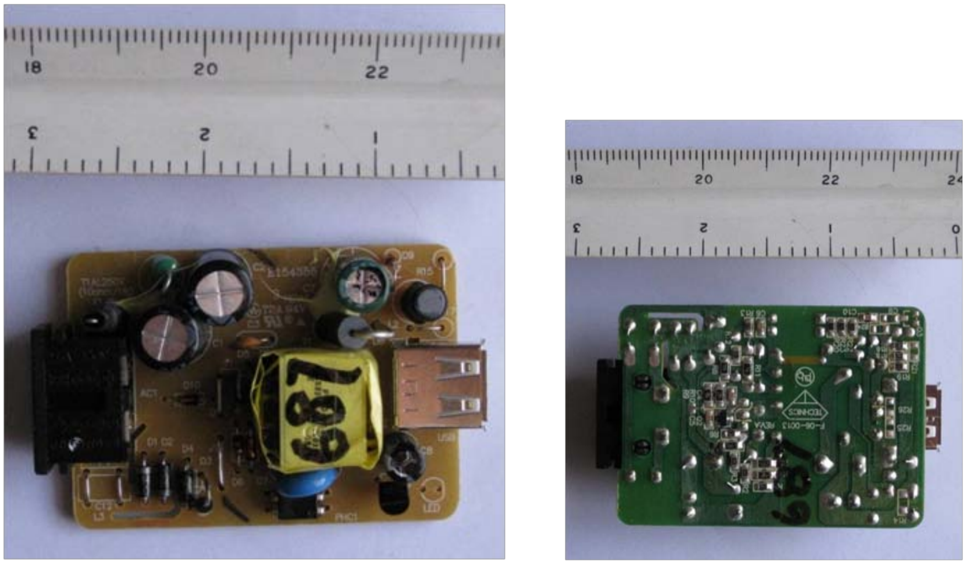


Figure 5.57 Top and Bottom of a Camera Charger

*Note the lack of any integrated circuit controller.

As can be expected, both chargers have additional circuitry beyond the power supply because of the sensitive nature of lithium-ion batteries. In particular, lithium battery charging requires a microcontroller or dedicated charge-management IC, as can be seen in Figure 5.58, increasing the charger’s cost. Nonetheless, these charge management ICs are necessary to provide not only safety, but also low energy consumption during maintenance and no-battery modes expected of best-in-market BCs.

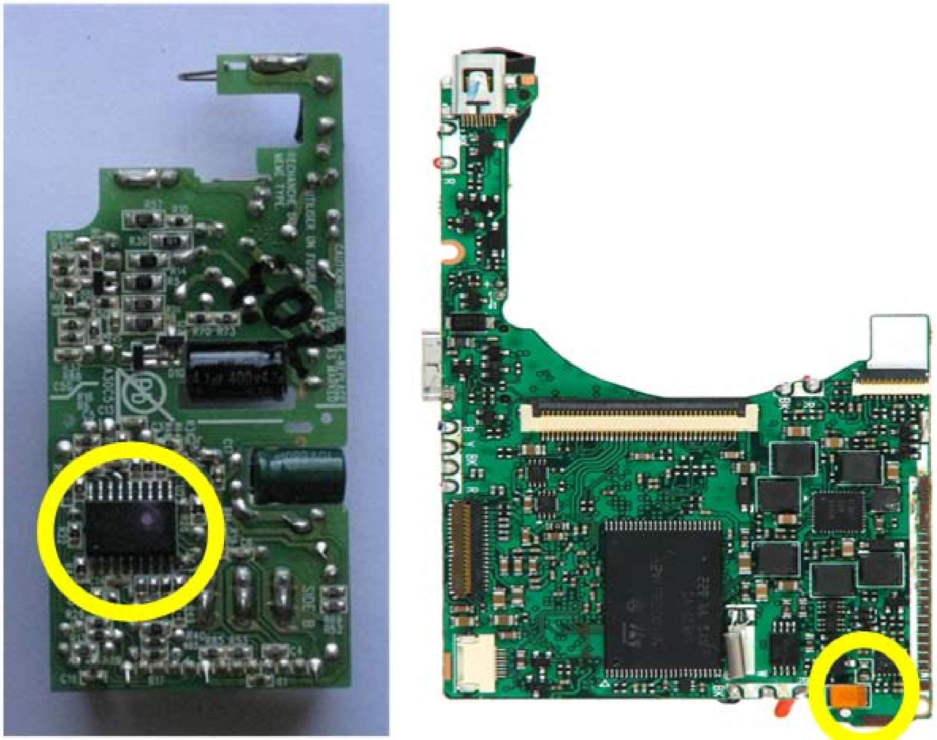


Figure 5.58 PCBs of Digital Camera Chargers meeting CSL 3

*Note the highlighted microcontroller in a black 14-pin surface-mount package in the left photograph. Similar functionality is provided in the other charger by the dedicated charger IC highlighted at the right.

In particular, the charge and maintenance waveforms for the two camera chargers are pictured in Figure 5.59 and Figure 5.60, below. As can be seen, the maintenance mode power is approximately 0.1 watts for both chargers. This is likely accomplished through a combination of minimal no-load/low-load losses in the wall adapters and effective power management in the end-use application using the ICs mentioned previously.

Finally, the no-battery power for the best-in-market chargers is also approximately 0.1 watts. Since no-battery power is in many cases analogous to EPS no-load power,[h] the two can be compared, and based on the responses obtained during the EPS manufacturer interviews (summarized in section 5.4 specifically5.4.8), these power levels are near the theoretical minimum achievable with today's technology.

---

[h] In many cases, such as all integral-battery products powered by wall adapters, the two are equivalent.

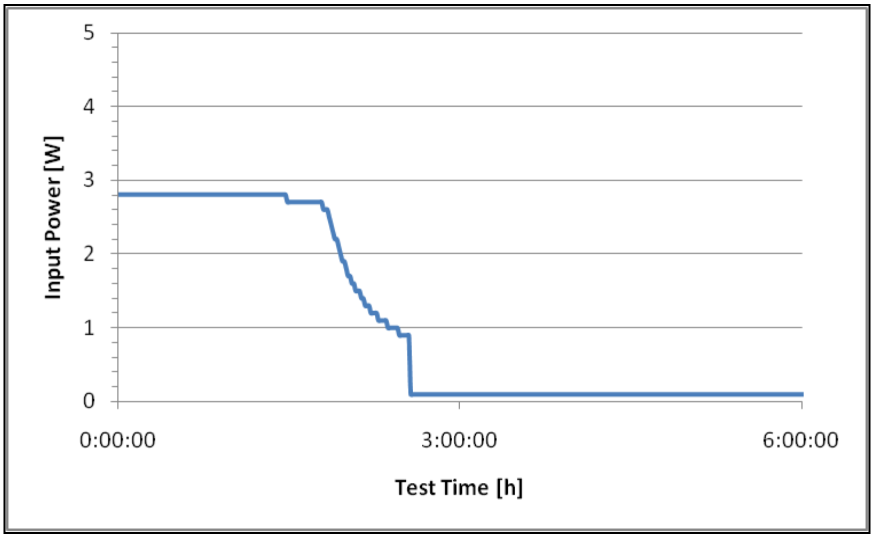


Figure 5.59 Input Power Waveform during Charge and Maintenance Modes for a Digital Camera Charger

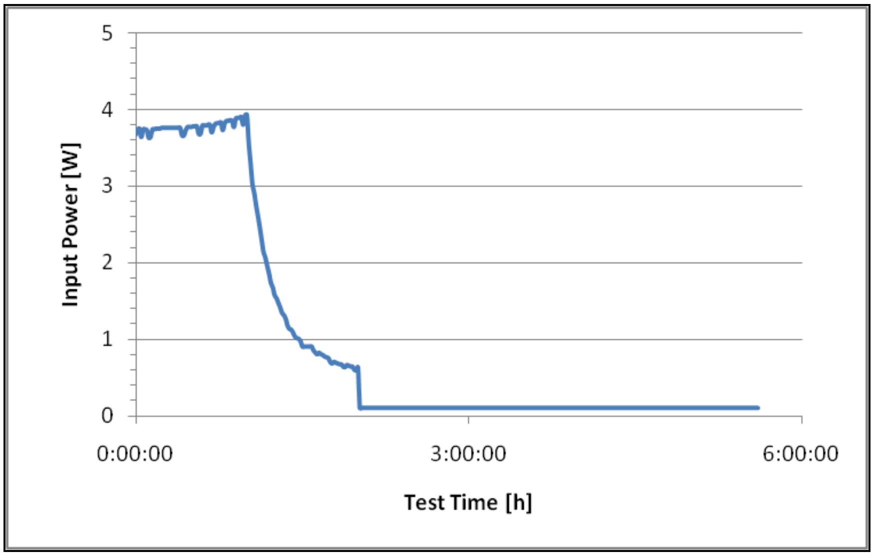


Figure 5.60 Input Power Waveform during Charge and Maintenance Modes for a more Efficient Digital Camera Charger

DOE obtained average performance parameters of the two units that were evaluated for this CSL and the UEC calculated is 1 kWh/yr.

5.7.8.6 CSL 4—Max-Tech (UEC of 0.8 kWh/yr)

Finally, DOE estimated the efficiency of a unit that is designed with the maximum technology feasible. These units are not commercially available due to their high manufacturing cost. Therefore, an independent estimate of the efficiency of a max-tech unit was achieved by DOE through extrapolation from its analysis of the best-in-market (CSL 3) unit by estimating the impacts of adding any remaining energy efficiency design improvements with the consultation of DOE’s subject matter experts.

For product class 2, the max-tech level can be achieved by making further improvements to the best-in-market units. One way of enhancing the design is by improving the transformer to reduce the leakage inductance. Another way is to use a lossless snubber that diverts transients back into the input filter to be reused. These methods would improve the charge efficiency by 5 – 10 percent. In addition, using a skip-mode control could reduce the no-battery power. Skip mode control is a method that forces the power switch to periodically stop for a number of cycles when the output load is disconnected or very low. Performance parameters of the max-tech design using the above mentioned improvements and the calculated UEC are given in Table 5-53. The MSP for the max-tech level is achieved by adding the cost of the additional components required to make the aforementioned efficiency improvement to the CSL 3 MSP.

5.7.8.7 Estimate of Manufacturer Selling Price

The MSPs derived from teardowns are pictured in Figure 5.61 and detailed in Table 5-54 for each CSL. The MSPs correspond to the MSP of the units that were torn down. When DOE analyzed more than one unit for a CSL, the results of the teardown analysis were averaged to give one MSP. No unit meeting the baseline CSL was torn down and hence, the manufacturer MSP was obtained by aggregating the costs provided by manufacturers. Additionally, DOE normalized its teardown results to align with this aggregated manufacturer data point. Figure 5.61 shows the product class 2 cost-efficiency curve and Table 5-54 shows the detailed UEC and MSP results.

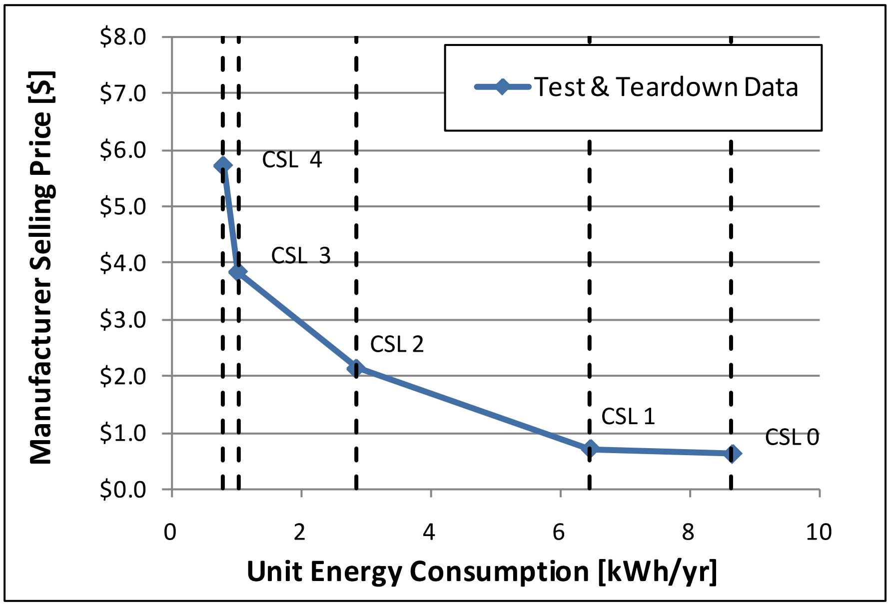


Figure 5.61 MSP vs. UEC for Product Class 2

Table 5-54 CSL Description for Product Class 2

CSL	UEC *kWh/yr*	MSP from Teardowns *$*
0	8.7	0.62
1	6.5	0.71
2	2.9	2.13
3	1.0	3.84
4	0.8	5.72

5.7.9 Product Class 3: Low Energy, Medium Voltage (Test and Teardown Data)

The low energy, medium voltage product class includes BCs for batteries between 4 and 10 volts and below 100 Wh of battery energy. It spans the gap between the low energy, low voltage and low energy, high voltage product classes (*i.e.*, BC product classes 2 and 4). The applications in this product class are fairly similar to those in the other two product classes, and include: power tools, handheld vacuum cleaners, two-way radios, digital cameras, digital camcorders and portable DVD players. The BC designs are also similar to that of the other two product classes, consisting of multi-cell nickel chargers (both fast and slow) and fast lithium-ion chargers.

The lithium-ion batteries used with chargers in this product class are multi-cell, like those in product class 4. However, evaluations of some portable DVD players revealed none of the complexities common to the design of the higher-voltage notebook computer batteries; rather, they were more similar to the single-cell lithium-ion batteries for cellular phones and portable media players. Additionally, the most efficient BCs in the market for portable DVD players can achieve an energy consumption as low as some of the low energy, low voltage units.

5.7.9.1 Units Analyzed

For this product class, DOE tested 17 units in a range of applications and sizes. DOE tested units with a battery energy as small as 2.2 Wh and as large as 33 Wh. The resulting UECs DOE found for these products are plotted versus battery energy in Figure 5-60 below. The figure also includes the results of tests conducted by Ecos Consulting. From these test results, DOE selected four units for further analysis based on their measured energy consumption, which is detailed along with other pertinent performance data in Table 5-55. These units were selected to span a wide range of efficiencies available in the market.

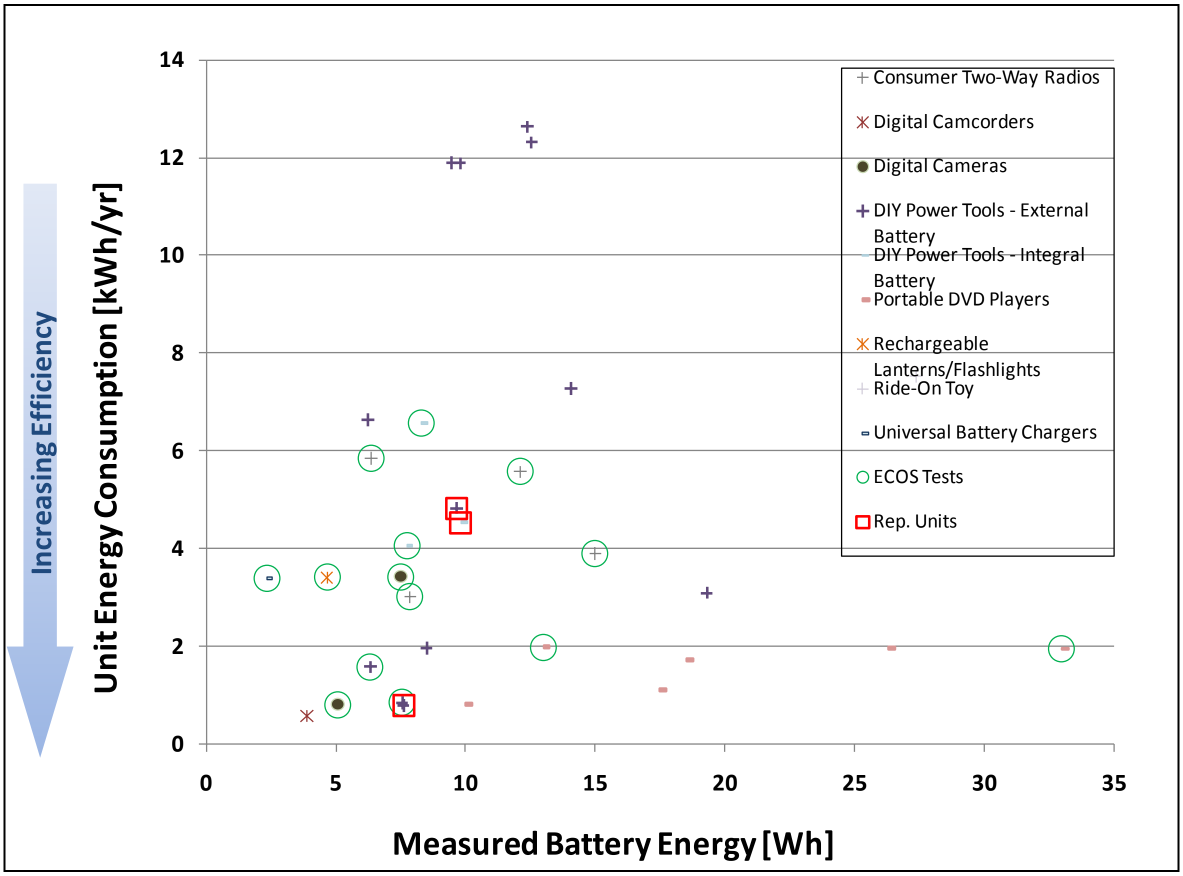


Figure 5.62 Test Results for Product Class 3: Low Energy, Medium Voltage

As can be seen from the graph above, the majority of the products tested in this product class have a measured battery energy in the range of 5 to 15 Wh. DOE focused its analysis on units at approximately 10 Wh to make its analysis applicable to the widest range of BCs in this class.

Table 5-55 Manufacturer Performance Data for Product Class 3 Representative Unit

CSL	Application	Battery Energy *Wh*	Charge Test Duration *h*	24-Hour Energy *Wh*	24 Hour Energy Efficiency *%*	Maint. Power *W*	No-Battery Power *W*	UEC *kWh/yr*
0	Power Tool	9.5	24	123.0	8%	4.5	3.5	11.9
1	Power Tool	9.7	24	53.6	18%	1.8	1.0	4.68
2	Power Tool	7.6	24	17.0	45%	0.3	0.2	0.8
3	Power Tool	7.6	24	15.9	48%	0.3	0.2	0.7

5.7.9.2 CSL 0—Baseline (UEC of 11.9 kWh/yr)

At the baseline efficiency level, DOE tested a BC that was designed to charge NiCd batteries. An in-depth technical evaluation revealed that the charger was designed with a switch-mode power converter. Instead of the commonly used pulse width modulation found in most switch mode converters, this charger uses a fixed pulse width and modulates the pulse frequency to control output current. Further examination showed that the charging pulse is constant with a 150 V amplitude with a 4 microsecond width. The pulse is filtered by an inductor, a clamp diode, and a small film capacitor for application to the battery.

It was also observed that at maximum charging current of 1.4A, the switching frequency was 15.8 kHz. As the battery approaches the maximum charge voltage, the frequency lowers which can be an efficient approach to charging. However, because the rectified line voltage is quite high the losses are also relatively high. These loses are constant and become more significant when the battery approaches full charge. Additionally, regardless of charging current the internal operating losses are significant, which manifests in the poor rating for 24-hour energy and maintenance mode power. This can be observed in Figure 5.63 below, which illustrates how input power fluctuates during a 24-hour charge test of this product.

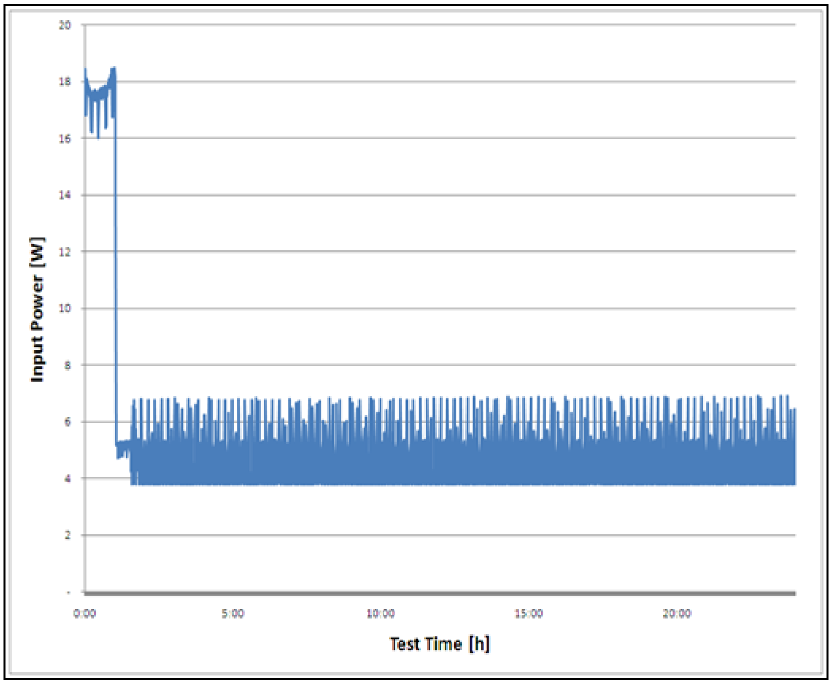


Figure 5.63 Input Power Waveform during the Charge Test of a Power Tool

One final observation about this unit is that the charger is physically configured to prevent user contact with the output terminals, which means there is no need for a safety isolation transformer. Usually, such a transformer can provide a high efficiency method to obtain lower voltages required for internal controls, however to avoid the relatively highexpense of the transformer, this charger uses shunt regulators and power resistors to drop the voltages to the necessary levels.

5.7.9.3 CSL 1—Improved (UEC of 4.7 kWh/yr)

For this product class, DOE tested two units at CSL 1 that demonstrated similar performance and unit energy consumptions less than 5 kWh/yr. DOE's evaluation of one of the units showed that it uses a high frequency switch mode control; however the transformer was a 60 Hz line frequency unit. The transformer is a split bobbin unit that provides isolation from the power line and conforms to the insulation and spacing required by safety regulations. The low frequency transformer that is found in this unit is larger and heavier than a high frequency device of the same rating. Measurements on the transformer alone showed a power loss of 2.4 watts. This unit keeps the transformer connected to the input power at all times; therefore, the transformer input current directly affects the standby losses. The internal converter circuits shut down when the power tool's battery is not being charged. Consequently standby and maintenance mode losses are the excitation losses of the transformer. Maintenance mode and standby mode power were both greatly reduced relative to performance of the CSL 0 unit. Additional losses were measured in the DC converter and in the control. These losses result from the input rectifiers, the switching power transistor conduction loss, a clamp diode, an output blocking diode and the switching losses. The combination of the design characteristics used for this device also caused the 24-hour energy to be significantly improved (*i.e.* lowered).

DOE analyzed two units at this efficiency level and considers them comparable units with comparable performance and utility. Therefore, to generate a UEC (and a cost) at this CSL for this product class, DOE averaged the two devices' performance characteristics and calculated a corresponding UEC.

5.7.9.4 CSL 2— Best-in-Market (UEC of 0.8 kWh/yr)

The unit evaluated for CSL 2 was a power tool operated with lithium-ion batteries. There was no charge control or discharge control electronics in the battery assembly. The charger was found to have a lot of electronics on the secondary side of the power converter. These regulate charging current, monitor battery temperature and terminate charging when the battery is charged. Consequently, performance in maintenance and standby modes is improved relative to CSL 1; the maintenance mode power and standby mode power measured for this unit were 0.26 W and 0.20 W, respectively.

The design also utilizes a flyback transformer in a switched mode power supply that is operated by an integrated circuit at 100 kHz. The device appeared to charge its battery quickly and entered maintenance mode, which was lower relative to the previous designs because of the lithium-ion battery being maintained. These changes caused 24-hour energy to be significantly improved again, as is demonstrated by the jump from 19 percent to 45 percent in 24-hour efficiency (measured battery energy divided by 24-hour energy).

5.7.9.5 CSL 3— Max-Tech (UEC of 0.7 kWh/yr)

Finally, for product class 3 DOE estimated the efficiency of a unit that is designed with the maximum feasible technology. These units are not commercially available due to their high manufacturing cost. Therefore, an independent estimate of the efficiency of a max-tech unit was achieved by DOE through extrapolation from its analysis of the best-in-market (CSL 2) unit by estimating the impacts of adding any remaining energy efficiency design improvements with the consultation of DOE's subject matter experts.

DOE developed its max-tech efficiency level for this product class based on the unit tested at the best-in-market level. By improving voltage transients, reducing the voltage stresses in the unit and by eliminating the leakage inductance transients, the active energy consumption could be reduced by 10%. This could be done by adding a second power switch, which creates a two transistor forward converter and by substituting in Schottky diodes for rectification. These suggested technological improvements would lead to a unit energy consumption of less than 0.7 kWh at the max-tech efficiency level.

5.7.9.6 Estimate of Manufacturer Selling Price

The MSPs derived from teardowns are pictured in Figure 5.64 and detailed in Table 5-56 for each CSL. The teardown MSPs correspond to the MSP of the units that were torn down; where more than one unit was analyzed, DOE used the average MSP found to describe the CSL. No unit at the baseline CSL was torn down, so the manufacturer MSP was obtained by aggregating the costs provided by manufacturers.

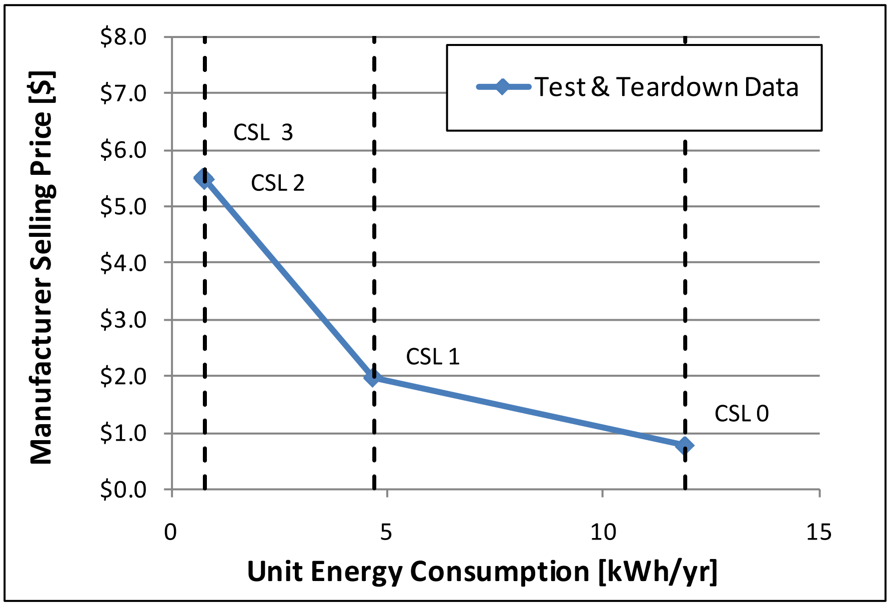


Figure 5.64 MSP vs. UEC for Product Class 3

Table 5-56 CSL Descriptions for Product Class 3

CSL	UEC *kWh/yr*	MSP from Teardowns *$*
0	11.9	0.77
1	4.7	1.98
2	0.8	5.47
3	0.7	5.51

5.7.10 Product Class 4: Low Energy, High Voltage (Test and Teardown Data)

The low-energy, high-voltage product class includes BCs for batteries from 10 to 48 volts and less than 100 Wh, in particular the majority of these BCs are used with notebook computers, power tools, hedge and weed trimmers, and handheld vacuums. The notebook computer BCs tend to cluster around 11 volts and 20 to 55 Wh, while the remaining applications tend to span the voltage range between 10.8 and 24 volts, though with lower battery energies.

The battery voltage and energy for all the applications in this product class, obtained from the market survey, are illustrated in Figure 5.65.

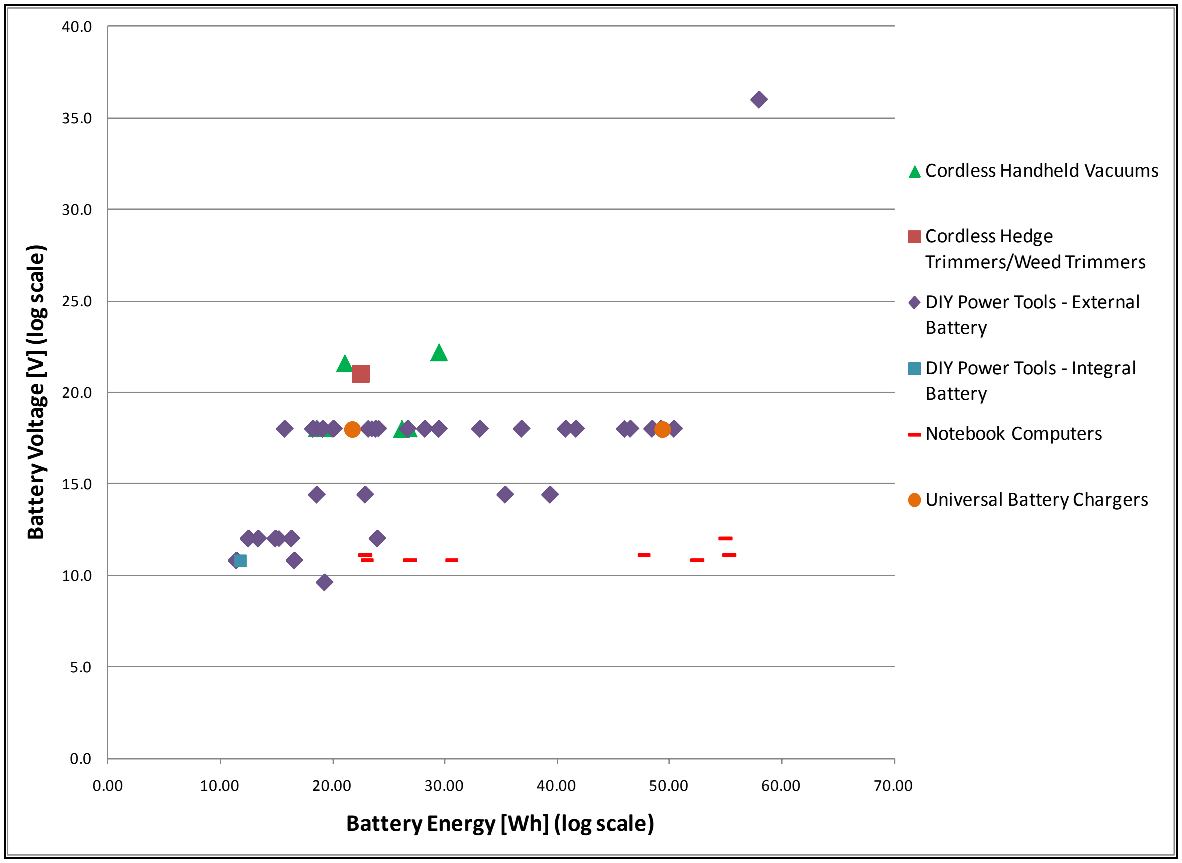


Figure 5.65 Typical BC Characteristics of Product Class 4 Devices

To ensure an analysis appropriate for all of the applications in this product class, DOE chose as its representative unit a BC with a 12 volt 20 Wh battery, which falls in the overlap of the notebook computer and power tool ranges discussed above. The limited overlap between the major applications in this product class made it difficult for DOE to test BCs from both applications with the same battery voltage and energy. However, even though the characteristics of the BCs tested during this analysis differed somewhat from the representative unit and each other, these variations are small compared to the differences in efficiency.

5.7.10.1 Units Analyzed

DOE tested 31 units for this product class; their unit energy consumption, assuming an average usage profile, is pictured in Figure 5.66. For comparison, the figure also includes the results of tests conducted by Ecos Consulting. Of these, DOE chose five units for further evaluation and teardowns based on their test results and internal design. Detailed information regarding the measured performance of these five units is presented in Table 5-57.

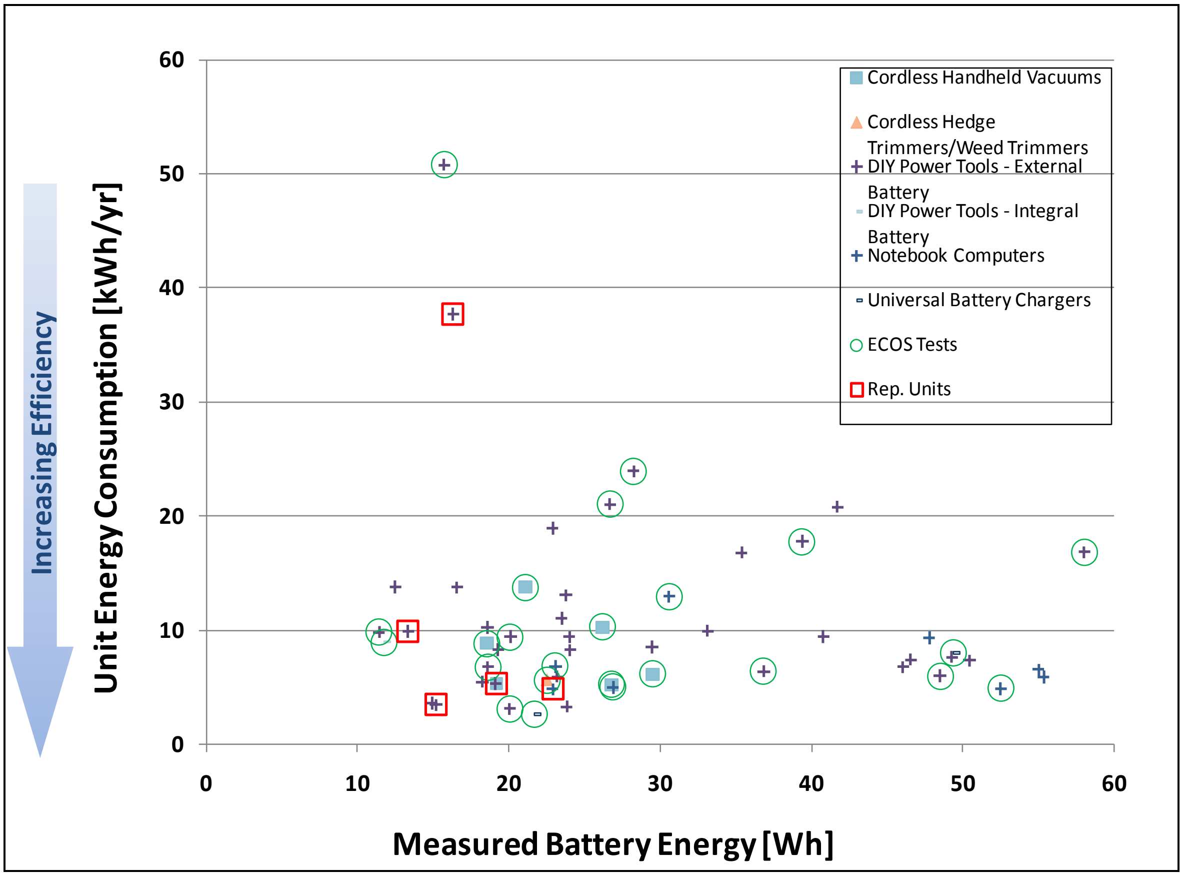


Figure 5.66 Test Results for Product Class 4: Low Energy, High Voltage

Table 5-57 Manufacturer Performance Data for Product Class 4 Representative Unit

CSL	Application	Battery Energy *Wh*	Charge Test Duration *h*	24-Hour Energy *Wh*	24-Hour Energy Efficiency *%*	Maint. Power *W*	No-Battery Power *W*	UEC *kWh/ yr*
0	Power Tool	16.3	24	167.5	10	5.9	2.2	37.7
1	Power Tool	13.4	24	52.6	25	1.4	1.4	9.9
2	Cordless Handheld Vacuum/ Notebook/ Power Tool	19.1	24	39.1	49	.5	0.3	4.6
3	Power Tool	14.9	24	27.2	55	0.4	0.3	3.0

As can be seen in Figure 5.66, BCs tested at the representative-unit battery energy and voltage were used to establish the CSLs for the low-energy, high-voltage product class. Three BCs of comparable energy consumption were used as the basis for CSL 2 to make this analysis applicable to the major applications in this product class.

Three BCs in Table 5-57 are standalone chargers for DIY power tools with external batteries. They consist of a single enclosure that contains the power conversion and charging circuitry and have a “cup” that holds the battery during charging. One or two charge indicator LEDs are also present. The chargers are powered through a non-detachable AC line cord.

A fourth BC, intended for notebook computer applications resides in two enclosures. One is a wall adapter with a detachable AC line cord, while the other is the notebook computer itself, containing an integral battery. The wall adapter performs the AC/DC conversion, outputting regulated 20 volts DC, while the charge control and battery monitoring is performed by circuits located on the computer motherboard, as shown in Figure 5.67.

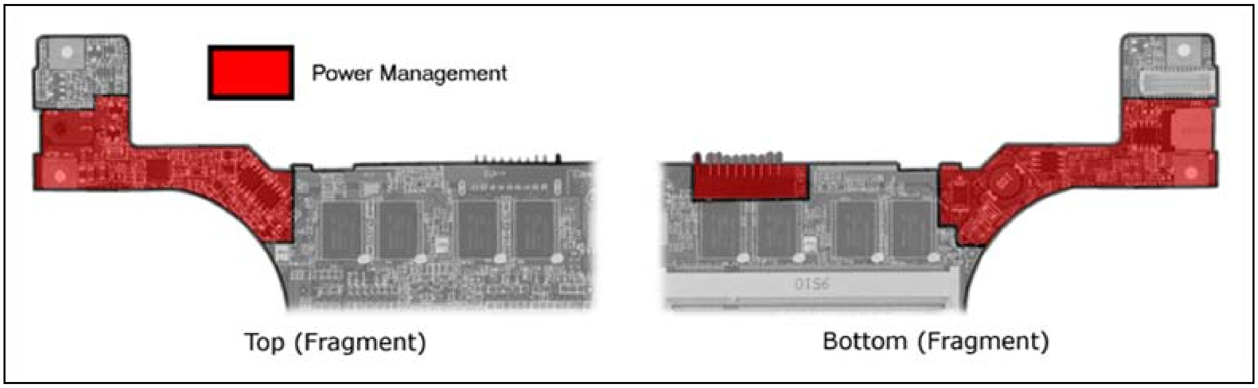


Figure 5.67 Top and Bottom of the Motherboard of a Notebook Computer

Despite their slightly different constructions, the BCs provide comparable utility. Each has an output power between 36 and 47 watts, and while the AC/DC converters of the power tool chargers must convert to a lower voltage than that for the notebook computer (approximately 12 volts versus 20 volts), the latter must perform two-stage voltage conversion (from 120 volts AC to 20 volts DC to 12.3 volts DC). Lower output voltages and successive conversions decrease the conversion efficiency, which impacts the energy consumed in active mode. Because DOE’s analysis focused on these real-world BCs, it is applicable to a wide-range of BCs in this product class, regardless of their physical construction or inefficiencies due to the requirements of the end-use application.

5.7.10.2 CSL 0—Baseline (UEC of 37.7 kWh/yr)

DOE chose a 12 volt BC with a measured battery energy of 16.3 Wh and unit energy consumption of 37.7 kWh as its baseline unit for this product class. The energy consumption of this unit was the highest of all the 12 volt units that DOE tested and exceeded the energy consumption of the majority of BCs in this product class, regardless of battery voltage and energy.

The baseline unit charges nickel-cadmium batteries for power tool use. Its design consists of a flyback converter with some additional circuitry to control the charging of the battery. For example, in contrast to AC/DC converters that serve as voltage sources (*e.g.*, EPSs), the baseline BC unit has two optocouplers. As in an EPS, the first is likely intended to send feedback signals related to the output voltage from the secondary to the primary sides of the power converter, while the second likely controls the charging current.

As can be seen in Table 5-57, the baseline unit has a low 24-hour energy efficiency (approximately 10 percent), calculated by dividing the battery discharge energy by the energy consumed by the charger over a 24-hour charge and maintenance cycle. However, this low performance is not due to low power conversion efficiency in the AC/DC converter. In fact, if one examines only the initial portion of the 24-hour test, when the battery is actively charging, up to the point where the charger enters maintenance mode, the charger energy consumption is only 29 Wh, for an active-only battery charging system efficiency of:

$$\eta_{ACTIVE} = \frac{E_{BATT}}{E_{ACTIVE}} \frac{16.3Wh}{29\,W\mathrm{h}} = 56.2 \text{ percent}$$

Eq. 5.3

Where:

η_{ACTIVE} is the active-only efficiency;

E_{BATT} is the energy recovered from the battery during discharge; and

E_{ACTIVE} is the energy consumed by the charger during active mode, as defined through the examination of the input power measurements presented in Figure 5.66.

The inefficiency, therefore, occurs in maintenance mode. Because the charge time for this BC is only 0.6 hours, the high input power in maintenance mode (almost 6 watts) dominates the 24-hour combined charge and maintenance efficiency. This high energy consumption is not due to overhead losses in the charger, but rather to an inefficient maintenance strategy, which uses high-current pulses to periodically “top off” the battery. While topping off the battery may be beneficial over the long run, it should not be implemented immediately after the battery has finished charging.

As can be seen in Figure 5.68, the input power of the baseline unit following the full charge is periodic in time, with each of the spikes in the figure lasting approximately 2 minutes, consuming an additional 1.1 Wh and delivering a significant portion of that energy to the battery after it has already been fully charged. Not only does this result in inefficient operation, but the resulting elevated temperature also decreases battery lifetime.

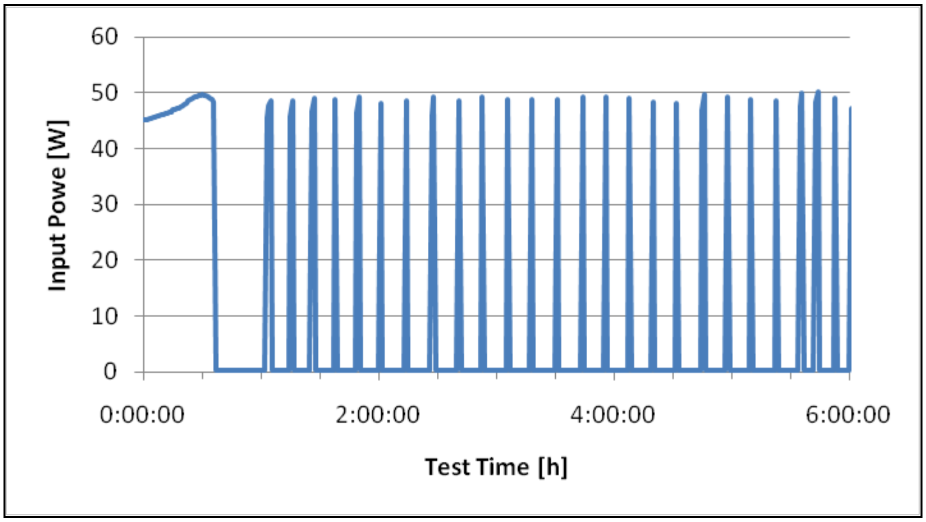


Figure 5.68 Input Power of the Baseline Unit During Charging and Maintenance Modes

The overall efficiency of the baseline unit is further compromised by the choice of components. None are optimized for energy efficiency. For example, the design relies on standard *pn*-junction diodes for output rectification, while the switching is performed by a generic UC3842-series PWM controller, which draws up to 17 milliamperes with a supply voltage above 10 volts DC and a frequency in the 50 kilohertz range. In sum, the baseline unit has a unit energy consumption of 37.7 kWh.

5.7.10.3 CSL 1—Improved (UEC of 9.9 kWh/yr)

The BC unit associated with CSL 1 is also a fast power tool charger. It also charges a 12 volt battery and when said battery was discharged, it measured at 13.4 Wh. In contrast to the baseline unit, the CSL 1 unit does not continue to charge the battery while in maintenance mode. For this design, a lithium-ion battery was used which will not tolerate overcharging.[i] Instead, as can be seen in Figure 5.69, the input power to the unit drops to 1.4 watts. As can be seen in Table 5-57, this is also the input power to the unit in no-battery mode, when the battery is removed from the charger. Since the BC draws the same power whether or not the battery is present, this indicates that maintenance mode power is already as low as possible. Further improvements can only be made by focusing on the overhead power dissipation of the electronics, such as the on-board microcontroller, op-amp, voltage reference, etc., which impact both no-battery and maintenance modes.

---

[i] Unlike nickel-based batteries, lithium-ion batteries cannot tolerate overcharge so lithium-ion chargers must terminate following full charge.

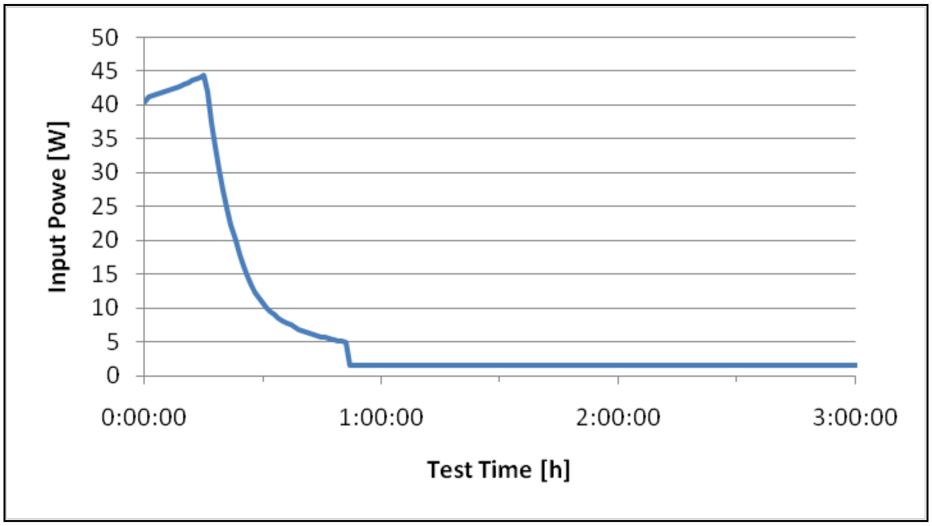


Figure 5.69 Input Power Waveform during Charge and Maintenance Modes

The conversion efficiency of this BC is also improved over the baseline unit. Unlike the baseline, the CSL 1 unit uses a Schottky diode for rectification, which has a lower voltage drop, resulting in lower power dissipation during charging and higher active mode efficiency. Nonetheless, the design evaluated for CSL 1 continues to use UC3842-series PWM controller to drive the switching FET. As mentioned previously, the high supply current requirements of this controller limit the maximum active mode efficiency and minimum maintenance and no-battery power.

5.7.10.4 CSL 2—Best-in-Market (UEC of 4.6 kWh/yr)

As mentioned previously, DOE identified three units that exhibited a unit energy consumption superior to all other BCs tested in this product class. These units demonstrate that this level of energy consumption is commercially achievable for both power tools and notebook computers, the two major applications in this product class. Because of their lithium-ion batteries, these BCs must use efficient maintenance-mode strategies that minimize current to the battery after it has reached its fully charged state.

In the case of the power tool charger, these electronics are fairly efficient and include a Schottky diode for rectification, reducing energy consumption during power conversion associated with charging. The BC also features a more efficient PWM controller, which integrates the controller and FET into a single package with a maximum supply current of 1.3 to 2.0 milliamperes, depending on the switching frequency. This is an order of magnitude less than that of the controller in the baseline and CSL 1 units.

The design of the BC for notebook computer applications demonstrates alternate methods of reaching CSL 2 and maintaining energy consumption below 4.9 kWh per year. Unlike the power tool chargers examined earlier, this BC features a two-stage architecture, with an external power supply with an industry-standard regulated 20 volt DC output, followed by a battery charger embedded inside the application.

The EPS uses Schottky diodes for rectification, resulting in lower forward voltage drops across the rectifier and higher conversion efficiency in active mode. The EPS also features a more efficient PWM controller for driving the switching FET, with a maximum supply current of 1.2 to 2.0 milliamperes, depending on the switching frequency.

The charger portion of the BC internal to the notebook computer uses a dedicated integrated circuit (IC) for charge control. This IC consists of a DC/DC buck converter, which reduces the 20 volt input from the EPS to a lower voltage suitable for the 11.1 volt lithium-ion battery, while monitoring the current and voltage to the battery to ensure safe charging.

Although a two-stage architecture typically introduces further losses into a battery charging system,[j] these are lowered by using a switched-mode second stage. Synchronous rectification used on the output of this second stage makes it even more efficient and puts this BC on par with the best-in-market single-stage BC. Nonetheless, a two-stage solution does offer some benefits. As can be seen in Table 5-57, the input power during no-battery mode is six times less than that during maintenance mode.

This is not due to any detection of the presence of the battery (another design option), but is simply achieved by disconnecting the entire second stage together with the battery. Because the notebook computer has an integral battery, a user does not remove it from the application for recharging; rather, the user connects the entire application—the computer, the battery, and the second-stage battery charging electronics—to the EPS. In no-battery mode, the inverse is true, with the notebook computer disconnected and the EPS the only part of the product connected to the AC line. Therefore, the second stage and other potential sources of loss from the computer power-management circuitry are no longer present, decreasing the input power compared to that in maintenance mode. Such a strategy could have broader applicability beyond notebook computers, as additional electronics continue to be packaged with detachable batteries for such applications as power tools, and was in fact called out by manufacturers during interviews as a possible efficiency design option.

DOE obtained average performance parameters of the three units that tested at this CSL and the consequent UEC calculated for this efficiency level is based on their average performance parameters. Accordingly, the calculated UEC for this CSL is 4.6 kWh/yr.

5.7.10.5 CSL 3—Max-Tech (UEC of 3.0 kWh/yr)

Finally, for product class 4, DOE estimated the cost and efficiency of the maximum technologically feasible design. To do so, an independent estimate of the efficiency of a max-tech unit was achieved by DOE through extrapolation from its analysis of the best-in-market (CSL 2) unit by estimating the impacts of adding any remaining energy efficiency design improvements. DOE consulted its subject matter experts in developing the max-tech design improvements and the resulting MSP.

The max-tech design for product class 4 is a lithium-ion battery charger with a switch-mode power supply. A switch-mode power supply can usually be divided into four parts, the AC

---

[j] The efficiencies of each stage are multiplied together to arrive at the system-efficiency, such that two 90-percent-efficient stages will result in a system with only 81 percent efficiency.

line input circuits, rectifiers, and DC filters; the power switching circuits; the output power rectifier and filter; and the control circuits.

For this design the main improvement to the AC line circuits can be achieved by using low ESR (Equivalent Series Resistance) filter capacitors. For the power switching circuits it is best to use a half-bridge converter that uses two switching transistors that operate at low stress levels allowing the use of lower loss power transistors. A redesigned transformer would also be necessary, but will result in lower losses due to better core usage and the windings will have less high frequency losses. Synchronous rectifiers using low loss MOSFETS will be used in the output rectifier filter. Finally, the Power Integrations TOP255EN can be used for the power switch control, in the control circuits portion of the BC.

By improving the design of the best-in-market performance, the max-tech unit would bring down both the maintenance mode power and no-battery mode power to 0.4 W. Additionally this new design would improve the 24-hour energy efficiency to 55% and result in a unit energy consumption of 3.0 kWh/yr.

5.7.10.6 Estimate of Bill-of-Materials Costs

iSuppli, a DOE contractor, tore down the five BCs corresponding to CSL 0–CSL 2 for this product class. iSuppli estimated the manufacturing costs (*i.e.*, the materials, assembly, and test costs) of the components related to battery charging. For example, in the case of the notebook computer at CSL 2, iSuppli only evaluated the circuitry related to battery charging and supplying power to the battery charger, including battery charging components mounted to the computer motherboard.

Figure 5.70 shows the test and teardown cost-efficiency curves for this product class. To construct the teardown curve, DOE took the cost and efficiency of the two units at CSL 0 and CSL 1 directly. To accommodate any remaining differences in cost between power tool, notebook computer BCs and other potential applications, DOE averaged the cost of the three most efficient units to arrive at a CSL 2 cost representative of many applications. Similarly, to arrive at the final efficiency point for CSL 2, DOE averaged the three UECs calculated. These data are also presented in Table 5-58.

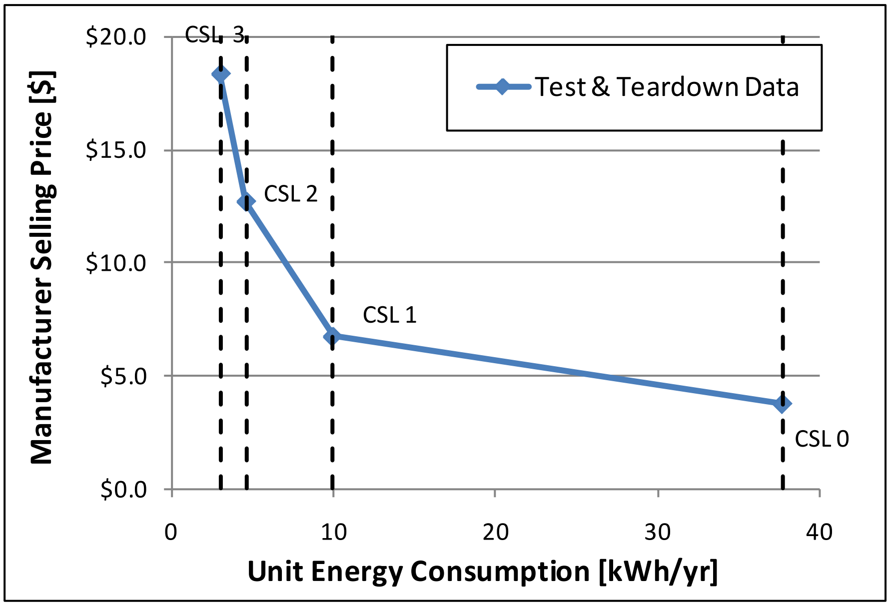


Figure 5.70 MSP vs. UEC for Product Class 4

Table 5-58 CSL Descriptions for Product Class 4

CSL	**UEC** ***kWh/yr***	**MSP from Teardowns** ***$***
0	37.7	3.79
1	9.9	6.76
2	4.6	12.71
3	3.0	18.34

5.7.11 Product Class 5: Medium Energy, Low Voltage (Test and Teardown Data)

The medium-energy, low-voltage product class includes BCs for batteries less than 20 volts and 100-3000 Wh. Batteries that meet these criteria typically have a sealed lead-acid chemistry and are used for medium-sized motor-operated products such as lawn mowers, marine trolling motors, and wheelchairs. Because of the higher capacities of these batteries, chargers in this product class typically have much higher output powers than chargers for the majority of consumer products (higher energy transferred to the battery over a similar period of time). As a result, they employ different power converter designs (forward and half-bridge as opposed to flyback) than those lower-power chargers.

Unlike the lower-energy high-volume consumer product BCs represented by the earlier product classes, these BCs tend to use standard-sized 6 or 12 volt lead-acid batteries, typically purchased separately from the BC and the end-use application. This presents a problem for the purposes of the analysis. Because the batteries are purchased separately from the BC, tests of a BC may produce different results depending on which battery is chosen. To best address this issue, DOE chose test batteries for these BCs by following the steps laid out in the BC test procedure. See appendix Y in 10 CFR 430.

5.7.11.1 Units Analyzed

DOE tested sixteen chargers for 12 volt, sealed lead acid batteries typically used with scooters, wheelchairs, and marine trawling motors. Because the batteries for these applications vary only in terms of capacity (measured in ampere-hours), the same charger can hypothetically be used for any of these applications.[k] Therefore, where possible, DOE tested chargers in this product class with batteries for both wheelchair and marine applications. The results of these tests, as well as ones performed by Ecos Consulting, are summarized in Figure 5.71, below.

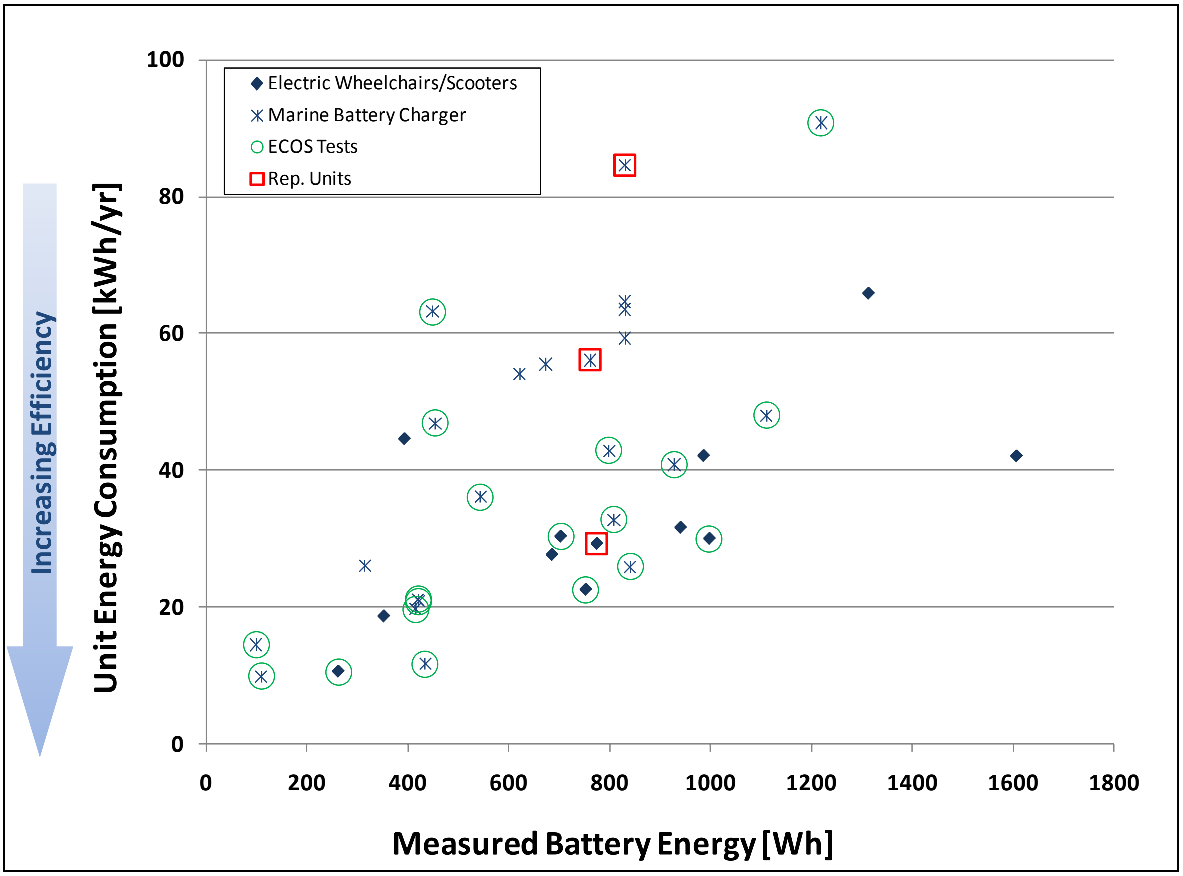


Figure 5.71 Test Results for Product Class 5: Medium Energy, Low Voltage

As can be seen in the figure, the two marine chargers that DOE selected as its teardown units for analysis lie in the middle and low end of marine charger efficiency, with shipment-weighted average energy consumption in the range of approximately 50 to 90 kWh per year. On the other hand, Ecos tests with a roughly 800 Wh sealed lead-acid battery resulted in a range of energy consumption from 25 to over 330 kWh[l] per year—a much wider range.

---

[k] In practice, however, the smallest (and also least expensive) charger will be selected which can recharge a given battery within a required time. For example, since wheelchair batteries have a capacity around 15 ampere-hours (at the 5-hour rate) while marine batteries have a capacity around 60 ampere-hours, chargers for the former have a two to four times smaller output power and size than the latter.

[l] The Ecos test result over 330 kWh/yr is not pictured in Figure 5.71 because it drastically skews the test results.

At the high end of energy consumption, DOE purchased and examined a charger with similar characteristics as the inefficient one tested by Ecos, but determined that this charger was not suitable for testing with the sealed lead-acid batteries used for marine application because of its lack of voltage control, which could lead to overcharge and damage to the battery. (The BC was likely intended for use with automotive starting batteries). Therefore, DOE discarded the results of this test as representing a suitable baseline for this product class.

At the low end, DOE again purchased and examined chargers with similar characteristics as those tested by Ecos, but was unable to replicate equivalent measurements. These discrepancies may have been due (1) shortened tests, (2) inefficiencies in the battery used for the DOE tests, and/or (3) an insufficiently broad variety of chargers.

Although the recently-adopted DOE active-mode battery charger test procedure specifies a 24-hour measurement period for the charge and maintenance mode tests, several of the DOE tests were shortened for the sake of expediency when the battery charger was observed to enter a constant lower-power mode characteristic of maintenance. Nonetheless, it is possible that the behavior of the charger would not have stayed constant had the charger continued operating past this early termination, perhaps entering an even lower-power state, resulting in lower measured maintenance mode power.

Secondly, an inefficient battery may have caused the lower-than-expected active mode efficiencies of the battery charging system. Because DOE used a different sealed lead-acid battery than Ecos, it is conceivable that its electrochemical charge and discharge efficiencies were lower, resulting in lower results for all the chargers tested.

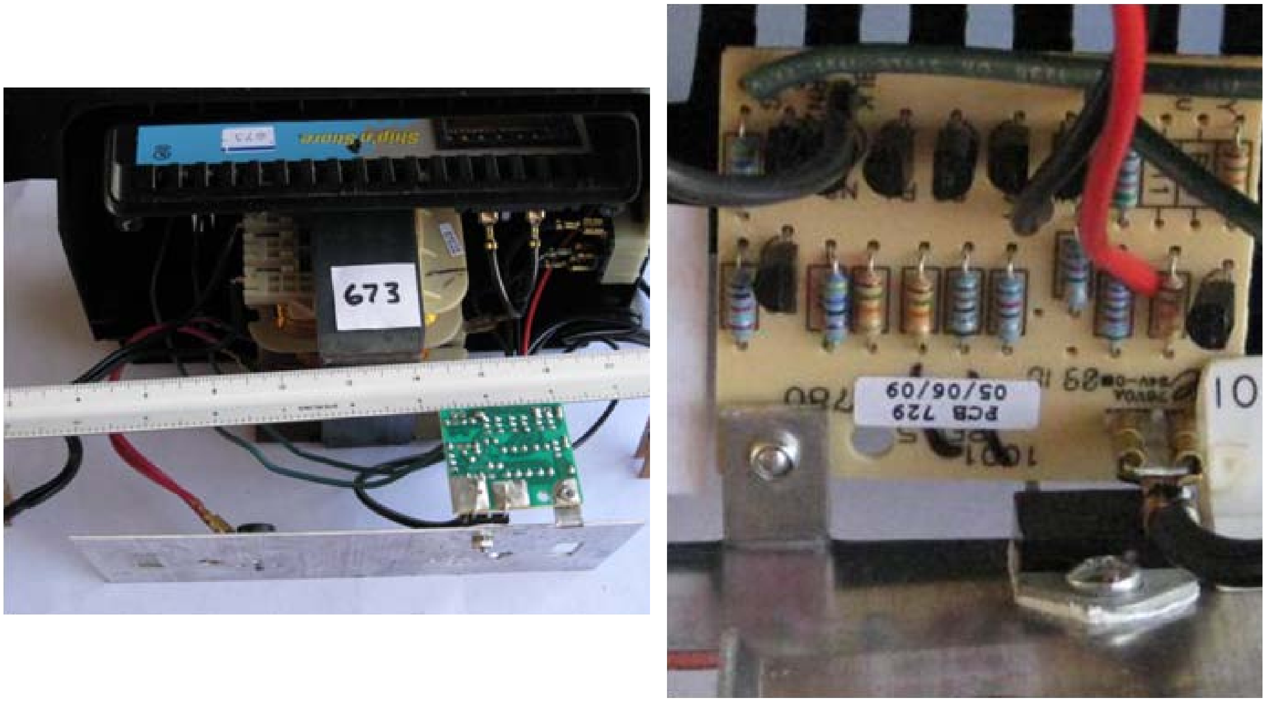
Finally, it is possible that none of the four marine chargers that DOE tested performed at the highest levels available in the market. Regardless of the cause of the higher-than-expected energy consumption of the chargers tested by DOE, additional testing and teardowns should resolve this issue. In the meantime, DOE has used the units it has torn down— described in detail in Table 5-59—to represent the baseline, improved, and best-in-market CSLs (CSL 0 through CSL 2). The remaining CSL was supplied by manufacturers through interviews.

Table 5-59 Manufacturer Performance Data for Product Class 5 Representative Unit

CSL	**Application**	**Battery Energy** *Wh*	**Charge Test Duration** *h*	**24-Hour Energy** *kWh*	**24-Hour Energy Efficiency** *%*	**Maint. Power** *W*	**No-Battery Power** *W*	**UEC** *kWh/yr*
0	Marine	831	24	2.04	41	21.2	20.1	84.6
1	Marine	762	24	1.65	46	11.9	11.6	56.1
2	Wheelchair	775	24	1.20	65	8.0	4.2	29.3
3	Wheelchair	800	24	1.18	68	0.0	0.0	15.4

5.7.11.2 CSL 0—Baseline (UEC of 84.6 kWh/yr)

The baseline marine charger tested by DOE is typical of low-cost chargers in this class, and is composed of a line-frequency transformer with a center-tapped secondary winding and two rectifier diodes. In addition, there is a small charge management circuit board with a BTW69 silicon-controlled rectifier (SCR) in series with the DC output lead, pictured in Figure 5.72. This subcircuit is responsible for the linear input power characteristic evident in Figure 5.73. Finally, the unit contains rather small diodes in button packages, which are held against the heatsink with a plastic clamp. Over time, the plastic is likely to change shape decreasing the contact pressure between the diodes and the heatsink. While this can positively impact the efficiency of the unit because at a given current, the diode forward voltage decreases as the temperature rises, in the long run, the diodes will overheat leading to failure and a shorter lifetime.



(a) (b)

Figure 5.72 Photographs of the Baseline Marine Charger

Figure 5.72 shows (a) the line-frequency transformer and (b) the heatsink-mounted SCR. Note the difference in size and design compared to the low-energy BCs.

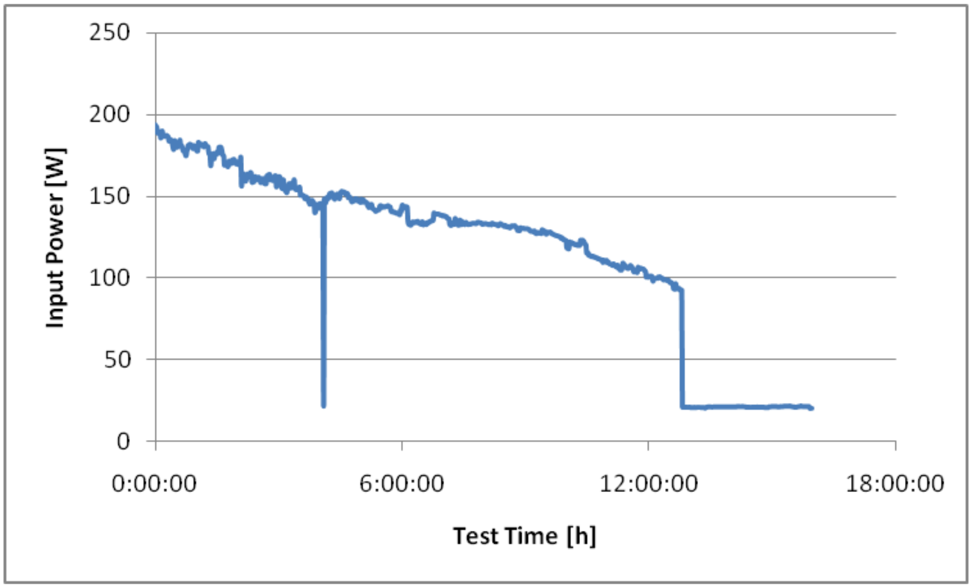
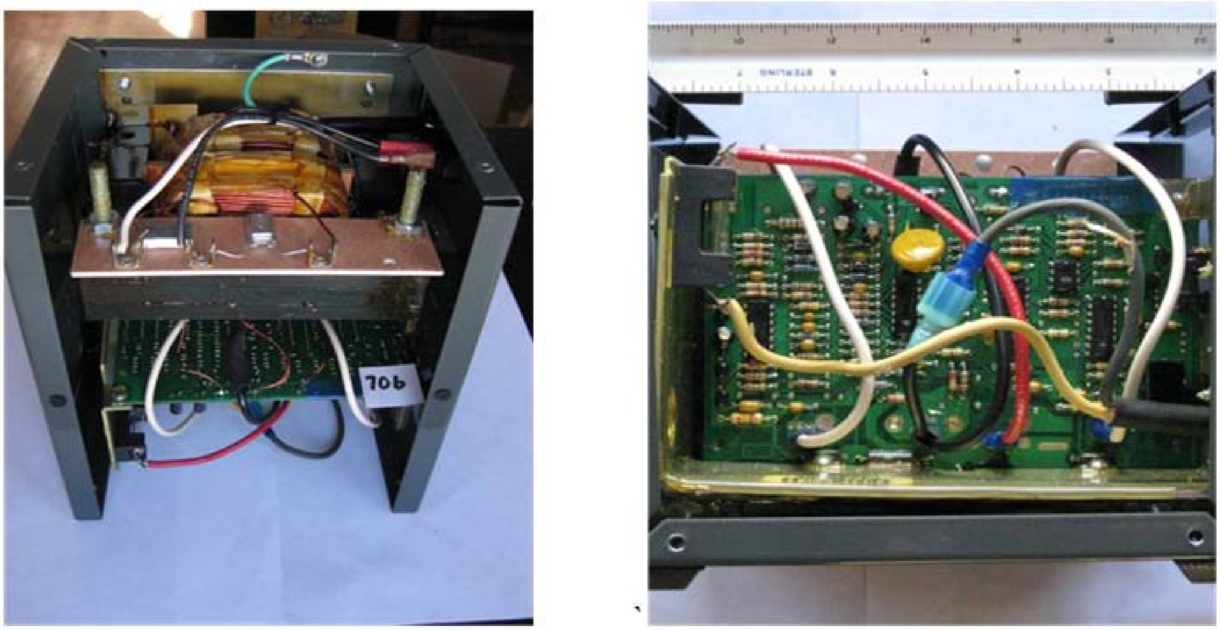


Figure 5.73 Input Power Waveform during Charge and Maintenance Modes of Baseline Marine Charger

5.7.11.3 CSL 1—Improved (UEC of 56.1 kWh/yr)

The improved (CSL 1) marine charger analyzed by DOE also features a large line-frequency transformer with a center-tapped secondary winding and two rectifier diodes. The large PCB, containing a microcontroller and other through-hole parts provides charge control, and can be adjusted using a front-panel switch depending on the type of battery (flooded or sealed lead-acid).

On the whole, this charger appears much more durable than the baseline unit, with a heavy conformal coating on the board (increasing the longevity of the unit in damp and dirty environments) and a heavier-than-usual aluminum bracket, which serves as a heatsink for the diodes.



(a) (b)

Figure 5.74 Photographs of the CSL 1 Marine Charger

Figure 5.74 shows (a) the line-frequency transformer and (b) complex charge-control PCB.

Despite providing the additional functionality of charging two battery types, this unit performs better than the baseline, charging the battery in less time with fewer losses. The input power characteristic of the improved unit in active and maintenance modes is presented in Figure 5.75.

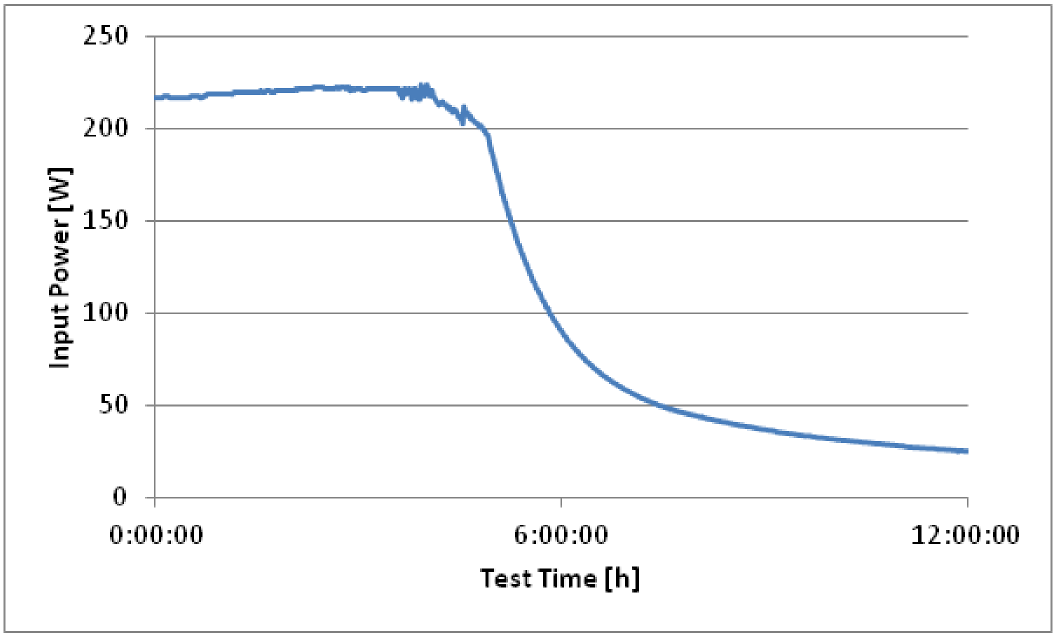


Figure 5.75 Input Power Waveform during Charge and Maintenance Modes for the CSL 1 Unit

5.7.11.4 CSL 2—Best-in-Market (UEC of 29.3 kWh/yr)

The wheelchair battery charger that DOE analyzed for the best-in-market efficiency level was tested with a 12 V lead acid battery. The BC employs a switch-mode power supply that is typical of designs in this power range. The input section contains high frequency noise filtering, inrush current limiting, rectification, ripple filtering, and power switch transistors. This portion of the BC is isolated from the output portions of the supply with high voltage rated open paths on the circuit board. Communication across this path is obtained with two transformers rated to provide high voltage isolation. One is a primary power transformer and the other is a switching transformer used to drive the control inputs of the power switch transistors.

The switching circuit utilized by this BC is a half-bridge converter and is widely used at power levels of this order and when needed to operate at both 115V and 230V line voltages. This circuit design makes better use of the power transformer copper than the typical push-pull converter and it is protected from core saturation caused by flux unbalance. Power wasting transient snubbers needed in many other circuits, are not needed in this design.

Charger control circuits were observed to be more complex than a common EPS because of the need to control the current as the battery voltage changes and to limit the current at charge completion. This unit used three integrated circuits, one was a PWM control and the others were quad op-amps. All three integrated circuits have been in production for decades and remain widely used, which explains part of the reason that this design was relatively inexpensive.

The output power circuits use two dual power rectifiers. One is the standard output rectifier; the other is a blocking diode that prevents battery power from being fed back into the charger. These devices share an L-shaped aluminum heat sink with power switches. The power switches are equipped with sleeve type voltage isolators for safety protection.

On the whole, the design of this unit causes a vast improvement in 24-hour energy efficiency, up from 46% to 65% and drops in maintenance and no-battery mode power, down from 11.9 W to 8.0 W and 11.6 W to 4.2 W respectively. Finally, the BC yields a unit energy consumption of 29.3 kWh/yr.

5.7.11.5 CSL 3—Max-Tech (UEC of 15.4 kWh/yr)

To achieve the maximum technologically feasible efficiency, resulting in a unit energy consumption of less than 15.4 kWh/yr, manufacturers did not propose any novel topologies. Instead they provided incremental improvements to a SCR and switched-mode topology that they believed could provide comparable performance to the unit described for CSL 2.

Non-active energy consumption in maintenance and no-battery modes could be eliminated entirely for some applications through the use of a relay. Manufacturers also focused on further reducing the energy consumption in active mode to meet CSL 3. This could be achieved by increasing the efficiency of the transformer through further investment in core steel (reducing magnetization losses) and winding copper (reducing resistive conduction losses). Similar reductions in resistive losses could be made throughout the rest of the charger by increasing the widths of the conductive traces on the PCB or the gauge of the connecting cables.

These improvements could result in a system-wide active-only efficiency approaching 70 percent (above 90 percent, excluding the battery), maintenance and no-battery power at 0 watts, and unit energy consumption below 15.4 kWh.

5.7.11.6 Estimate of Manufacturer Selling Price

As before, iSuppli, a DOE contractor, tore down the three BCs at CSL 0, CSL 1 and CSL 2 for this product class and estimated the cost of the electronic components. These were subsequently marked up to reflect manufacturers’ costs, resulting in the teardown curve in Figure 5.76. The detailed results for teardowns are presented in Table 5-60.

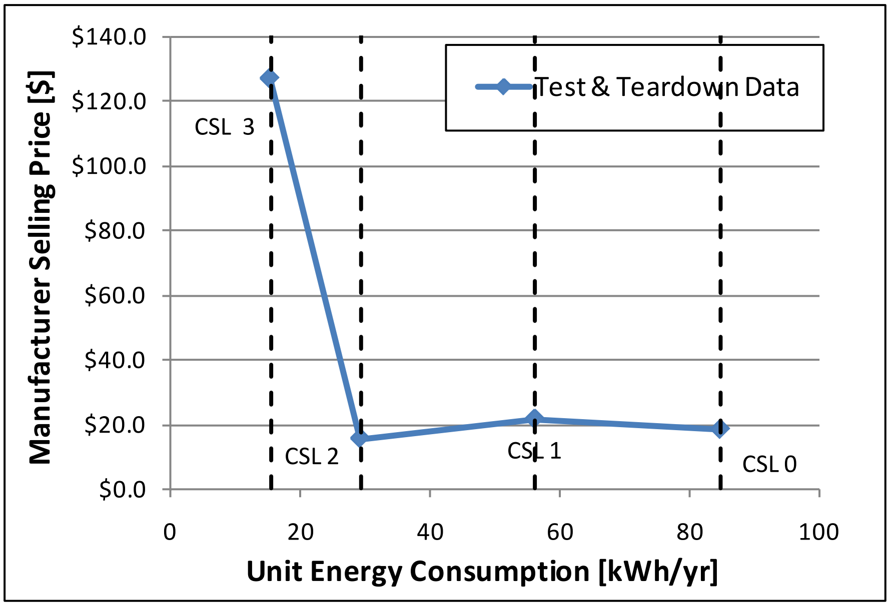


Figure 5.76 MSP vs. UEC for Product Class 5

Table 5-60 CSL Description for Product Class 5

CSL	**UEC** ***kWh/yr***	**MSP from Teardowns** ***$***
0	84.6	18.48
1	56.1	21.71
2	29.3	15.69
3	15.4	127.00

5.7.12 Product Class 6: Medium Energy, High Voltage (Scaled Data)

This product class is similar to product class 5: medium energy, low voltage. BCs in this product also charge sealed lead-acid batteries, though for a slightly different set of applications. Because of the general similarities between chargers at the higher battery energies, DOE used the cost-efficiency data obtained from manufacturers for product class 5, scaled according to the typical battery energy and voltage of product class 6, and weighted by the usage profiles of product class 6 applications, such as lawnmowers and electric bicycles.

For the NOPR, DOE did additional product class 6 testing, but was unable to obtain a complete data set upon which to base its engineering. DOE could not find products with similar enough battery energies and the products tested did not span a sufficient range of performance. Therefore, in order to develop an engineering analysis for this product class, DOE relied on its subject matter expert, the results gleaned from product class 5, interviews with manufacturers, and its limited test data from product class 6.

The difference between product class 5 and product class 6 is the range of voltages that are covered. Product class 5 is the low voltage (less than 20 V), medium energy (100 Wh to 3,000 Wh) class, while 6 is the high voltage (greater than or equal to 20 V), medium energy (100

Wh to 3,000 Wh) class. The representative unit examined for product class 5 is a 12 V, 800 Wh battery charger, while the representative unit analyzed for product class 6 is a 24 V, 400 Wh battery charger.

Despite the change in voltage, DOE found that similar technology options and battery charging strategies are available in both classes. Both chargers are used with relatively large sealed-lead acid batteries in products such as wheelchairs, electric scooters, and electric lawn mowers. However, since the BCs in product class 6 are working with higher voltages, currents can be less for the same output power and therefore these devices can be slightly more efficient because I^2R losses will be reduced.

For the NOPR, DOE examined its product class 5 results and consulted with subject matter experts on how the performance may change if similar technologies are used. The resulting performance parameters are shown in

Table 5-61. To account for the variation in energy, or capacity, DOE used information on charge time and maintenance mode power to adjust the corresponding values for 24-hour energy. Additionally, DOE discussed with manufacturers about how costs may differ in manufacturing a 12 V charger versus a 24 V charger. Manufacturers indicated that there would be minimal change in the cost, if any at all. Therefore, rather than scaling the product class 5 results for costs, DOE used the same MSP's for product class 6 that were developed from the iSuppli tear down data for product class 5. The fundamental assumption for this approach is that the same design considerations and design options are used at the corresponding CSLs for product classes 5 and 6.

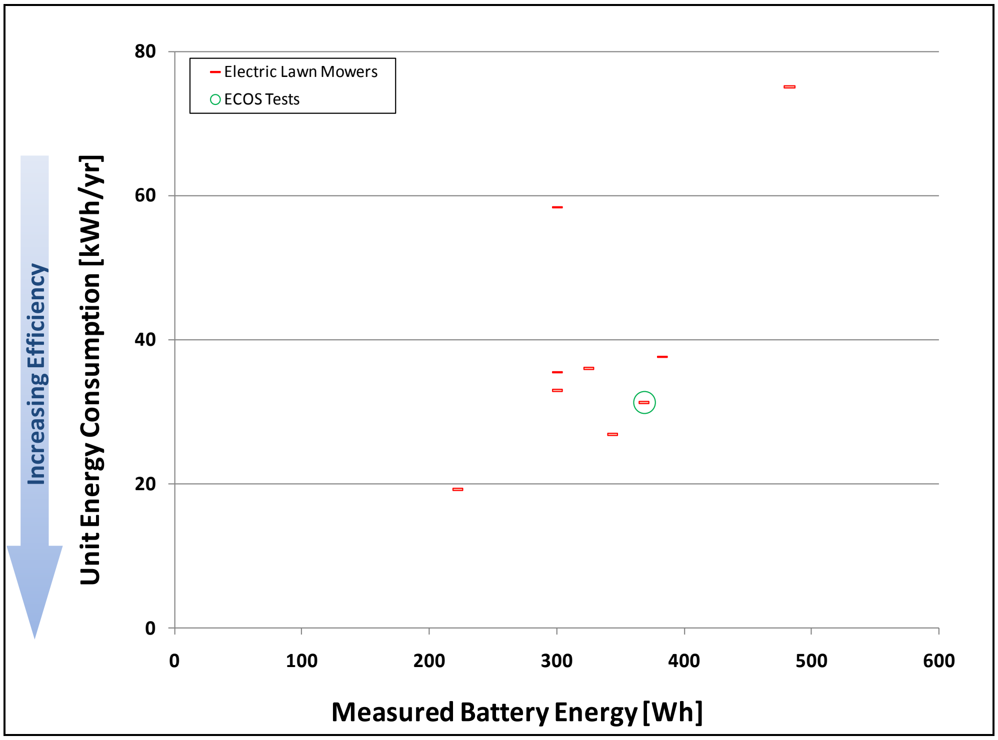


Figure 5.77 Test Results for Product Class 6: High Voltage, Medium Energy

Table 5-61 Manufacturer Performance Data for Product Class 6 Representative Unit

CSL	Application	Rated Battery Energy Wh	Est. Charge Test Duration h	Est. 24-Hour Charge Energy Wh	Est. 24 Hour Energy Efficiency %	Est. Maint. Power W	Est. No-Battery Power W	UEC kWh/yr
0	Marine	400	24	891.6	45	10.6	10.0	120.6
1	Marine	400	24	786.1	51	6.0	5.8	81.7
2	Marine	400	24	561.0	71	4.0	2.1	38.3
3	Marine	400	24	536.4	75	0.0	0.0	16.8

5.7.12.1 Estimate of Manufacturer Selling Price

As discussed, the costs developed for product class 6 are the same as those developed for product class 5. However, the performance parameters have varied slightly and the usage profiles assumed are also different. Therefore, although the cost versus efficiency curve for product class 6 has the same shape as the curve for product class 5, the values of UEC are different. The cost versus efficiency curve for product class 6 is shown in Figure 5.78, while the detailed results are shown in Table 5-62.

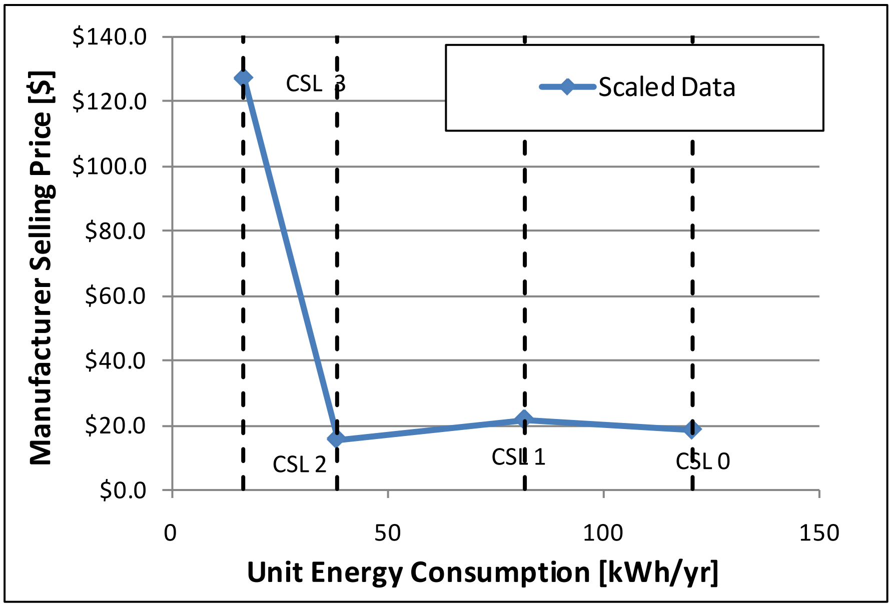


Figure 5.78 MSP vs. UEC for Product Class 6

Table 5-62 CSL Descriptions for Product Class 6

CSL	UEC kWh/yr	MSP from Teardowns $
0	120.6	18.48
1	81.7	21.71
2	38.3	15.69
3	16.8	127.00

5.7.13 Product Class 7: High Energy (Test and Teardown Data)

The high-energy product class includes BCs for batteries with energy greater than 3000 Wh. Whereas the BCs included in product classes 5 and 6 were intended to charge batteries for a variety of applications, the high-energy batteries associated with chargers in product class 7 are only used for golf cars and utility vehicles. Furthermore, these high-energy batteries use a flooded or wet lead-acid construction, meaning that the batteries are free to vent to the outside air in case of excessive gas buildup. Although this requires additional care in handling (*e.g.*, the batteries should not be tipped or left exposed to the elements), it does make the batteries more resilient to overcharge and results in looser tolerances (and lower costs per watt of output power) on the chargers. These differences led DOE to place these chargers in a separate product class, though some manufacturers claimed there was broad similarity between all chargers for medium and high energy batteries.

5.7.13.1 Units Analyzed

DOE tested four units for this product class and their calculated unit energy consumption values are pictured in Figure 5.79. Of these, DOE chose two units that tested with similar battery energies for further evaluation and teardowns based on their efficiency test results and internal design. Detailed information regarding these units is presented in Table 5-63.

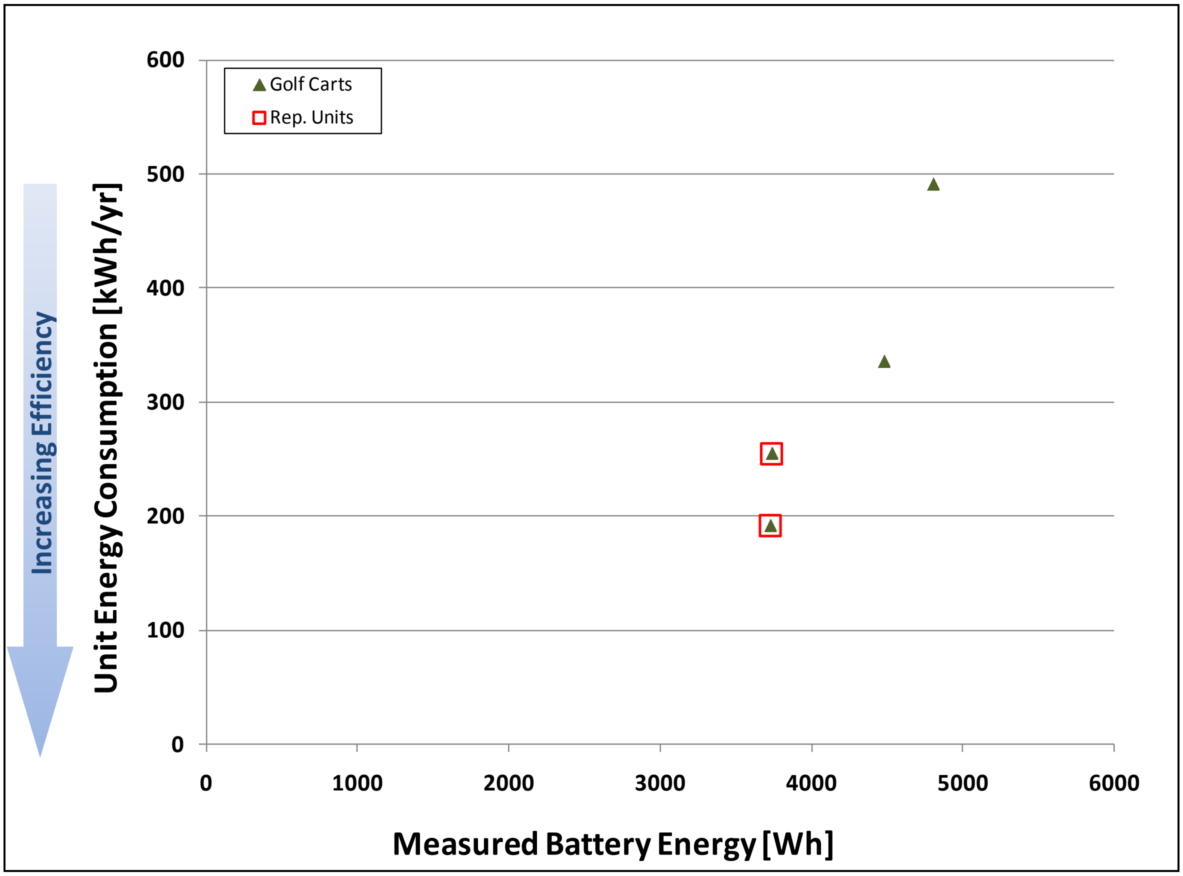


Figure 5.79 Test results for Product Class 7: High Energy

Table 5-63 Manufacturer Performance Data for Product Class 7 Representative Unit

CSL	**Application**	**Battery Energy** *Wh*	**Charge Test Duration** *h*	**24-Hour Energy** k*Wh*	**24-Hour Energy Efficiency** *%*	**Maint. Power** *W*	**No-Battery Power** *W*	**UEC** *kWh/yr*
0	Golf Car	3736	24	5.88	63	10.0	0.0	255.0
1	Golf Car	3726	24	5.31	70	3.3	1.5	191.7
2	Golf Car	3750	24	4.86	77	2.6	0.0	131.4

5.7.13.2 CSL 0—Baseline (UEC of 255 kWh/yr)

The circuit of the baseline unit torn down by iSuppli utilized a current-fed buck push-pull converter. With this circuit, a current fed buck converter reduces the rectified input line to obtain the desired output voltage. There is an inductor in the buck output, but no significant filter capacitor, and the output is delivered to a push-pull transformer driver that has slightly more than 100% duty. That is, each half of the push-pull driver is turned on just before the other half turns off. This practice can be tolerated because the inductor in the buck converter limits what would otherwise be a destructive transition current. Control of the charger output is obtained by varying the duty cycle of the buck converter.

This approach has some advantages for a high power charger operating over a wide input voltage range. The transformer size and cost are otherwise reduced because it operates at full duty cycle from a regulated source. The switching methods reduce the need for power dissipating snubbers and the system is compact for its power level. Power loss is reduced by using parallel power transistors. The buck converter uses three power metal-oxide-semiconductor field-effect transistors (mosfets) in parallel and the push-pull driver uses two parallel transistors in each leg. The thermal design uses two large finned heat sinks that make-up two walls of the package.

A small line frequency transformer provides the input to a 12V DC auxiliary supply to operate the power logic and the charging regulation control circuits. Relays are located in both the input and output circuits. The output relay prevents the unit from operating into a reverse battery polarity or an excessive battery voltage situation. The input side relay disconnects the unit in a no-battery condition.

5.7.13.3 CSL 1—Best-in-Market (UEC of 191.7 kWh/yr)

The main power circuit of the best-in-market device tested and torn down by DOE uses switch-mode conversion with an operating frequency is 23 kHz. The input circuits are fitted with high frequency noise reduction filters, transient suppressors, and inrush current limiting. Power switching is done with a push-pull buck converter operating in current mode. Current mode control prevents the damaging unbalance that can occur with push-pull switching and simplifies control loop stabilization. The power switches each use two power mosfets in parallel and the output rectification uses two power diodes in parallel for both the rectification and the clamping functions.

A small line-frequency, low voltage, auxiliary power supply with a separate transformer is provided to support the logic and control circuits. This supply uses linear regulation, a method with lower efficiency. This loss is often tolerated with low power circuits; however the losses often show up in maintenance and standby operation. Multi-step charging adds complexity that is not required in ordinary power converters or simple chargers. In this charger a digital micro-controller and supporting logic provide charging control. Both the input and the output power of the charger pass through relays. The output relay provides a disconnect if reverse battery polarity or excess battery voltage occur. The input relay disconnects the power from the converter when charging is complete to reduce maintenance power dissipation. Temperature control is provided by a fan cooled heatsink and thermal conduction to the aluminum case and temperature sensors monitor the heatsink.

Manufacturers often design these chargers in order to improve the overall efficiency. The energy savings due to no-battery power is often considered trivial and receives little attention in the design process for these high-energy chargers. This explains the fact that the unit tested at CSL 0 has zero no-battery power and the unit tested at CSL 1 consumes 1.5 W in no-battery mode. Regardless of which design options are implemented, the unit energy consumption is less than 191.7 kWh in this efficiency level.

5.7.13.4 CSL 2— Max-Tech (UEC of 131.4 kWh/yr)

Finally, manufacturers speculated on ways of further reducing the energy consumption of current best-in-market units, though, according to manufacturers, no further improvements in topology exist and additional incremental improvements offer diminishing returns.

Manufacturers first proposed increasing the widths of all conductors in the battery charger as a way of reducing resistive losses. These conductors include the PCB traces, the cables connecting the charger to the battery, and the transformer windings. However, these improvements have limitations: space inside the charger is limited and wires with a thicker gauge will be bulkier and less flexible. Furthermore, wider wires in the transformer will push the windings away from the core. The resultant spacing will cause more magnetic flux to leak away from the transformer and reduce the coupling from the primary to the secondary winding, counteracting any improvement in efficiency due to lower resistance. At best, such improvements could result in a charger-only active-mode efficiency slightly above 90 percent.

Further improvements would include upgrades to the magnetic components (including the transformer cores), replacing diodes with FETs (synchronous rectification), and finally decreasing the losses of the FETs, in order of increasing costs. Such techniques could increase the active-mode efficiency to around 95 percent in active mode (excluding the battery), though at very high cost. In addition, by introducing a relay or solid state power switch, the no-battery power of this design could be brought down to virtually zero. These changes would be necessary to decrease the unit energy consumption below 131.4 kWh.

5.7.13.5 Estimate of Manufacturer Selling Price

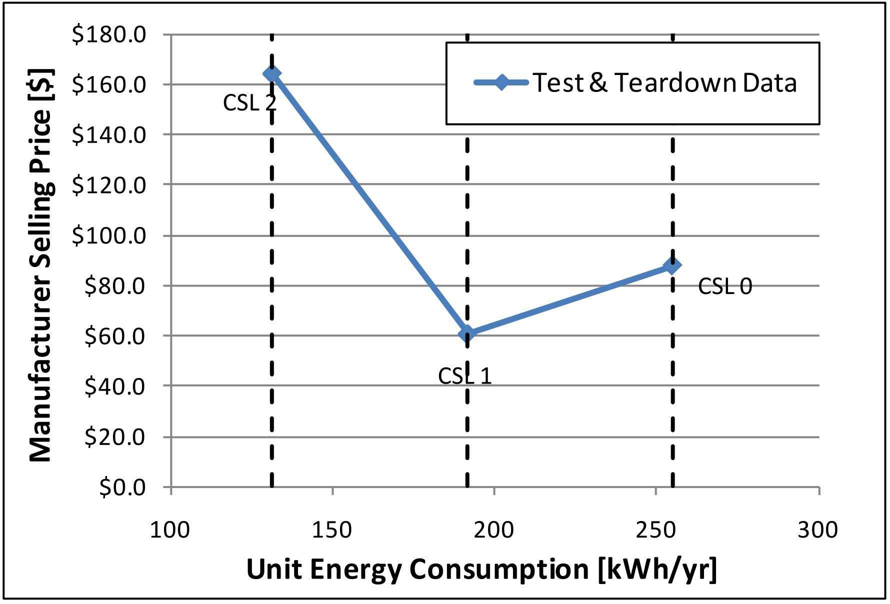


Figure 5.80 shows the cost-efficiency curve developed from the combination of DOE's teardowns (at the baseline and best-in-market CSLs) and discussions with manufacturers for the maximum technology CSL. Due to such a few number of golf car manufacturers, DOE only analyzed 3 CSLs for this product class. Detailed cost information is also presented in Table 5-64.

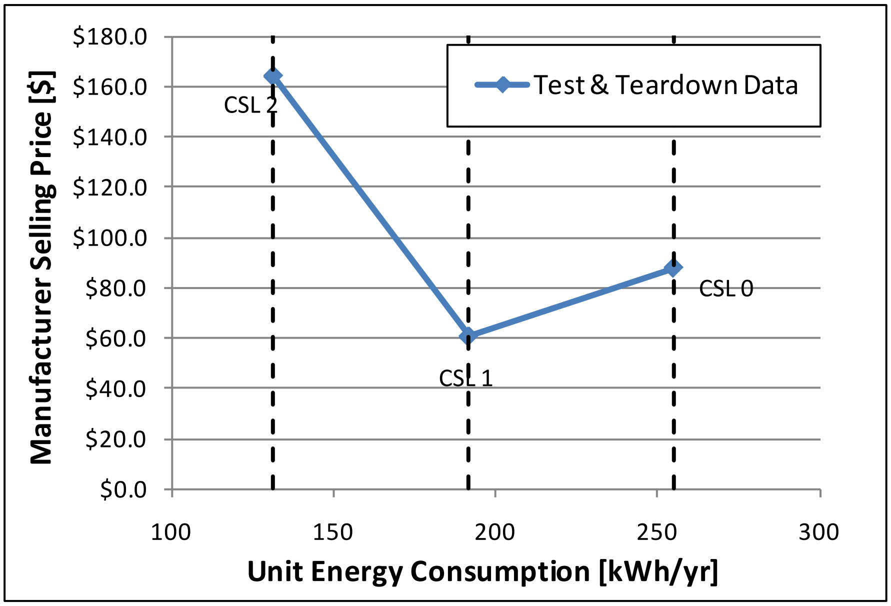


Figure 5.80 MSP vs. UEC for Product Class 7

Table 5-64 CSL Descriptions for Product Class 7

CSL	UEC *kWh/yr*	MSP from Teardowns *$*
0	255.1	88.07
1	191.7	60.86
2	131.4	164.14

Technical evaluation of the two units at CSL 0 and 1 indicated that unit tested at CSL 0 operates over the international input voltage range of 100V to 240V. Whereas, the unit tested at CSL 1 is restricted to the domestic range of 105V to 130V. This wider operating range adds circuit complexity and requires higher voltage, and warrants more expensive, components. Moreover, the physical design of CSL 0 unit is more complex and uses more expensive materials than the CSL 1 unit. Most part of the outer surface of this unit is made with an extruded aluminum heat sink, which is a costly unique shape to manufacture.

This explains the MSP of unit at CSL 0 being higher than that of unit at CSL 1, in Figure 5.80 above, and hence the reverse relationship in prices among these two units.

5.7.14 Product Class 8: Low Energy, DC Input (Test and Teardown Data)

This product class contains small consumer electronic products typically recharged using the 5 volt output of a computer’s USB port, in particular portable media players and personal data assistants (PDAs), and smart phones. Interviews with manufacturers revealed that the BCs in this product class are similar to those in product class 2, which are typically used with cellular telephones, except that they do not require an EPS.

5.7.14.1 Units Analyzed

DOE tested six units for this product class and the calculated unit energy consumption values relative to measured battery energy are pictured in Figure 5.81. Based on their test results, DOE chose three units that tested with relatively similar batter energies for further evaluation and teardowns. Detailed information regarding these units and each CSL that DOE analyzed for product class 8 is presented in Table 5-65.

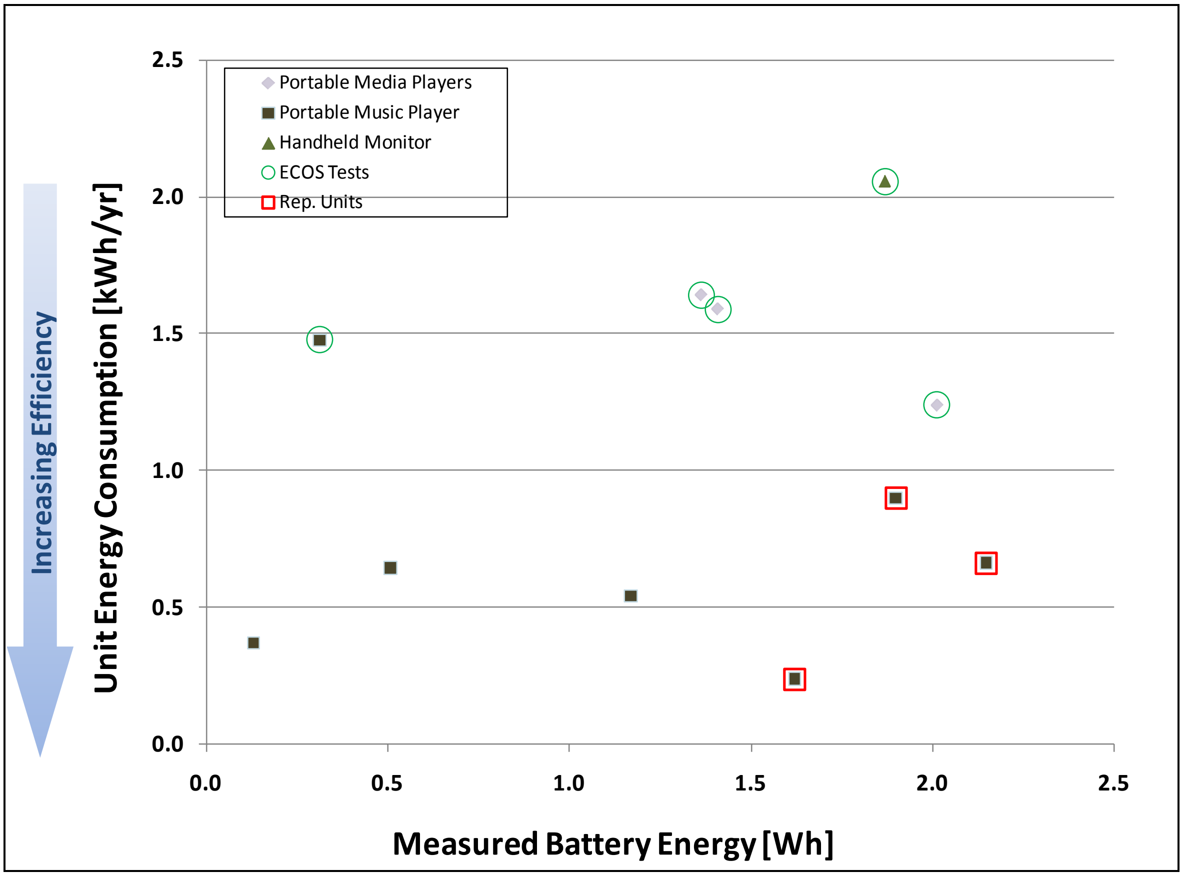


Figure 5.81 Test Results for Product Class 8: Low Energy, 5V DC Input

Table 5-65 Manufacturer Performance Data for Product Class 8 Representative Unit

CSL	Application	Battery Energy Wh	Charge Test Duration h	24-Hour Energy Wh	24-Hour Energy Efficiency %	Maint. Power W	No-Battery Power W	UEC kWh/yr
0	Portable Music Player	1.9	24	10.4	18	0.30	0.0	0.90
1	Portable Music Player	2.1	24	8.4	25	0.20	0.0	0.66
2	Portable Music Player	1.6	24	3.7	44	0.10	0.0	0.24
3	Portable Music Player	1.6	24	3.1	52	0.04	0.0	0.19

5.7.14.2 CSL 0—Baseline (UEC of 0.90 kWh/yr)

For the baseline efficiency level, DOE analyzed a portable music player. All of the units that DOE tested in this product class were designed to work with lithium-ion batteries and in the baseline device, DOE found a single cell 3.7 volt lithium-ion battery. As with other devices that use a USB bus, the key element affecting efficiency is the line voltage to USB 5V conversion. This configuration allows relatively simple and efficient charge control. As found in similar products, this device uses multilayer circuit boards with many traces out of sight. Consequently, specific circuit configurations could not be determined by visual inspection or probing.

In its review DOE was able to identify a standard grouping of component types typically found in power control circuits such as inductors, power diodes, and high-value capacitors. A lack of other power converter parts indicates that the circuit is likely a buck converter. The converter was found to have a high switching frequency, roughly 960 kHz. A high frequency usually results in higher switching losses. However, a higher frequency also allows the use of physically smaller filter components. In highly compact products such as this, the designer is faced with a size versus efficiency trade off. Additionally, a very important performance parameter is operating time between charges and charge efficiency has no effect on this time and smaller chargers allow larger batteries. The discharge energy of a fully charged battery was 1.9 Wh. The energy out of the USB source during charging was 3.85 Wh, for a charge efficiency of nearly 50 percent. The 24-hour energy efficiency of this device dropped to 10 percent because of the duration and energy consumed while in maintenance mode.

The charging efficiency of this unit can be improved by reducing the switching frequency. The resulting increase in component size will likely affect the case or battery size and the energy saved would probably be minimal compared to the losses in the line to USB converter.

5.7.14.3 CSL 1—Improved (UEC of 0.66 kWh/yr)

At CSL 1, DOE analyzed another portable music player. In this BC, a switch mode converter is used to drop the 5 volt DC input to approximately 3.7 volts. The converter also controls the charging current and voltage level applied to the lithium-ion battery. The battery energy used in this device was slightly greater than what was found in the CSL 0 unit, up from 1.9 Wh to 2.1 Wh.

As with the CSL 0 unit, the circuit board is multilayered and most traces are hidden. Parts are unlabeled or marked with non-standard identifications, so determining the specific circuits used was not possible. However, the circuit board is divided into eight areas by metal shielding dividers. One of these areas contained a large wound inductor, a Schottky diode, and a large capacitor, components typically used in a buck converter.

AC measurement of the power used to charge the battery was performed. The battery energy delivered at discharge was 2.3 Wh. The power taken from the AC power bus was 6.1 Wh for a total efficiency of 37 percent. To evaluate this result, factors to consider are battery efficiency, USB power module efficiency, charger circuit efficiency, and power diverted to other functions. The media player’s display was off during this test but there is no assurance that some power was not required elsewhere. The measured efficiency of the USB module was 69 percent.

With a regulated DC source provided by a USB bus, a buck converter is the most efficient means of regulating the battery charging voltage. It is simple with two primary loss elements, the switch transistor and the Schottky diode. Inductor loss is usually quite small and the filter capacitor loss is negligible. The most significant transistor loss occurs during switching and the easiest way to improve this loss is to reduce the switching frequency. The forward drop of the Schottky diodes, particularly at the low voltages involved, is difficult to improve. In all, 24-hour energy efficiency is mildly improved over the CSL 0 unit and the maintenance mode power is dropped 0.1 watts, resulting in a calculated UEC of 0.66 kWh/yr.

5.7.14.4 CSL 2— Best-in-Market (UEC of 0.24 kWh/yr)

The portable music player that was used to represent the best-in-market efficiency level is a highly compact device with a relatively large 3.7 V lithium-ion polymer battery. As is typical of lithium based batteries, the battery was equipped with an integral safety circuit.

The primary power source was a USB bus that supplies the 5 V DC. The circuit board was comprised of five large and two small multi-pin integrated circuits. Additionally, an inductor was located near a large value capacitor and a relatively large Schottky diode. The existence of these parts indicates that a switch mode power converter was probably used.

Again, operation on a regulated 5 V DC source allowed the use of a simple buck converter. This converter type has been found in a number of DC powered compact devices. It is likely that one of the smaller integrated circuits provided the battery charging control function. Consequently, 24-hour efficiency improved to 44 % and maintenance mode power dropped by 0.1 W again, all of which resulted in a unit energy consumption of 0.24 kWh/yr.

5.7.14.5 CSL 3— Max-Tech (UEC of 0.19 kWh/yr)

Finally, for product class 8, DOE estimated the efficiency of a unit that is designed with the maximum feasible technology. An independent estimate of the efficiency of a max-tech unit was achieved by DOE through extrapolation from its analysis of the best-in-market (CSL 2) unit by estimating the impacts of adding any remaining energy efficiency design improvements with the consultation of DOE’s subject matter experts.

Switching losses of the CSL 2 unit may be reduced by lowering the switching frequency of said BC. The trade-off for this design is that the inductor and the filter capacitor will be larger. Another design option is to reduce the maintenance and standby power consumption to near zero by designing a full shut-down when charging is complete. As the performance of the best-in-market BC for this product class showed a very small UEC, these changes in performance will only mildly drop the UEC. The maximum-technology feasible UEC developed for this product class is 0.19 kWh/yr relative to 0.24 kWh/yr for the best-in-market efficiency level.

5.7.14.6 Estimate of Bill-of-Materials Costs

Figure 5.82 shows the cost-efficiency curve developed from the combination of DOE’s teardowns and discussions with its subject matter experts for the maximum technology CSL. Detailed cost information is also presented in Table 5-64. Although the unit tested at the lowest CSL (highest UEC) performed the worst, relative to the other units torn down, it had the highest cost. All BCs likely used a buck converter design topology, so the difference in cost of the CSL 0 unit to the CSL 1 and CSL 2 unit, is the integrated circuit that was use and captured in CSL 0’s bill of materials. The integrated circuit was a large portion of the bill of materials and was also likely responsible for functionality other than just battery charging.

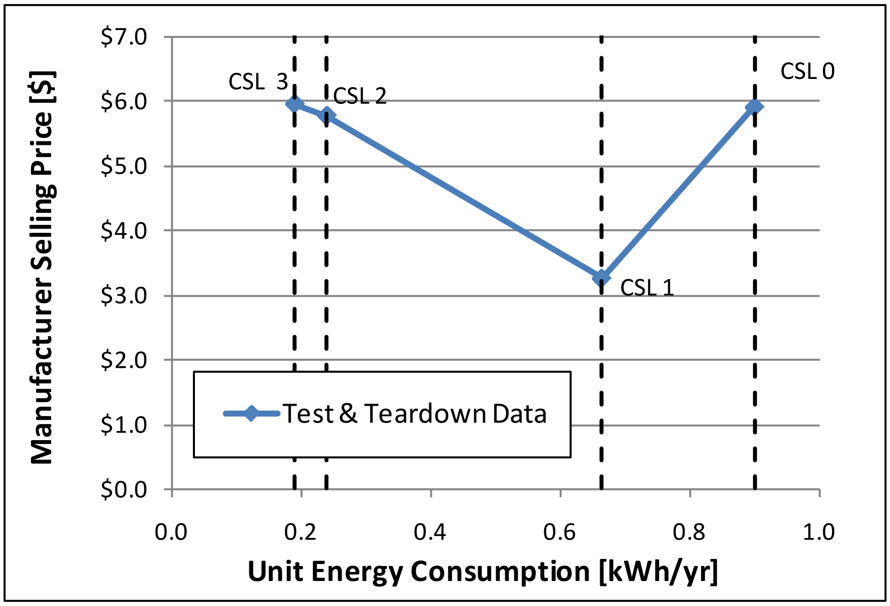


Figure 5.82 MSP vs. UEC for Product Class 8

Table 5-66 CSL Descriptions for Product Class 8

CSL	**UEC** ***kWh/yr***	**MSP from Teardowns** ***$***
0	0.90	5.90
1	0.66	3.26
2	0.24	5.77
3	0.19	5.95

5.7.15 Product Class 9: Low Energy, 12 V DC Input (Test and Teardown Data)

This product class contains small consumer electronic products typically recharged using the 12 volt output of an automotive cigarette lighter receptacle, in particular satellite navigation units intended for use in cars. Through product disassembly, DOE noticed many similarities to the design of BCs in product class 2, though, again, without the need for an EPS because the 12 V DC input is converted into the voltage necessary for battery charging and operation using a DC-DC converter inside the unit.

5.7.15.1 Units Analyzed

DOE tested four GPS units for this product class; their unit energy consumption, assuming a shipment-weighted product class-average usage profile, is pictured in Figure 5.83. For comparison, the figure also includes the results of tests conducted by Ecos Consulting. For the four units that DOE tested, DOE chose to conduct further evaluations and have them torn down. Detailed information regarding these four units is presented in Table 5-67.

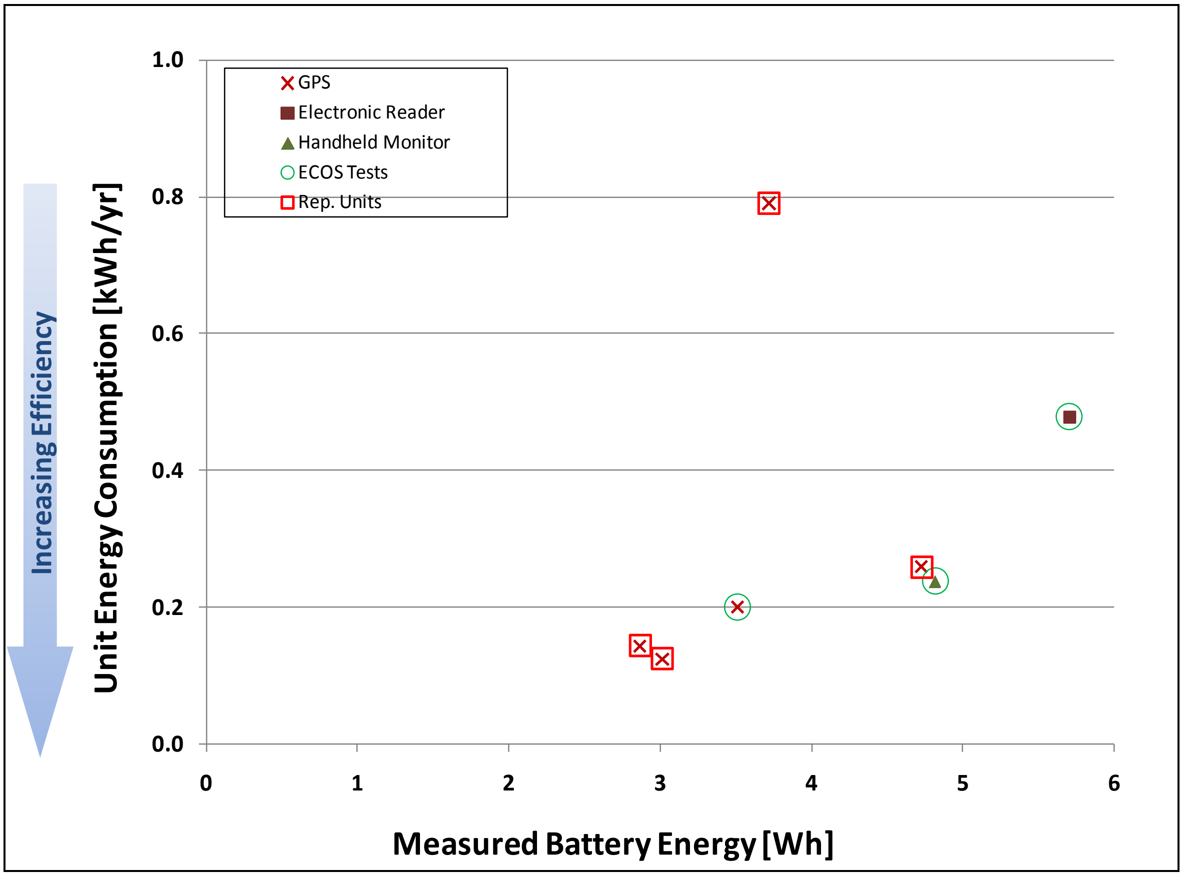


Figure 5.83 Test Results for Product Class 9: Low Energy, 12V DC Input

Table 5-67 Manufacturer Performance Data for Product Class 9 Representative Unit

CSL	Application	Battery Energy *Wh*	Charge Test Duration *h*	24-Hour Charge Energy *Wh*	24 Hour Energy Efficiency *%*	Maint. Power *W*	No-Battery Power *W*	UEC *kWh/yr*
0	GPS	3.7	24	48.1	8	1.8	0.0	0.8
1	GPS	4.7	24	13.5	35	0.2	0.1	0.3
2	GPS	2.9	24	8.1	36	0.2	0.1	0.1

5.7.15.2 CSL 0—Baseline (UEC of 0.8 kWh/yr)

The disassembly of the GPS unit that DOE evaluated for this CSL showed that it contains a switch mode voltage converter with a measured output of 5.1 V. This output is regulated and showed little change when the input voltage or output current varied. The internal circuit is a simple forward converter controlled by a widely used power controller (TL 494) driving a MOSFET with a switching frequency of 56 kHz.

The link between the power adapter and the GPS unit is a 6 foot cable permanently attached to the adapter and equipped with a USB male connecter at the unit end. The cable has only two leads conveying 5 V DC power. There is no feedback signal between the GPS unit and the power adapter.

The GPS unit is complicated with a number of metal shields soldered over the circuitry signifying that noise suppression is a likely a critical element of the design. The battery charging regulator is difficult to separate from the GPS circuits. Measurements revealed a switching frequency of 1.45 MHz. This frequency is quite high and results in elevated switching losses. Space limitations may have been a factor in this design choice, hence the high frequency and relatively small components.

The charger applies the voltage level needed to achieve a charging current of approximately 0.25 A until the battery voltage reaches 4.1 V. A measurement of charger efficiency, exclusive of the adapter, at nominal battery voltage (3.7 V), showed an efficiency of 74%.

The product of the two measured converter efficiencies is 61%. Cascading two converters in this fashion is certain to reduce efficiency. A significant improvement in efficiency can be achieved by eliminating the charger in the GPS and using the available spare leads in the USB cable (there are five leads) to send signals of the battery state to control the output of the converter in the power adapter, which is rather efficient.

5.7.15.3 CSL 1—Improved (UEC of 0.3 kWh/yr)

At the improved efficiency level, the GPS analyzed uses a single lithium-ion battery with no visible rating label. Because it is a fixed battery and the adapter output is 5V and 1A with only two connections, it was concluded that charge control electronics are in the GPS unit. The power converter in the adapter is a buck converter, with a MC34063 chip and two transistors. The transistors are identical 2SK550s connected in parallel. The MC34063 chip is very inexpensive, and has been in production since before 1985.

When tested as an EPS, it showed efficiencies of 78% at full load, 77.8% at ¾ load, 75.1% at ½ load, 65.5% at ¼ load, for an average of 74.1%. Efficiency at the converter output was 80.1%, 79.4%, 76.1%, 66.0% for an average of 75.4%. This implies that a lower resistance output cable would make only a very small improvement in performance. The choke was the warmest part, followed by the output capacitor. There is room in the package for a bigger choke and for a larger output capacitor. A larger choke would also allow operation at lower frequencies and reduce switching losses. None of the other parts appeared to get very warm. The next improvement would have to be the use of a synchronous switch, in place of the Schottky diode, which might mildly improve efficiency.

5.7.15.4 CSL 2— Best-in-Market (UEC of 0.1 kWh/yr)

DOE only evaluated one of the GPS battery chargers that was tested at the best-in-market efficiency level. Just like the CSL 1 unit, it works with a single lithium-ion battery with no visible rating label. Because it is a fixed battery and the adapter output is 5V, 2A with only two connections, it can be concluded that charge control electronics are in the GPS unit. The power converter in the adapter is a buck converter, using the LM2576-5.0 chip, in a TO-220 package, but with no heat sink. As with the chip in the CSL 1 unit, this BC employs a chip, the LM2576-5.0, which has been in production since the 1980s.

When tested as an EPS, it showed efficiencies of 73.2% at full load, 76.1% at ¾ load, 78.1% at ½ load, 77.4% at ¼ load, for an average of 76.2%. Efficiency at the converter output was: 78.3%, 80.0%, 80.6%, 78.5% for an average of 79.4%. Again a lower resistance output cable would make only small improvements in performance. The LM2576-5.0 chip became the warmest part of the circuit (especially at full-load) followed by the choke.

DOE averaged the performance parameters of the two units that were evaluated for this CSL and the UEC calculated is based on those average performance parameters. The resulting UEC for this efficiency level, CSL 2, is 0.1 kWh/yr.

5.7.15.5 CSL 3— Max-Tech (UEC less than 0.1 kWh/yr)

For this product class, DOE did not evaluate a maximum-technology feasible level. When a life-cycle cost analysis was done for this product class with just CSL's 0 through 2, no economically justifiable level was found.

5.7.15.6 Estimate of Bill-of-Materials Costs

The MSPs derived from teardowns are pictured in Figure 5.84 and detailed in Table 5-68 for each CSL. The teardown MSPs correspond to the MSP of the units that were torn down and these MSPs are averaged, where DOE analyzed more than one unit for a CSL.

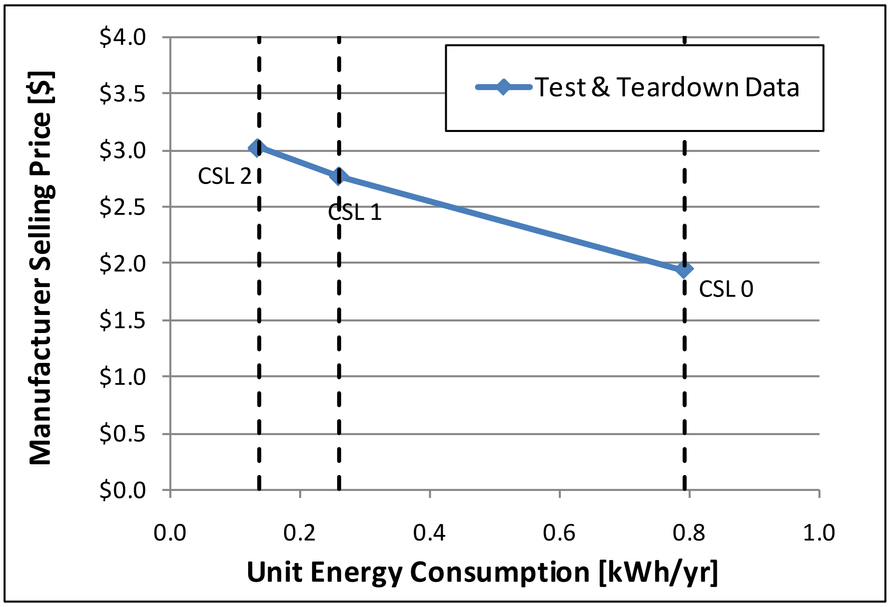


Figure 5.84 MSP vs. UEC for Product Class 9

Table 5-68 CSL Descriptions for Product Class 9

CSL	UEC *kWh/yr*	MSP from Teardowns *$*
0	0.8	1.94
1	0.3	2.77
2	0.1	3.02

5.7.16 Product Class 10: Low Energy, AC Output (Manufacture Interview Data)

The final product class analyzed includes BCs that are a part of uninterruptible power supplies (UPSs). UPSs are battery-operated products that provide backup power to other electronic products in case of a power outage. As such, they differ from other BC products in that they are never used except in cases of emergency and have additional circuitry downstream of the battery (an inverter) to provide AC output to the electronic appliances protected.

Navigant specifically interviewed manufacturers of uninterruptible power supplies to determine the impact of the inverter and other specialized circuitry on the cost-efficiency relationship of BCs for these applications. The results of these interviews are summarized in the sections below. The typical performance of units at each CSL as reported by manufactures is presented in Table 5-69, while further discussion is presented in the sections below.

Table 5-69 Manufacturer Performance Data for Product Class 10 Representative Unit

CSL	Application	Rated Battery Energy *Wh*	Est. Charge Test Duration *h*	Est. 24-Hour Charge Energy *Wh*	Est. 24 Hour Energy Efficiency *%*	Est. Maint. Power *W*	Est. No-Battery Power *W*	UEC *kWh/yr*
0	UPS	70	24	-	-	2.2	-	19.3
1	UPS	70	24	-	-	0.7	-	6.1
2	UPS	70	24	-	-	0.5	-	4.0
3	UPS	70	24	-	-	0.2	-	1.5

5.7.16.1 CSL 0—Baseline (UEC of 19.3 kWh/yr)

The baseline CSL corresponds to the lowest efficiency UPS tested by DOE. According to manufacturers, this level can be met by a variety of charger designs, including a fairly inefficient line-frequency charger with charger-only active-mode efficiency less than 50 percent. For the majority of U.S. consumers power outages are so rare, BCs for UPSs seldom operate in active mode. Therefore, the active mode efficiency does not impact the BC's unit energy consumption. Furthermore, since the battery is internal and the AC line cord attaches directly to the UPS (such that no component of the BC can remain connected to the line), the no-battery mode is not applicable to this product class. Therefore, the only metric influencing unit energy consumption is input power during maintenance mode.

According to the interviews, typical input power during maintenance mode for line-frequency BCs is approximately 2 watts, due to typical linear converter standby losses such as magnetization losses in the transformer or leakage in the bulk capacitor. The parasitic losses in the transformer windings, which are used to control charge current to the battery, also play a role.

Additional losses specific to the UPS, and which cannot be disabled, include the power draw of a microcontroller that monitors not only the battery charging, but also the state of the AC line and communications and control lines connected to a personal computer (the typical electronic product connected to such a UPS). The result is a unit energy consumption of less than 19.3 kWh.

5.7.16.2 CSL 1—Improved (UEC of 6.1 kWh/yr)

More efficient UPSs use a switched-mode topology as the input stage to the charger. The switched-mode chargers have a similar cost as the line-frequency chargers meeting the baseline CSL, but higher active-mode efficiency, typically higher than 85 percent.

However, as before, it is the maintenance mode power that impacts the energy consumption of BCs for this application. The switched-mode charger, because it operates at a much higher frequency, can use a smaller transformer, with consequently lower magnetization losses. Overhead losses due to line monitoring and microcontroller operation can be further reduced, resulting in a maintenance mode power less than 0.75 watt, resulting in a unit energy consumption of less than 6.1 kWh.

5.7.16.3 CSL 2— Best-in-Market (UEC of 4 kWh/yr)

Although DOE was unable to identify any UPSs with a unit energy consumption below 6.1 kWh (the CSL 1 level), manufacturers indicated that incremental improvements could be made to decrease the energy consumption of the BC to this level. In particular, energy-efficient power controller ICs and improved FETs can be used to increase active-mode conversion efficiency of the BC to greater than 80 percent (for a system-wide active-only efficiency above 65 percent). Improvements to the microcontroller (typically used to control the charging process as well as other aspects of the operation of the UPS) can also further decrease energy consumption in maintenance below 0.5 watts. Together, these changes can reduce the unit energy consumption below 4 kWh.

5.7.16.4 CSL 3—Max-Tech (UEC of 1.5 kWh/yr)

Finally, manufacturers speculated on further methods of decreasing the energy consumption of these BCs beyond what is currently available in the market to a max-tech level. Although higher-efficiency switching converters for active-mode efficiency are available, they will not be effectual in further reducing the unit energy consumption of the BC.

As in the other product classes, high-efficiency switched-mode controller ICs that decrease energy consumption at low-load are a potential means of reducing maintenance power. However, manufacturers also speculated on ways to completely disable the primary side of the switched-mode power converter that is the first stage of the BC. By running from the integral battery, the on-board microcontroller could completely shut down the input stage, enabling it only when the battery had discharged past a desirable level or some external condition (such as input voltage variation or communication with a personal computer) warrants it.

According to manufacturers, such a strategy could result in maintenance mode power of 0.2 watts, resulting in a max-tech UEC of 1.5 kWh.

5.7.16.5 Estimate of Manufacturer Selling Price

The results of the aggregated manufacturer interviews are shown in Figure 5.85. Manufacturer selling price was calculated across all CSLs, even though manufacturers only provided data for CSL 2 and CSL 3. The MSPs and the unit energy consumptions are detailed in Table 5-70.

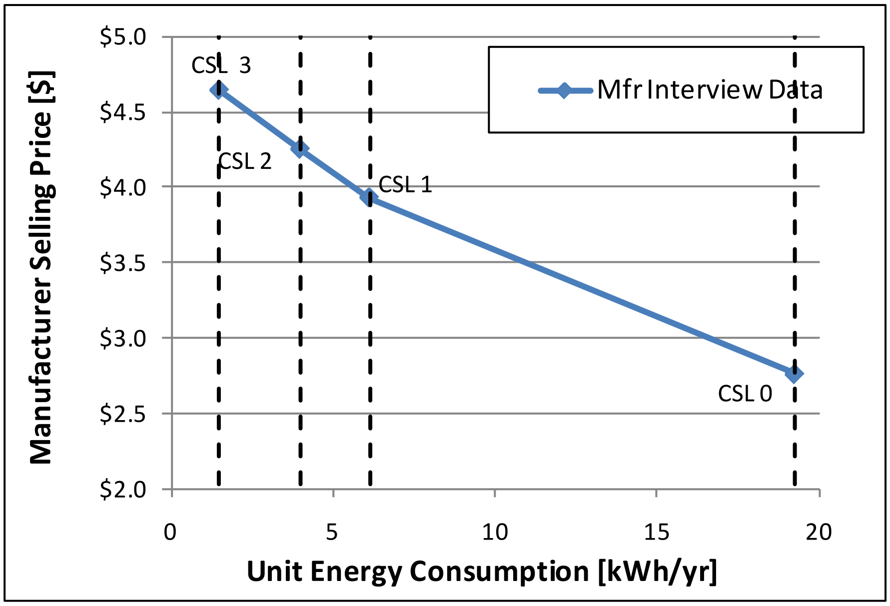


Figure 5.85 MSP vs. UEC for Product Class 10

Table 5-70 CSL Descriptions for Product Class 10

CSL	UEC *kWh/yr*	MSP from Interviews *$*
0	19.3	2.76
1	6.1	3.93
2	4.0	4.25
3	1.5	4.64

5.7.16.1 Test Results and Additional UPS Functionality

When Navigant revisited UPS manufacturers for the NOPR analysis, the manufacturers expressed concerns about the additional functionality that is embedded in many of their UPSs. Manufacturers stated that the additional functionality can cause test measurements (particularly, “maintenance mode” power) to be overstated. When the BC of a UPS is in maintenance mode, it does not mean that the UPS is only maintaining the charge of the internal battery. Instead, many UPSs often perform other functions such as automatic voltage regulation (AVR) or have an extended run battery; two characteristics and end-user utilities that can lead to a high maintenance mode power relative to a basic function UPS. As a result, it is difficult to separate the energy consumption required for battery charging and maintenance from that due to device operation. The situation is analogous to trying to measure the energy consumption of a BC for a notebook computer with the notebook computer turned on and operational. Furthermore, unlike in a notebook computer, the charging and power conditioning functions may not be separable—*i.e.*, turning off the unit may also disconnect the power provided to the battery. Hence, DOE found that it was difficult to accurately compare costs of products because of the varying functionalities of different UPS units. Also, the test results for efficiency were skewed by the additional functions performed by the UPSs. However, additional tests were conducted in an effort to separate out power provided to the battery charging circuitry and the power consumed by the additional functionalities.

When additional UPS testing was done for the NOPR, DOE specifically targeted products with similar volt-ampere (VA) ratings (and therefore generally the same rated battery energy) but varying functionality. Like transformers and other power-electronic components, UPSs are rated in terms of maximum VA output, which is a measure of the total power (both real and reactive) they can provide, and is equal to the maximum power drawn by a load divided by its minimum power factor. DOE intended to test these products and characterize the effects of additional functionality on the UEC calculated for a UPS BC. The units were tested according to the DOE BC test procedure. As was the case for the other product classes, the per-mode measurements obtained using the test procedure were then weighted according to the usage profile to obtain a unit energy consumption. In the case of UPSs, which spend the vast majority of their time in maintenance mode, this simply involved multiplying the maintenance power by number of hours per year (8760).

In order to further understand the variances caused by additional functionalities within various UPSs and their effect on test results produced by the DOE test procedure, a second round of interviews was conducted with manufacturers for the NOPR. From these interviews DOE found that it needed to make a modification to its approach for dealing with battery chargers within UPSs.

When DOE tested UPSs according to the battery charger test procedure, it was unable to obtain maintenance mode power measurements as low as those that manufacturers indicated were possible. DOE believes that the discrepancies between test measurements and the data provided by the manufacturers must be due to its test procedure. That is not to say there is a deficiency in DOE's test procedure; rather there was simply a difference between what data is provided as a result of the test procedure and what data the manufacturers were providing during interviews. DOE believes that their estimates of power consumption due to the battery charger within UPSs are still appropriate estimates; however, DOE still needed to account for the discrepancies between manufacturer data and its test procedure.

For the NOPR, DOE conducted additional testing of UPSs in which it attempted to describe the differences between its test procedure measurement and the values provided by manufacturers. During this round of testing, DOE performed the DOE test procedure, but added another measurement. As mentioned previously, it is extremely difficult to isolate the power consumption due to battery charging from any other UPS functionality, but DOE could measure the input power to the battery. With this additional measurement at the battery charger output terminals, DOE obtained two useful pieces of information. First, it allowed DOE to isolate a portion of battery charging power consumption from all other functions within a UPS and therefore develop a trend line that describes how maintenance mode power will vary as battery energy changes. Second, this measurement combined with the tested units that corresponded to DOE's best-in-market test results (in terms of maintenance mode power as measured in the DOE test procedure) allowed DOE to develop "adders" that it could use to increment the data provided by manufacturers such that it correlated to DOE test results. DOE developed two adders, shown in Table 5-71 below, one for basic UPSs and one for UPSs that incorporate AVR. DOE has proposed to use these two adders to develop an appropriate standard for basic UPSs and UPSs with AVR.

Table 5-71 Supplemental Values for Product Classes 10a and 10b

Product Class	**Maintenance Mode Adder for Proposed Standard (W)**	**UEC Adder for Proposed Standard (kWh/yr)**
10a (UPSs without AVR)	0.4	3.45
10b (UPSs with AVR)	0.8	7.08

The data obtained by testing sample units in the manner described above, resulted in enough data to develop equations in order to accommodate additional functionalities within both basic UPSs and UPSs with AVR functionality. The key data point obtained from this additional testing was the input power to the battery, measured at the exposed terminals of the battery charger throughout the duration of the 24 hour standard test procedure and therefore completely dependent on battery energy and not additional functionality within the UPS. From this additional data, DOE was able to plot resulting input power data points across the various battery energies. After doing so it was revealed that as battery energy increases so does the power required to maintain the battery. The trend line in Figure 5.86 below illustrates this increase in the key metric of battery input power (BIP) versus battery energy for each of the sample units.

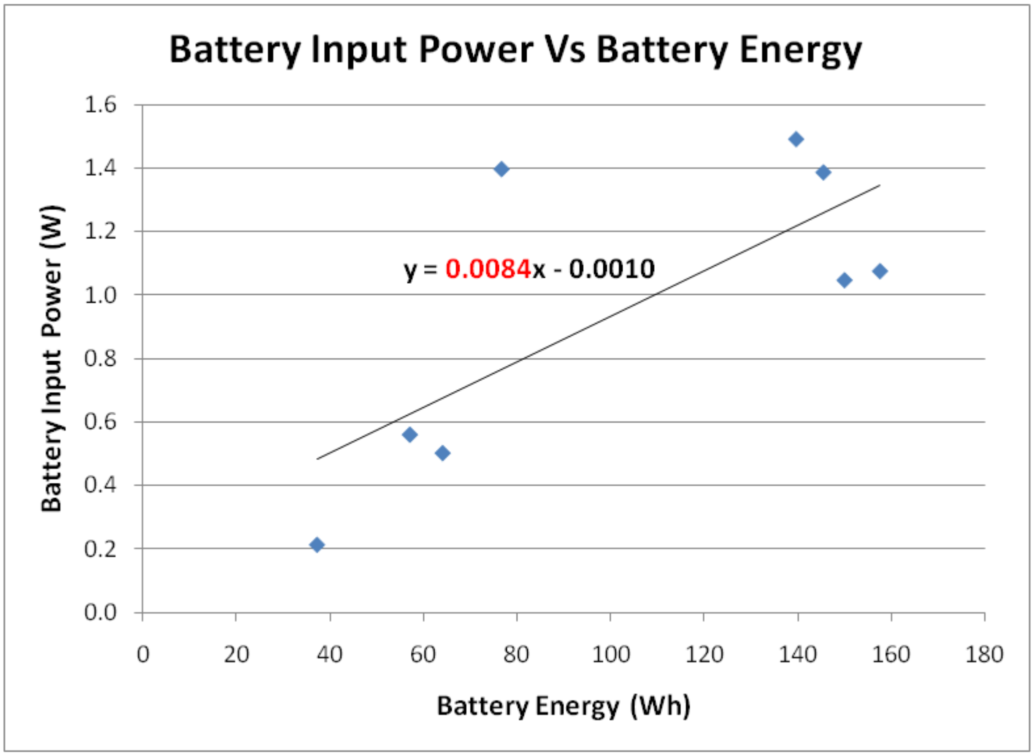


Figure 5.86 Battery Input Power (BIP) with Respect to Battery Energy

From this data, DOE obtained the relative increase in required power at various battery energies. In order to obtain the adder for each of the two types of UPSs, basic UPS and UPSs with AVR functionality, DOE took the trend line shown above and extrapolated out through the representative best-in-market (BIM) test point for each of the two types found during DOE initial testing and teardown. By plotting these three new trend lines (BIP, basic UPS, and AVR UPS) together, DOE could then calculate the difference between BIP and each of the two types of UPSs at the representative unit level, which was a unit with a measured battery energy of 70 Wh. This calculated difference thus becomes the added maintenance mode power which DOE would apply to the standard levels. As with other product classes, boundary conditions were applied to these equations to accommodate the minimum levels of power required at lower battery energies Figure 5.89 below shows the calculation for basic UPSs.

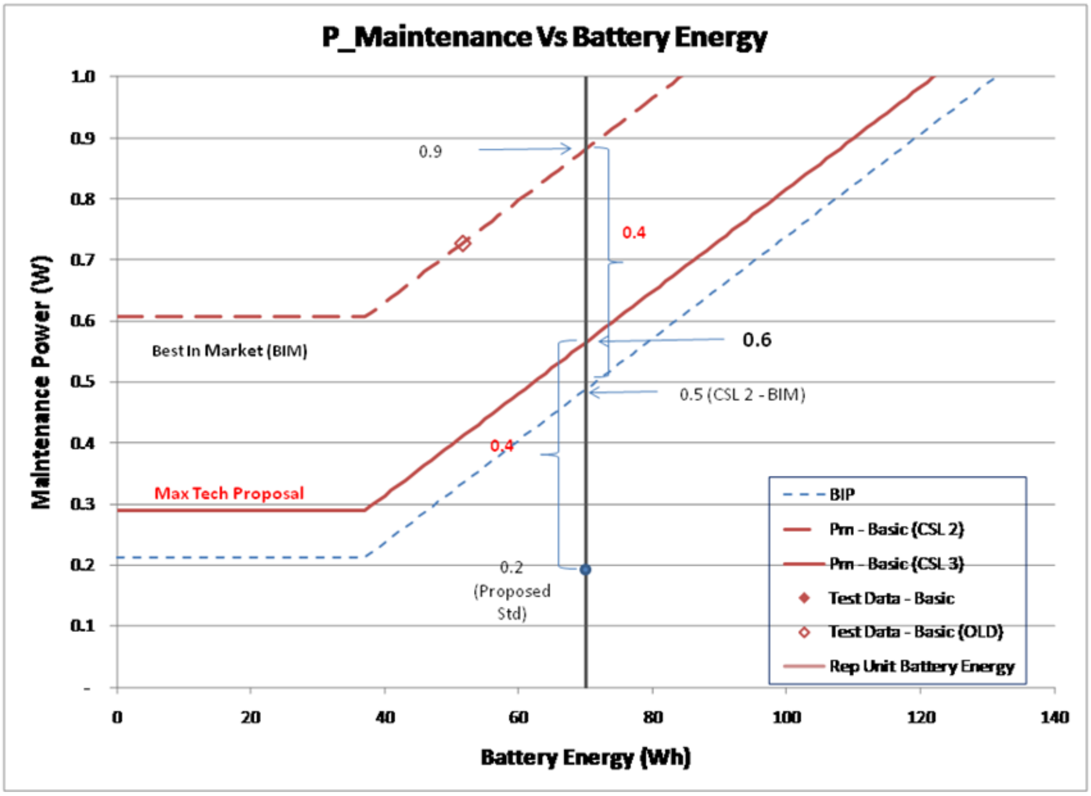


Figure 5.87 Basic UPS Adder developed from Battery Input Power (BIP) Test Results

Finally, the results of testing and weighting appear in Figure 5.88, which shows DOE results as well as the Ecos Consulting results. Additional details on BC testing of UPSs are available in appendix 5B.

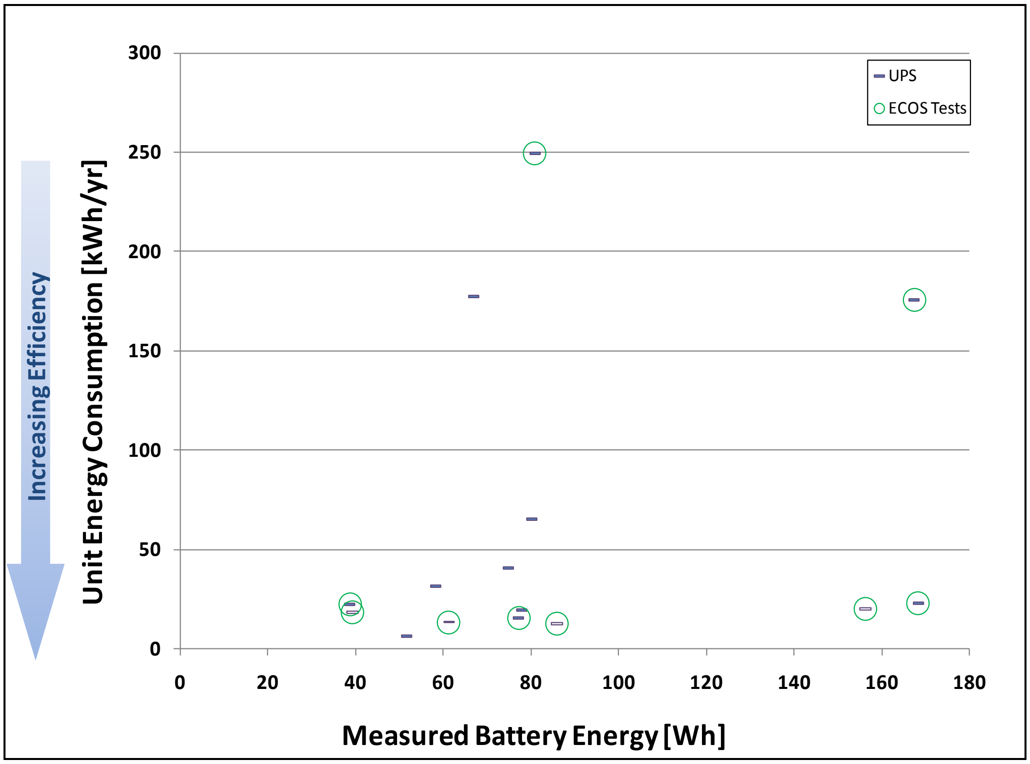


Figure 5.88 Test Results for Product Class 10: Low-energy, AC-output

5.7.17 Scaling of BC Candidate Standard Levels

In order to establish appropriate energy conservation standards for products with all battery energies and battery voltages within a product class, DOE developed an approach to scale UEC for the NOPR. After obtaining the engineering analysis results for each representative unit, DOE had to determine a methodology for extending the UEC at each CSL to all other ratings not directly analyzed for a given product class. To do this, DOE developed an approach in which it makes UEC a function of battery energy.

DOE's scaling approach for the NOPR relies heavily on the test data that has been gathered throughout the rulemaking process. DOE examined each performance parameter individually and when possible, looked at groups of product class test results. For example, product classes 2, 3, and 4 are similar products that use similar technologies and battery chemistries and they all span the same range of battery energy. Therefore, DOE found it prudent to examine all of these products' test results together. DOE developed regression equations for each of the performance parameters needed to calculate UEC at each efficiency level and ultimately, aggregated those equations with assumptions about usage profiles for each product class. That is, DOE examined test results for 24-hour energy, maintenance mode power, and no-battery mode power individually. From this data, DOE derived equations for each parameter as it relates to battery energy. Finally, because each equation was a function of the same parameter, battery energy, they were combined with assumptions about product usage to develop one equation for UEC that consequently became a function of battery energy.

5.7.17.1 Modeling 24-Hour Energy

One of the performance parameters that contributes heavily to a product's UEC is its measured 24-hour energy. As discussed in TSD chapter 3, 24-hour energy is a measurement of how much energy a BC consumes to fully charge its battery plus at least 5 hours worth of energy consumed to maintain the battery's fully charged state. Therefore, it was essential for DOE to accurately model how this parameter changes relative to battery energy.

To begin, DOE plotted its test results of 24-hour energy versus battery energy. From this information DOE found that as battery energy increases, 24-hour energy correspondingly increases in a linear fashion. That is, an equation of the form $y = mx + b$, is an appropriate way to model the relationship between battery energy (x), and 24-hour energy (y). In this form, m represents the slope of the line describing that relationship and b is the y-intercept. The figure below is a graphical depiction of tested values of 24-hour energy relative to battery energy for all products DOE examined in product classes 2, 3, and 4 and as can be seen, that relationship demonstrates very linear characteristics.

The figure also illustrates another relationship that DOE found and used when modeling 24-hour energy in its scaling methodology. In the figure below, blue diamonds correspond to BCs that charge lithium-ion batteries and the red squares correspond to BCs that charge nickel based batteries (both NiMH and NiCd). The regression line that is based on the nickel based data set is steeper than the line describing the lithium-ion BCs. For product classes 2, 3, and 4, DOE found that nickel based chemistries were more prevalent at the baseline and incremental efficiency levels (typically CSL 0 and 1) and products using lithium-ion based chemistries appeared at the best-in-market efficiency level (typically CSL 2). Consequently, when DOE modeled 24-hour energy for each CSL within a product class, it decreased the slope of the regression line as efficiency level improved. That is, as CSL increased, the slope of the line describing 24-hour energy became flatter, which causes DOE's CSL equations to converge as they approach a battery energy value of zero.

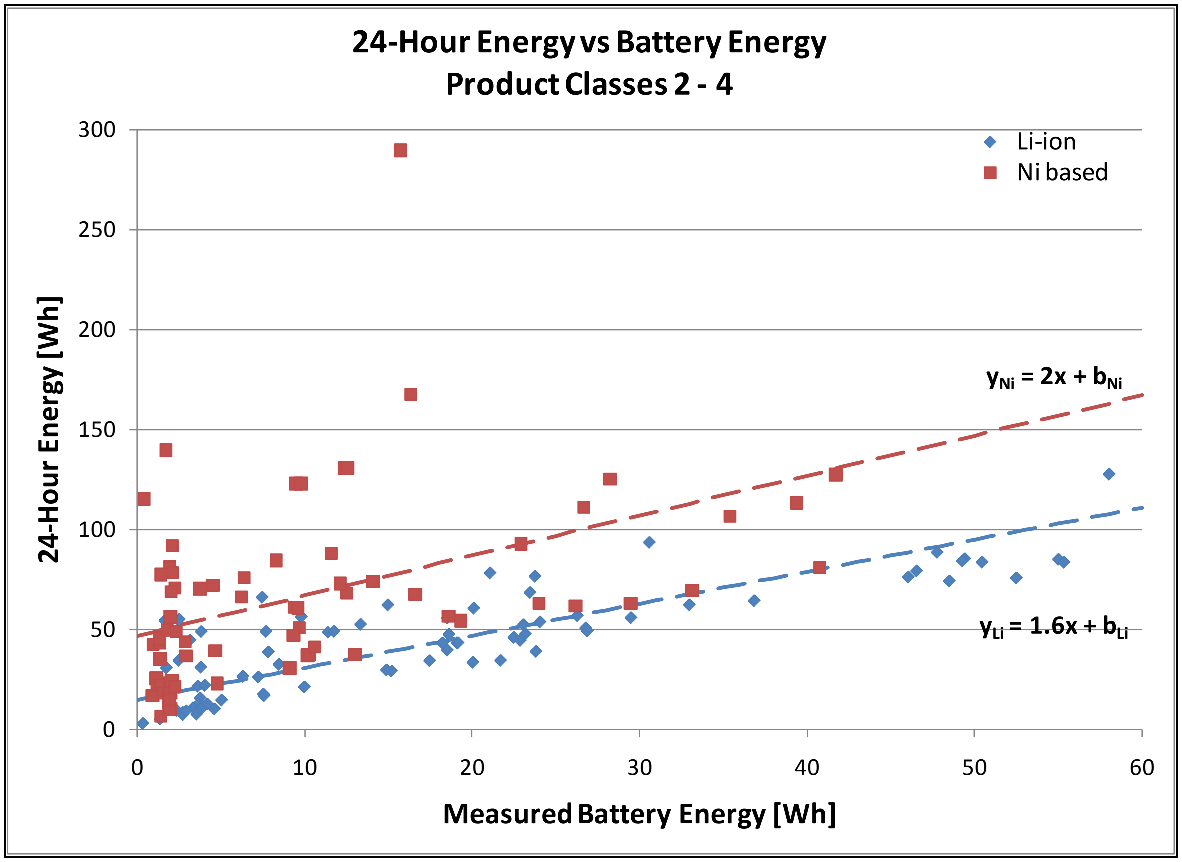


Figure 5.89 24-Hour Energy vs. Battery Energy for Product Classes 2, 3, and 4

To determine the exact slope for the equation of 24-hour energy for each of its CSL equations and for each product class, DOE used slightly varying approaches. For product classes 2, 3, and 4, DOE utilized test data and the relationships it found between 24-hour efficiency (measured battery energy divided by 24-hour energy, expressed as a percent) and battery chemistry. For product classes 5, 6, and 7, which are composed of products that only use lead based battery chemistries, DOE used the 24-hour efficiency of its representative units.

For product classes 2, 3 and 4, DOE found that the 24-hour efficiency of nickel-based batteries peaked around 50 percent, while the same parameter for lithium-ion BCs consistently reached 62.5 percent. When these percentages are inverted to arrive at the slopes, 2 and 1.6 are obtained for the respective chemistries. DOE found that these values correlated well with the slopes of the regression lines it found when modeling 24-hour energy versus battery energy and segregating data series based on chemistry (as depicted in the figure above). Consequently, with one exception, DOE assumed a slope of 2 for those efficiency levels that corresponded to BC products that used Ni-based batteries and 1.6 for those that used lithium-ion batteries. In product class 4, the peak lithium-ion based charger had a 24-hour efficiency of 69 percent. So, for the best-in-market equation describing 24-hour energy for that product class, DOE assumed a slope of 1.45 (or 1/.69).

To determine an appropriate intercept for each equation of 24-hour energy, DOE used the test data of its representative units. After determining the appropriate slope for each CSL, as discussed in the previous paragraph, *b* is the only unknown in the equation $y = mx + b$. For that equation, *y* is equivalent to the 24-hour energy of the tested unit, *x* is its corresponding measured battery energy, and *m* is variable depending upon which efficiency level is being modeled. Plugging those values in and solving for *b* ensures that the equation of 24-hour energy for each product class and for each efficiency level, runs through DOE's representative unit value. After DOE developed its equations for 24-hour energy, it combined them with its equations for maintenance mode power and no-battery mode power to obtain the equation for UEC.

5.7.17.2 Modeling Maintenance and No-Battery Mode Power

The other performance characteristics that DOE examined when developing its scaling methodology, which contribute to UEC, were maintenance mode power and no-battery mode power. To develop equations for these parameters, DOE used an approach similar, but slightly simpler, to that described above for 24-hour energy.

As with 24-hour energy, DOE examined these two performance parameters relative to battery energy. Also, when possible, DOE compiled and examined the test data of multiple product classes at one time. Just as it did for 24-hour energy, DOE grouped product classes 2, 3, and 4; product classes 5 and 6; product classes 7 and 10 were examined on their own. DOE found that the regression equation that demonstrated the highest correlation was again, a linear regression line. However, DOE did not believe that the same regression equation was appropriate for each efficiency level within a product class.

To determine the appropriate slope for the different CSL equations for maintenance mode power and no-battery mode power DOE used slightly different approaches for each of its groups of product classes. For the group containing product classes 2, 3, and 4, DOE again based its value of slope on the different battery chemistries that are found at each CSL. For those CSLs that are representative of nickel-based chemistries, DOE used the slope of the regression line that was found when just examining nickel-based test results. For those CSLs that are representative of lithium-ion battery chargers, DOE used the slope of the regression line found when just examining lithium-ion battery charger test results. For CSLs 0 and 1 for product classes 5 and 6, DOE used the slope of the regression lines that it obtained when examining the performance parameters with respect to battery energy. However, for the higher CSLs and for product class 7, using the slope of regression lines caused erroneous results at the lower range of battery energies. Therefore at those CSLs, DOE held the performance parameter of the representative unit constant across all battery energies.

Finally, to obtain a value for the y-intercept for each of DOE's equations for these two performance parameters, DOE used the same approach as it did for 24-hour energy. That is, DOE set the *y*-intercept equal to the value that causes a line with its predetermined slope to run through the representative unit value of battery energy and maintenance mode power (or no-battery mode power).

The end result of DOE's modeling of 24-hour energy, maintenance mode power, and no-battery mode power is a unique set of equations. For each product class analyzed and each CSL within those product classes, DOE has an equation of the form $y = mx + b$, where *y* represents one of the three aforementioned performance parameters and *x* represents battery energy. The combination of *m* and *b*, is based on the relationships DOE found by examining its test results. For each product class and CSL, this combination is unique such that each equation runs through the corresponding performance parameters of its representative unit.

Finally, the distinct equations obtained for each CSL within each product class for the three performance parameters were aggregated with the assumed usage profile for each product class to obtain a unique UEC equation in the form of $y = mx + b$. For these equations, y is the UEC, x is the battery energy, and m and b are the slope and intercept combinations obtained for each CSL within each product class.

5.7.17.3 Boundary Condition

When DOE was developing its CSL equations for UEC, it found that the correlation between points at very low battery energies was much worse than for the rest of the range of battery energy. Consequently, DOE's equations generated results that were overly restrictive and were not corroborative with DOE's test results. Therefore, DOE generated a boundary condition for its CSL equations, which flattens the UEC below a certain threshold of battery energy. This was in recognitions of the fact that below certain values, fixed power components of UEC, such as maintenance mode power and no-battery power, dominate UEC.

To address this observation, DOE assumed a low boundary (*i.e.* low battery energy) condition. DOE assumed that the smallest theoretical amount of energy that could be consumed by a BC is in the case that the device is never in active mode. Instead, all of the energy consumed during the time allocated to active and maintenance mode in a product class usage profile (See TSD Chapter 7 for a discussion of usage profiles) is time and energy consumed in maintenance mode. Additionally, because the usage profiles for all product classes assume no time in off-mode, the only value added to the maintenance mode energy spent would be energy consumed in standby (no-battery) mode. Thus, the smallest UEC possible is when the unit is assumed to only consume energy in maintenance and no-battery modes throughout the 24 hour period. This minimum value of UEC is calculated using the equation below equation. For those CSLs where DOE found a value of battery energy that corresponded to the minimum UEC calculated with the equation below, DOE did not scale UEC below that threshold battery energy. Instead, DOE assumed a flat value of UEC corresponding to that minimum UEC below the threshold battery energy.

$$UEC_{min} = 365\big((P_m t_{a\&m}) + (P_{sb} t_{sb})\big)$$

Where,
P_m = Maintenance mode power
P_{sb} = Standby mode power
$t_{a\&m}$ = *Time per day spent in active and maintenance mode*
t_{sb} = *Time per day spent in standby mode*

5.7.17.4 Product Classes Not Scaled

When DOE examined its test results, it found that for some product classes, UEC did not vary much with either battery voltage or battery energy. For these few product classes, DOE has elected not to scale UEC with respect to battery energy. Instead, DOE believes that it is sufficient to simply make UEC constant with respect to battery energy. In other words, for these product classes, the energy efficiency standards that DOE promulgates will be the same for all devices manufactured within that product class. The product classes that DOE found little variance in its test results were for BC's capable of inductive charging in a wet-environment (product class 1) and BC's that run off of a DC input voltage (product classes 8 and 9).

5.7.17.5 Results

DOE developed equations in each product class and for each CSL. A notable difference between the equations at each CSL is the changing slope. For higher CSL equations in a given product class, the slope of the UEC line becomes smaller, which means that the line describing UEC versus battery energy becomes flatter. Thus, as products became more efficient, or DOE increased CSLs, the slope of the equation used to describe UEC versus battery energy became smaller. The UEC equations for all CSLs for all product classes are given in the tables below.

Table 5-72 Product Class 2 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.2043 * BE + 8.04	-
1	0.2095 * BE + 5.87	-
2	0.1170 * BE + 2.69	-
3	0.1170 * BE + 0.70	-
4	0.1170 * BE + 0.45	For BE < 0.79Wh, UEC = 0.55 kWh/yr

Table 5-73 Product Class 3 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.0933 * BE + 11.01	For BE < 7.64Wh, UEC = 11.73
1	0.0933 * BE + 3.77	For BE < 9.74Wh, UEC = 4.68 kWh/yr
2	0.0294 * BE + 0.57	For BE < 3.66Wh, UEC = 0.67 kWh/yr
3	0.0294 * BE + 0.53	For BE < 5.04Wh, UEC = 0.67 kWh/yr

Table 5-74 Product Class 4 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.2411 * BE + 33.79	For BE < 9.51Wh, UEC = 36.09 kWh/yr
1	0.2411 * BE + 6.69	For BE < 9.71Wh, UEC = 9.03 kWh/yr
2	0.0891 * BE + 2.87	For BE < 4.18Wh, UEC = 3.24 kWh/yr
3	0.0891 * BE + 1.68	For BE < 9.45Wh, UEC = 2.53 kWh/yr

Table 5-75 Product Class 5 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.0674 * BE + 28.60	For BE < 412.59 Wh, UEC = 56.41 kWh/yr
1	0.0557 * BE + 13.65	For BE < 327.82 Wh, UEC = 31.91 kWh/yr
2	0.0219 * BE + 12.28	For BE < 355.18 Wh, UEC = 20.06 kWh/yr
3	0.0192 * BE	-

Table 5-76 Product Class 6 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.1770 * BE + 49.79	For BE < 234.84 Wh, UEC = 91.36 kWh/yr
1	0.1445 * BE + 23.91	For BE < 193.19 Wh, UEC = 51.83 kWh/yr
2	0.0495 * BE + 18.51	For BE < 239.48 Wh, UEC = 30.37 kWh/yr
3	0.0420 * BE	-

Table 5-77 Product Class 7 Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.0679 * BE + 1.35	-
1	0.0502 * BE + 4.53	-
2	0.0350* BE + 5.68	-

Table 5-78 Product Class 10a Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.0733*BE + 17.86	For BE < 37.2 Wh, UEC = 20.59 kWh/yr
1	0.0733*BE + 4.72	For BE < 37.2 Wh, UEC = 7.45 kWh/yr
2	0.0733*BE + 2.59	For BE < 37.2 Wh, UEC = 5.32 kWh/yr
3	0.0733*BE + 0.19	For BE < 37.2 Wh, UEC = 2.54 kWh/yr

Table 5-79 Product Class 10b Compliance Formula

Candidate Standard Level	Compliance Formula for Unit Energy Consumption	Boundary Condition
0	0.0733*BE + 21.50	For BE < 37.2 Wh, UEC = 24.23 kWh/yr
1	0.0733*BE + 8.36	For BE < 37.2 Wh, UEC = 11.09 kWh/yr
2	0.0733*BE + 6.23	For BE < 37.2 Wh, UEC = 8.96 kWh/yr
3	0.0733*BE + 3.45	For BE < 37.2 Wh, UEC = 6.18 kWh/yr

REFERENCES

---

[1] Environmental Protection Agency (EPA). "ENERGY STAR Program Requirements for Products with Battery Charging Systems: Eligibility Criteria." May 2007. http://www.energystar.gov/ia/partners/product_specs/program_reqs/battery_chargers_prog_req.pdf

[2] Ecos Consulting energy efficiency tests. Provided to DOE by Pacific Gas & Electric. July 7, 2009 and November 2010.

REFERENCES

---

[1] Environmental Protection Agency (EPA). “ENERGY STAR Program Requirements for Products with Battery Charging Systems: Eligibility Criteria.” May 2007. http://www.energystar.gov/ia/partners/product_specs/program_reqs/battery_chargers_prog_req.pdf

[2] Ecos Consulting energy efficiency tests. Provided to DOE by Pacific Gas & Electric. July 7, 2009 and November 2010.

CHAPTER 6. MARKUPS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

This chapter presents DOE's method for estimating the prices paid by end-use consumers for baseline and more efficient battery chargers (BCs) and external power supplies (EPSs), an analysis known as the markups analysis. The markups analysis draws upon the market assessment, contained in chapter 3 of this technical support document (TSD). The markups calculated in the markups analysis are necessary inputs to the life-cycle cost (LCC) and payback period (PBP) analyses, and the national impact analysis (NIA).

The manufacturer selling price (MSP) is the price at which a BC/EPS manufacturer sells a completed BC or EPS, usually to an end-use product manufacturer (sometimes called an original equipment manufacturer or OEM)[a]. In the engineering analysis, DOE estimated BC and EPS prices as MSPs for all product classes and representative units at each candidate standard level (CSL). In the markups analysis, DOE derived two kinds of markups, those that are applied to baseline costs (baseline markups) and those that are applied to incremental cost increases due to standards (incremental markups).

Markups are applied to BCs and EPSs as they move through each step in the distribution chain. The markup applied by an OEM (the manufacturer markup) and the markup applied by an end-use consumer product retailer (the retail markup) can be multiplied together to yield a composite markup. The final product prices, as estimated using these markups and sales tax data, are used in the LCC and NIA to forecast the increase in BC/EPS costs to the consumer that would result from standards.

6.2 METHODOLOGY

6.2.1 Key Assumptions

DOE made five key assumptions in conducting the markups analysis. They are explained in the following subsections.

- The dominant path to market establishes the retail price and, thus, the composite markup for a product.
- The markups applied to end-use products that use BCs and EPSs are proxies for BC and EPS markups.
- The baseline markups that manufacturers and retailers apply to end-use products that use BCs and EPSs are equal to those companies' average markups across their entire product lines.

---

[a] For further discussion of the MSP and its derivation, see chapter 5 of this TSD.

- Expenses like labor and administrative costs remain fixed and need not be recovered in the incremental markup. Profits and other operating costs are assumed to be variable and to scale with the MSP.
- Markups can be derived from inspection of companies' public financial filings.

Furthermore, DOE analyzed and intends to set standards for BCs and EPSs primarily intended for use with residential applications, but is accounting for applications available to residential consumers that are also purchased for and used in a commercial setting. DOE assumed that residential distribution channels represent the dominant path to market for BCs and EPSs, and thus applies markups to all BCs and EPSs based on these distribution channels.

6.2.2 Role of End-Use Product Markups

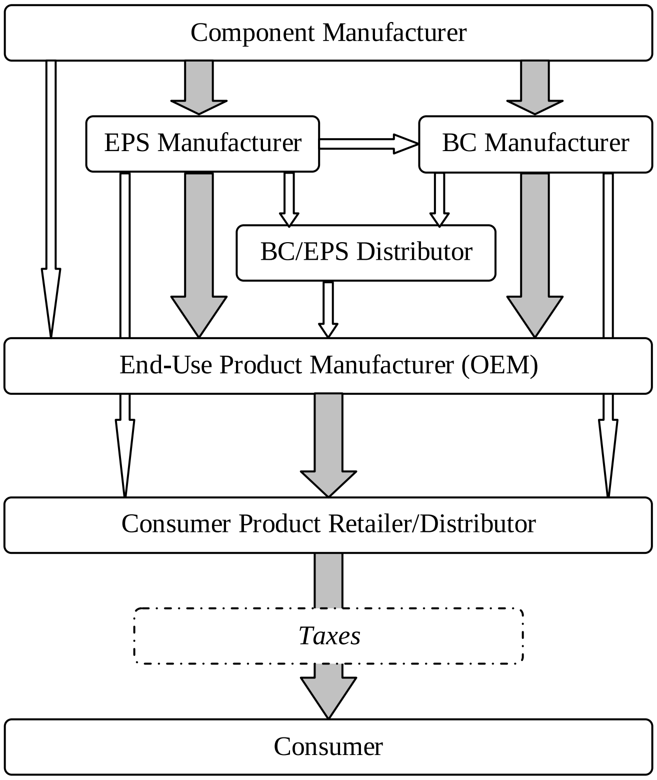
The markups applied to end-use products are used as a proxy for BC and EPS markups. BC and EPS markups generally cannot be measured directly, as these products are typically components of, or accessories to, other end-use products. The specific markups for BCs and EPSs at each stage are therefore assumed to be of equivalent percentages to the markups applied to the end-use products they accompany. For example, if a printer is marked up 30 percent by a retailer, then the individual components of that printer, including the EPS, are assumed to be marked up 30 percent as well.

6.2.3 Distribution Channels

Each company involved in manufacturing, distributing, and selling end-use products applies a markup to cover business costs and maintain profit margins. To determine which markups are applied to the MSP, DOE first needed to model the distribution channels for BCs and EPSs. Figure 6.1 illustrates this model. The most common path to market, as identified by DOE, is depicted by the gray arrows, while alternative paths are depicted by the white arrows. Based on comments from the Association of Home Appliance Manufacturers at the Framework Document public meeting, DOE combined the distribution models of BCs and EPSs. Despite minor variations, the two models are assumed to be similar in their basic structure. (Pub. Mtg. Tr., No. 14 at pp. 229-231) DOE based the markups analysis and stages at which markups were applied on the most common path to market.

DOE has revised its distribution model to include a situation in which a BC manufacturer sources an EPS from a separate EPS manufacturer, prior to distributing the completed BC (with the EPS as a component) to an OEM. DOE believes that this step in EPS distribution occurs for some EPSs used to power BCs for detachable batteries (i.e., BCs that are external to the application). For applications with an integrated BC system, the EPS often provides power to the BC and to the application, and it is therefore a component of the application as well as the BC. It is therefore likely sourced by the OEM, rather than the BC manufacturer.

It should also be noted that, while BC and EPS manufacturers are depicted as separate entities in this revised distribution model, there are instances where one manufacturer will produce both a BC and EPS.



Note that the widths of arrows and sizes of boxes are not drawn to scale and are not meant to be an exact indication of a distribution path's relative prominence. Some organizations may operate at more than one step in this distribution model.

Figure 6.1 Paths of Distribution for Battery Chargers and External Power Supplies

BC and EPS distribution begins with component manufacturers, who produce the circuitry, circuitry components, wiring, housing, and other materials needed to manufacture BCs and EPSs. These are often sold directly to BC/EPS manufacturers, who produce a finished BC or EPS, often for a specific end-use product manufacturer. DOE identified some cases in which BCs or EPSs are manufactured directly by the OEM[b].

BCs and EPSs are then typically purchased by an OEM, at the manufacturer selling price, as an input to an end-use consumer product. The BC and/or EPS is typically integrated into (or packaged with) a consumer product and marked up for sale to a retailer or, less frequently, a wholesaler. This markup applied by the OEM will be referred to as the manufacturer markup.

---

[b] For OEM's, it is more common to manufacture BCs in-house than it is to manufacture EPSs in-house.

While most consumer products are manufactured in an OEM-owned factory, there is a trend towards the use of electronics manufacturing services (EMS), also known as sourced suppliers. EMSs manufacture consumer products under contract to multiple OEMs and take advantage of economies of scale to source materials and components at lower costs. In cases where an EMS is used, both the EMS and OEM apply a markup to the product in question. DOE believes that the markup applied by the OEM, however, is typically lower than it otherwise would be if manufacturing were not outsourced, since the OEM does not need to cover direct manufacturing expenses in its markup. Additionally, DOE believes that the manufacturing expenses, and by extension the markup, applied by the EMS would be lower than that applied by a typical OEM, as the EMS is able to take advantage of economies of scale and other factors to manufacture the product at a lower cost. Thus, DOE does not believe that the presence of an EMS in the supply chain greatly affects the markup on that product and DOE therefore does not account for EMSs in the distribution chain for BCs and EPSs.

Retailers also add a markup to the consumer products they sell. DOE has identified a number of instances where the manufacturing and retail operations for a product are owned and managed by one company. An example is Apple, Inc., which manufactures consumer electronics that are sold in Apple-branded retail stores. DOE believes that the markups on these products are similar to the combination of the manufacturer and retailer markups found on other products, allowing the company to maintain gross margins competitive with other companies in the industry.

It is the OEM and retailer markups that DOE applied to the MSP in this analysis to determine the end-user product prices of BCs and EPSs. The MSP already takes into account BC/EPS manufacturer markups. The majority of states and some local governments then impose a sales tax, resulting in the final cost to consumers. Sales taxes are discussed further in section 6.5.

A note on distributors

Some OEMs, particularly smaller manufacturers, opt to source components through distributors for a variety of reasons, such as easier access to a wider array of components. Distributors tend to have low margins and, due to high sales volumes, can purchase and sell products at reduced prices. Distributors represent an additional step in the chain; however, this step is uncommon. Given DOE’s assumption that the most common path to market sets the final product price, the presence of an EPS or BC distributor in the distribution chain is assumed not to affect the final product price.

The distribution of EPSs and BCs for medical devices differs from those for other devices, as many medical devices are prescribed by a doctor and are not available at traditional retail outlets. These devices are therefore sold by medical distributors, rather than retailers. DOE calculated the retail markups for medical devices using the financial information from several large medical device distributors.

6.2.4 Data Sources

Individual product markups are generally confidential and are not readily available. As such, DOE used corporate sales revenue and the direct costs of products sold, known as costs of goods sold (COGS), to estimate the average baseline markup applied to all products that a company manufactures or sells. For each company analyzed, DOE calculated and averaged markups for the three most recent fiscal years reported (as far back as fiscal year 2006) as of this analysis to arrive at the average markup. The average markup was then used to estimate the markups applied to the company's relevant products that use BCs and/or EPSs. DOE sourced financial data from publicly available filings with the Securities and Exchange Commission (SEC) for all domestic companies analyzed, as well as for those foreign companies trading under an American Depositary Receipt (ADR). For foreign public companies that trade only on foreign stock exchanges, markups were calculated from annual reports and financial statements published on those companies' websites. DOE relied on these data under the assumption that financial data reported by a publicly traded company in a quarterly or annual report have been verified by an independent, certified auditor, and can therefore be considered accurate.

6.2.5 Baseline Markups

A markup is a percentage increase added to the input costs of a good or service so that a company can cover its costs and earn a profit. Gross margin is the component of a product's price, added to COGS, that includes overhead costs (selling, general, and administrative), research and development, other expenses, and profits. To calculate baseline markups, DOE used the following equation:

$$MU_{BASE} = \frac{1}{1-GM} = \frac{REV}{COGS} \qquad \text{EQ 1}$$

where:

$$GM = \frac{REV - COGS}{REV} \qquad \text{EQ 2}$$

and:

MU_{BASE} = baseline manufacturer or retailer markup,
GM = corporate gross margin as a percentage of revenue,
REV = revenue of the OEM/retailer, and
$COGS$ = cost of goods/services manufactured or sold.

For example, if a computer manufacturer operates with revenues of $100 million and has a COGS of $80 million, then the above calculations yield 1.25, or a markup of 25 percent applied to all computers manufactured. Therefore, it is assumed that any BCs or EPSs integrated into the company's computer during the manufacturing process will be marked up 25 percent.

6.2.6 Incremental Markups

DOE assumes a division of costs between those that do not scale with the MSP (fixed costs) and those that do (variable costs). DOE used the baseline markups (MU_{BASE}), which cover all of a retailer's costs (i.e., both fixed and variable costs), to determine the sales price of baseline models. The composite baseline markup relates the BC/EPS MSP to the final product price. DOE considers baseline models to be equipment sold under existing market conditions (i.e., without new energy efficiency standards). DOE calculated the baseline markups for manufacturers and retailers using Equation 1.

Incremental markups (MU_{INCR}) are coefficients that relate the change in the BC/EPS MSP of higher-efficiency models (incremental cost) to the change in the final product price. Incremental markups are applied only to the incremental cost of these higher efficiency models; the baseline markup is still applied to the baseline portion of the MSP. Incremental markups cover only those costs that scale with a change in the MSP (i.e., variable costs). The public financial filings DOE examined did not typically separate labor and occupancy costs from overall expenses, so DOE assumed these fixed costs to be encompassed by "selling, general, and administrative expenses" (SG&A), which are typically reported in financial statements. Incremental markups were calculated using the following equation:

$$MU_{INCR} = 1 + \frac{REV - COGS - SGA}{COGS} = \frac{REV - SGA}{COGS} \qquad \text{EQ 3}$$

where:

MU_{INCR} = incremental manufacturer or retailer markup,
REV = revenue of the OEM/retailer, and
$COGS$ = cost of goods/services manufactured or sold
SGA = selling, general, and administrative expenses

6.2.7 Markups for High Power External Power Supplies

The methodology used to determine markups for EPSs in product class H differs from that used for the other product classes. High-power EPSs used in amateur radio setups are typically sold as standalone products through specialized distributors. Since DOE was able to purchase these products directly, the retail price was known. DOE's contractor, iSuppli, then disassembled these products and estimated their component costs. Using these two costs (retail and component), DOE was able to estimate the typical markup for a high powered EPS at CSL 0 and CSL 1. Given a lack of available data for this product class, DOE assumed that these same markups were applied to products at higher efficiency levels as well. Additional information on the derivation of markups for product class H is available in chapter 5.

6.3 MARKUPS BY END-USE PRODUCT CATEGORY

To determine the markup applied to each BC and EPS product class (or representative unit), DOE first assigned each application to one of 16 end-use product categories, grouped by industry and similarity in manufacturing and/or retail practices. A categorized list of end-use product applications is available in the Excel workbook that accompanies this chapter. DOE then gathered gross margin data and calculated baseline and incremental markups for the leading, publicly traded end-use product manufacturers and retailers[c] in each category. DOE then calculated simple-average retailer and manufacturer markups for each category and multiplied those two markups together to obtain a composite markup for the category using equation 4:

$$MU_{COMP,i} = MU_{MFG,i} \times MU_{RET,i} \qquad \text{EQ 4}$$

where:

$MU_{RET,i}$ = simple average retailer markup in category i,

$MU_{MFG,i}$ = simple average manufacturer markup in category i, and

$MU_{COMP,i}$ = composite markup applied to BCs and EPSs that power applications in category i

Table 6.1 shows the retailer, manufacturer, and composite baseline and incremental markups DOE calculated for each end-use product category.

---

[c] Determined by product surveys, research reports, and most popular products on top retail websites such as www.amazon.com.

Table 6.1 Markups by End-Use Product Category

End-Use Product Category	Manufacturer Markup		Retailer Markup		Composite Markup	
	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental
Portable Audio & Accessories	1.42	1.15	1.48	1.16	2.11	1.34
Mobile Telephony	1.52	1.29	1.41	1.13	2.14	1.46
Stationary Telephony	1.47	1.17	1.40	1.13	2.06	1.32
Computers / Accessories	1.35	1.15	1.39	1.14	1.89	1.31
Printers / MFDs	1.47	1.15	1.35	1.13	1.99	1.31
Geospatial Equipment	1.86	1.51	1.40	1.12	2.60	1.69
Power Tools / Outdoor Appliances[d]	1.51	1.16	1.42	1.16	2.14	1.34
Transport	1.55	1.20	1.52	1.15	2.31	1.37
Photo / Video	1.53	1.12	1.40	1.12	2.14	1.26
Floor Care	1.41	1.14	1.42	1.15	2.00	1.30
Games / Entertainment	1.61	1.29	1.41	1.12	2.27	1.45
Personal Care	1.45	1.10	1.38	1.11	2.00	1.23
Medical	1.93	1.40	1.31	1.06	2.53	1.48
Home Systems	1.37	1.11	1.53	1.21	2.04	1.31
Amateur Radios*	--	--	1.24	1.24	1.24	1.24
Uninterruptible Power Supply	1.35	1.15	1.49	1.17	2.01	1.35
Other**	1.48	1.18	1.47	1.13	2.17	1.33

* These markups were calculated using the methodology described in section 6.2.7.
**“Other” contains applications that do not fit cleanly into any of the other 16 categories. For these applications DOE applied markups that were the simple averages of all individual manufacturer and retailer markups.

6.4 MARKUPS BY BATTERY CHARGER AND EXTERNAL POWER SUPPLY PRODUCT CLASS

In the engineering analysis, DOE identified 10 BC product classes and 15 EPS product classes. Since, by design, each BC/EPS application can be found in only one of the end-use product categories listed in Table 6.1, each BC/EPS end-use application is associated with one composite markup. To calculate the markup for a product class (or, in the case of EPS product class A1, one of four segments within that class), DOE calculated the shipment-weighted average of the markups for applications associated with that class. Table 6.2 gives an example of this.

---

[d] Interviews with at least one manufacturer indicated that DOE’s retailer markup estimate is high and that a markup of 1.13 may be more accurate. SEC data suggests that the retailer markup for power tools is 1.41. If DOE identifies or receives further evidence supporting a lower markup for power tools or an alternate manufacturer or retailer markup for any category, it will consider revising its estimates accordingly.

Table 6.2 Baseline Markup Calculation for EPS Product Class D

EPS Product Class D: AC-AC, Basic Voltage			
Application	EPS Shipments in 2009 (Thousand Units)	Shipments as Percent of Product Class	Baseline Markup
Home Security Systems	4,219	52.8%	2.10
Aquarium Accessories	1,750	21.9%	2.17
Water Softeners/Purifiers	1,150	14.4%	2.10
Indoor Fountains	500	6.3%	2.17
Irrigation Timers	375	4.7%	2.10
Product Class Markup (weighted average markup)			2.12

Table 6.3 and Table 6.4 display the results of these calculations for each BC and EPS product class. A list of applications associated with each class can be found in the market assessment (chapter 3) and the Excel workbook that accompanies the market assessment.

Table 6.3 External Power Supply Markups by Product Class

	Output	Class ID	Composite Baseline Markup	Composite Incremental Markup
AC-DC	Basic Voltage	B: 0-10.25 W	2.1	1.4
		B: 10.25-39 W	2.0	1.3
		B: 39-90 W	1.99	1.34
		B: 90-250 W	1.89	1.31
	Low Voltage	C	2.14	1.44
AC-AC	Basic Voltage	D	2.12	1.34
	Low Voltage	E	2.17	1.33
Multiple-Voltage	<100 W	X	2.27	1.45
High Power	>250 W	H	1.24	1.24

Table 6.4 Battery Charger Markups by Product Class

	Battery Energy	Battery Voltage	Class ID	Composite Baseline Markup	Composite Incremental Markup
AC-DC	<100 Wh	Inductive Connection	1	2.00	1.23
		<4 V	2	2.13	1.40
		4–10 V	3	2.16	1.33
		>10 V	4	1.98	1.32
	100–3000 Wh	<20 V	5	2.35	1.39
		≥20 V	6	2.29	1.37
	>3000 Wh		7	2.35	1.39
DC-DC		<9 V Input	8	2.12	1.37
		≥9 V Input	9	2.60	1.69
AC-AC		AC Output from Battery	10	2.01	1.35

6.5 SALES TAXES

A sales tax is a multiplicative factor applied to a product’s retail price that increases the user’s first cost. DOE obtained information on State and local sales taxes from the Sales Tax Clearinghouse. These data are displayed in Table 6.5 as weighted averages that include county and city sales tax rates.

Table 6.5 State and Local Sales Tax Rates

State	Combined State and Local Tax Rate (%)	State	Combined State and Local Tax Rate (%)	State	Combined State and Local Tax Rate (%)
Alabama	8.20	Kentucky	6.00	North Dakota	5.80
Alaska	1.40	Louisiana	8.75	Ohio	6.80
Arizona	8.15	Maine	5.00	Oklahoma	8.15
Arkansas	8.20	Maryland	6.00	Oregon	0.00
California	9.15	Massachusetts	6.25	Pennsylvania	6.40
Colorado	6.35	Michigan	6.00	Rhode Island	7.00
Connecticut	6.00	Minnesota	7.20	South Carolina	7.05
Delaware	0.00	Mississippi	7.00	South Dakota	5.50
Dist. Of Columbia	6.00	Missouri	7.25	Tennessee	9.40
Florida	6.70	Montana	0.00	Texas	8.05
Georgia	6.95	Nebraska	6.00	Utah	6.70
Hawaii	4.40	Nevada	7.85	Vermont	6.05
Idaho	6.05	New Hampshire	0.00	Virginia	5.00
Illinois	8.20	New Jersey	6.95	Washington	8.75
Indiana	7.00	New Mexico	6.55	West Virginia	6.00
Iowa	6.85	New York	8.45	Wisconsin	5.45
Kansas	8.05	North Carolina	7.85	Wyoming	5.25

Source: Sales Tax Clearinghouse[1]

DOE then calculated average tax rates for each Census division and four large States, weighted by 2009 state-level population. The population-weighted sales tax by division is displayed in Table 6.6. Developing this distribution allowed DOE to correlate the sales tax distribution with the electricity price distribution in the LCC. The table also displays the national, population-weighted average sales tax that is used in the NIA, where DOE did not use a distribution of inputs.

Table 6.6 Weighted Average Sales Tax Rates by Census Division

Division & Large State Name	2009 Population	Population-Weighted Sales Tax (%)
New England	14,429,720	5.55
Mid Atlantic	21,312,506	6.62
East North Central	46,500,668	6.88
West North Central	20,336,243	7.06
South Atlantic	40,657,961	6.45
East South Central	18,271,071	7.90
West South Central	11,068,576	8.41
Mountain	22,122,914	6.80
Pacific	12,483,503	5.21
New York State	19,541,453	8.45
California	36,961,664	9.15
Texas	24,782,302	8.05
Florida	18,537,969	6.70
U.S. Weighted Average:		7.25

Source: DOE analysis of data from the Sales Tax Clearinghouse and U.S. Census Bureau[2]

REFERENCES

---

[1] Sales Tax Clearinghouse, Inc. *State sales tax rates along with combined average city and county rates*. 2009. (Last accessed October 4/, 2010). <https://thestc.com/STRates.stm>

[2] U.S. Census Bureau. *Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2009*, 2009. (Last Accessed December, 2010). Washington, DC. <http://www.census.gov/popest/states/tables/NST-EST2009-01.xls >

CHAPTER 7. ENERGY USE ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 7. ENERGY USE ANALYSIS

The purpose of the energy use analysis is to identify how consumers use products and equipment and thereby to determine the energy savings potential of energy-efficiency improvements. For battery chargers (BCs) and external power supplies (EPSs), DOE's analysis focuses on how end users operate BCs and EPSs with the consumer products they power.

In the energy use analysis, DOE derives unit energy consumption (UEC), which is an input to the life-cycle cost (LCC) and payback period (PBP) analyses described in chapter 8 and the national energy savings (NES) and net present value analysis (NPV) described in chapter 10. The LCC and PBP analyses require data on annual energy use because these data, along with energy prices, establish the operating costs, while the NES and NPV require data on annual energy use to determine lifetime energy consumption.

The engineering analysis, described in chapter 5, reports energy use based on the DOE test procedures. These tests provide standardized results that serve as the basis for comparing the performance of different BCs and EPSs used under consistent conditions. Actual usage in the field varies depending on the conditions in which the appliances are operated.[a] The unit energy consumption calculated in this chapter represents the typical, or average, annual energy consumption of a BC or EPS in the field. A critical part of characterizing end-use loads for BCs and EPSs is identifying usage profiles, which are estimates of the average time a device spends in each mode of operation[b]. Because of the nature of BCs and EPSs, the usage profile of the device relates to the usage profile of the associated application. It is difficult to predict changes in the typical usage pattern over time, so DOE assumes that usage profiles will not change over the analysis period.

BCs and EPSs are power conversion devices that transform input voltage to suitable voltage for the end-use application or battery they are powering. A portion of the energy that flows into a BC or EPS flows out to a battery or end-use product and, thus, cannot be considered to be consumed by the BC or EPS. However, to provide the necessary output power, BCs and EPSs consume energy due to internal losses as well as overhead circuitry. Therefore, the traditional method for calculating energy consumption by measuring the energy a product draws from mains while performing its intended function(s) is not appropriate for BCs and EPSs. Instead, energy consumption is taken to be the energy dissipated by the BC or EPS (losses) and not delivered to the end-use product or battery. Once the energy and power requirements of those end-use products and batteries have been determined, they are considered fixed, and DOE considers only how standards would affect the energy consumption of BCs and EPSs themselves.

DOE used a single usage profile for each application to calculate unit energy consumption for BCs and EPSs. However, usage varies among users. For some applications

---

[a] DOE estimated the power requirements and usage of various end-use applications that use BCs and EPSs based on published reports, comments from interested parties, and test data. Unfortunately, some of the estimates were not based on metered data but rather relied on power measurements and assumptions regarding usage. When data were unavailable, DOE relied on its own estimates of power and usage.

[b] Based on industry convention, DOE estimates usage profiles for EPSs as the average time the device spends in each mode *per week*, while DOE estimates usage profiles for BCs as the average time the device spends in each mode *per day*.

DOE developed an average usage profile based on different user types. DOE examined multiple usage profiles for applications where usage varies widely. Although user types vary significantly and more than two common user types frequently exist, DOE typically examined a light user and a heavy user for those applications in which multiple common user types were identified and data on these user types was identified.

In cases where DOE found that an application was used to significant extents in both the residential and commercial sectors, then it was split into two separate applications: "residential" and "commercial." Applications using mains power at commercial rates are typically used by professional users and therefore experience heavier annual use, while most applications using mains power at residential rates are used by amateur users and therefore experience lighter use. Notable exceptions are power tools, which are often purchased by professional contractors for use in residences.

Section 7.1 explains how DOE calculated EPS energy consumption while section 7.2 is devoted to BC energy consumption. Appendix 7A, the only appendix for this chapter, shows application-level usage profiles, application states, and loading points.

7.1 EXTERNAL POWER SUPPLIES

This section describes EPS modes and application states, how UEC is calculated, and results for each product class.

7.1.1 Modes and Application States

When describing usage and energy consumption from the perspective of the EPS, DOE uses the term "EPS mode." When describing usage and energy consumption from the perspective of the application, DOE uses the term "application state."

7.1.1.1 EPS Modes

An EPS can be in active mode, no-load mode, off mode, or unplugged. Table 7.1 gives a summary of these modes, which are also discussed in chapter 3.

Table 7.1 Summary of EPS Modes

EPS Mode	Status of EPS Connection to Mains	Status of EPS Connection to Application	EPS On/Off Switch Selection (If Switch is Present)
Active	Connected	Connected	On
No-load	Connected	Disconnected	On
Off	Connected	Disconnected	Off
Unplugged	Disconnected	—	—

Active Mode: In active mode, the external power supply takes power from mains and converts it to a form usable by the consumer product or load. Thus, in calculating usage profiles and energy consumption, DOE considers active mode to include any condition where the EPS is connected to both mains and the application.

No-Load Mode: EPCA defines no-load mode for EPSs as the mode of operation when an external power supply is connected to the main electricity supply and the output is not connected to a load. (42 U.S.C. 6291(36)(D)) DOE determined that for EPSs, no-load mode is equivalent to standby, as explained in the "Final Rule on Test Procedures for Battery Chargers and External Power Supplies (Standby Mode and Off Mode)," published in the *Federal Register* on March 27, 2009. (74 FR 13318)

Off Mode: Off mode is a mode applicable only to an EPS with an on/off switch in which the EPS is connected to mains, is disconnected from the load, and the on/off switch is set to "off." This definition was promulgated in the final rule referenced just above. Of the EPSs DOE examined, only two included on/off switches: two high power EPSs used with amateur radios. In both cases, turning off the switch fully severed the circuit, creating a situation electrically equivalent to the EPS being unplugged from mains. Thus, to estimate energy consumption, DOE treated the time when the EPS switch is set to off as equivalent to unplugged time.

Unplugged: Unplugged mode refers to the time in which the EPS is disconnected from mains power. No energy is consumed in this state.

7.1.1.2 Application States

All energy-consuming application states are part of active mode from the perspective of the EPS. That is, since any energy-consuming application state requires the application to be connected to the EPS, any energy-consuming application state is part of EPS active mode. The number of application states and the power required in each state varies by application.

DOE identified application states and loading points for each application. Loading points are expressed relative to nameplate output power, which is the highest level of power an EPS is capable of delivering. DOE conducted loading point tests for three applications. Application states and the corresponding loading points for these three applications are shown in Table 7.2, Table 7.3, and Table 7.4.

Table 7.2 Notebook Computer Application States and Loading Points

EPS Mode	Application State	Description	Percent of Nameplate Output Power
Active	Charging the Battery and Operating	Device is charging the battery while operating (no USB devices are attached). (Sum of "Operating" and "Charging the Battery")	66%
	Operating - High	Device is on, battery is fully charged, DVD drive is operating, USB devices attached and powered.	60%
	Charging the Battery	Device is charging the battery while in device is turned off.	38%
	Operating	Device is on, battery is fully charged, DVD drive is not operating, no USB devices attached.	28%
	Sleep	Device is sleeping, battery is fully charged, DVD drive is not operating, no USB devices attached.	1.6%
	Off	Device is off, battery is fully charged, DVD drive is not operating, no USB devices attached.	0.6%
Source: Test results.			

Table 7.3 LAN Equipment Application States and Loading Points

EPS Mode	Application State	Description	Percent of Nameplate Output Power
Active (Wireless Equipment)	Operating - Transmitting	Device is on and transmitting data.	57%
	Operating – Not Transmitting	Device is on but not transmitting data.	57%
Active (Wired Equipment)	Operating - Transmitting	Device is on and transmitting data.	34%
	Operating – Not Transmitting	Device is on but not transmitting data.	34%
Source: Test results.			

Table 7.4 Portable DVD Player Application States and Loading Points

EPS Mode	Application State	Description	Percent of Nameplate Output Power
Active	Operating - High	Device is on and operating, battery is fully charged.	60%
	Idle	Device is on and idle, battery is fully charged.	54%
	Off	Device is off, battery is fully charged.	1%
Source: Test results.			

The average (across the three tested units) of the loading point corresponding to the highest application state was 60 percent of nameplate output power. DOE used this loading point as the default loading point in the operating application state. DOE assumed a 2 percent load when the application is idle, and a load of 1 percent of nameplate output power when it is off or "asleep". The default loading points DOE used when test data were not available are shown in Table 7.5 and Table 7.6.

Table 7.5 Default EPS Application States and Loading Points

EPS Mode	Application State	Description	Percent of Nameplate Output Power
Active	Operating - High	Application is performing its intended function.	60%
	Idle/Sleep	Application is in idle, ready, or sleep mode.	2%
	Off	Application is turned off	1%
Source: DOE estimates.			

Table 7.6 Default Application States and Loading Points for EPSs used with BCs

EPS Mode	Application State	Description	Percent of Nameplate Output Power
Active	Charging the Battery	BC is charging the application's battery.	37%
	Maintenance	BC is in maintenance mode	17%
Source: DOE estimates.			

7.1.2 Loading Points

For BC applications powered by an EPS, DOE examined test data to determine appropriate loading points to characterize charging and maintenance application states. The power requested by a BC varies considerably during charging, as illustrated by Figure 7.1. DOE estimated average input power over the duration of a single charge by dividing estimated BC active energy by estimated charge time. From this value, DOE deduced average EPS output power during a charge using the tested average active-mode efficiency of the EPS. Given the nameplate output power and average output power over a charge, DOE calculated the average loading point over a charge. DOE test results indicated an average maintenance mode loading point of 17 percent of nameplate output power. Application states and loading points for each EPS application examined are in appendix 7A.

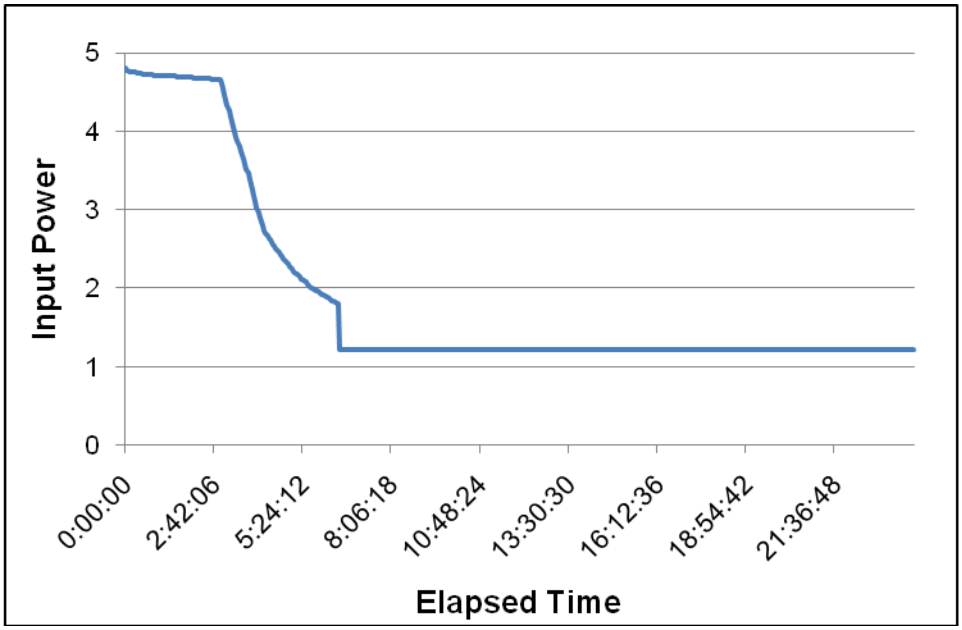


Figure 7.1 Charging Input Power over Time (Portable Video Game Console)

7.1.3 Calculating External Power Supply Energy Use

EPS energy consumption (UEC) is the sum of energy consumed in active mode (UEC_{Active}) and in no-load mode (UEC_{NL}).

$$UEC = UEC_{Active} + UEC_{NL}$$

To describe EPS active-mode energy, UEC_{Active}, it is necessary to examine each active-mode state:

$$UEC_{Active} = UEC_{Active1} + UEC_{Active2} + UEC_{Active3} + \cdots$$

Where $UEC_{Active(i)}$ is EPS active-mode energy in application state i. EPS active-mode energy in each application state is the product of EPS active power, $P_{Active(i)}$, and time, $t_{Active(i)}$ in each state. Therefore,

$$UEC_{Active(i)} = P_{Active(i)} \times t_{Active(i)}$$

and

$$UEC_{Active} = P_{Active1} \times t_{Active1} + P_{Active2} \times t_{Active2+} + \cdots$$

No-Load mode energy is given as:

$$UEC_{NL} = P_{NL} \times t_{NL}$$

Where P_{NL} is no-load power and t_{NL} is time in no-load. Combining active and no-load mode values provides total EPS unit energy consumption:

$$UEC = P_{Active1} \times t_{Active1} + P_{Active2} \times t_{Active2} + \cdots + P_{NL} \times t_{NL}$$

Thus, to calculate the energy consumption of an EPS, DOE combined the time values (from usage profiles) with power values. Section 7.1.4 explains how these power values were calculated, and section 7.1.5 explains how the time values were derived.

7.1.4 EPS Power by Mode of Operation

No-load mode power (P_{NL}) is the measured power drawn by the EPS from mains while in no-load mode. Because the EPS is disconnected from the application, all of the power drawn from mains is consumed by the EPS. For each candidate standard level (CSL), an associated no-load mode power is given.

EPS power in active mode is a function of four factors: the nameplate output power of the EPS, the proportion of full load required by the application (as discussed above), the active-mode efficiency of the EPS, and no-load mode power. EPS power during active mode varies as the power requirements of its load vary.

DOE used two different approaches to calculate EPS power in active mode—one for application states requiring 25 percent or more of the EPS's nameplate output power and another for application states requiring less than 25 percent.

The approach for application states requiring 25 percent or more of the EPS's nameplate output power is straightforward. The EPS test procedure measures the active-mode efficiency (η_{EPS}) of the EPS at 25, 50, 75, and 100 percent of nameplate output power or current. The active-mode efficiency of the EPS is then defined as the average of these four values (points 2, 3, 4, and 5 in Figure 7.2). As such, power is

$$P_{Active} = P_{Out} \times \left(\frac{1}{\eta_{EPS} - 1}\right)$$

For example, an EPS delivering an output power of 10 watts at 75 percent efficiency would consume:

$$P_{Active} = 10W \times \left(\frac{1}{0.75 - 1}\right) = 3.33W$$

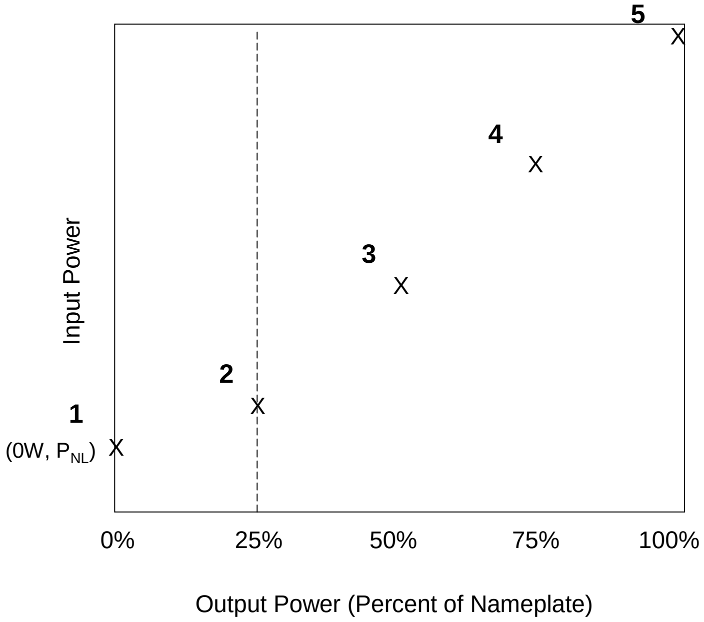


Figure 7.2 Example Measurements from the EPS Test Procedure

Most applications have some application states that require an output power below 25 percent of nameplate. Additionally, many applications spend a significant portion of time in these states. However, at these low power levels, the efficiency of an EPS is relatively low. Thus, DOE does not use the active-mode efficiency measurement alone.

Instead, DOE calculates energy consumption in this region by interpolating between two known points: (1) the no-load mode power and (2) the active-mode power at 25 percent of nameplate output power. These are points 1 and 2 in Figure 7.3. At an output power of 25 percent, the energy consumed by the EPS is:

$$P_{Active} = P_{Out} \times (\frac{1}{\eta_{EPS} - 1})$$

At an output power of 0 percent (no-load mode), EPS power is: $P = P_{NL}$. Given these two known values, DOE assumes that the energy consumed by an EPS at an output power between 0 and 25 percent of nameplate output power must fall on a curve between these two points.

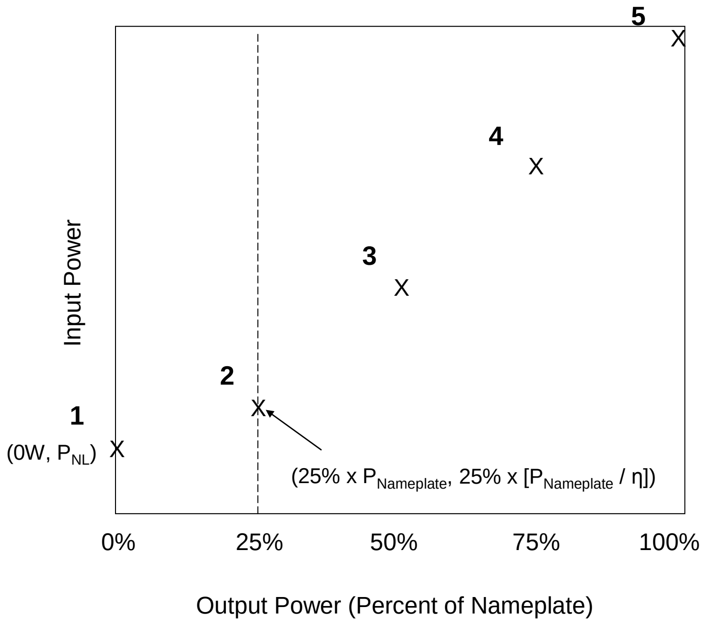


Figure 7.3 Relationship between EPS Input Power and Output Power at Five Loading Points

DOE approximates this curve with a straight line between points 1 and 2, which can be described by the following equation relating input power to output power:

$$P_{In} = m \times P_{Out} + B$$

Where P_{In} is the EPS input power, B is the y-axis intercept, or P_{NL}, and m is the slope, or:

$$m = \frac{\Delta y}{\Delta x}$$

$$m = \frac{\left(25\% \times \left[\frac{P_{Nameplate}}{\eta_{EPS}}\right]\right) - P_{NL}}{\left(25\% \times P_{Nameplate}\right) - 0}$$

Thus, for output power levels below 25 percent of nameplate output power, the input power of the EPS is:

$$P_{In} = \frac{\left(25\% \times \left[\frac{P_{Nameplate}}{\eta_{EPS}}\right]\right) - P_{NL}}{25\% \times P_{Namplate}} \times P_{Out} + P_{NL}$$

Since

$$\boldsymbol{P_{Active} = P_{In} - P_{Out}}$$

Then

$$P_{Active} = \frac{\left(25\% \times \left[\frac{P_{Nameplate}}{\eta_{EPS}}\right]\right) - P_{NL}}{25\% \times P_{Namplate}} \times P_{Out} + P_{NL} - P_{Out}$$

Or

$$P_{Active} = \frac{\left(25\% \times \left[\frac{P_{Nameplate}}{\eta_{EPS}}\right]\right) - P_{NL}}{25\% \times P_{Namplate}} \times P_{Out} + P_{NL}$$

7.1.5 External Power Supply Usage Profiles

Because usage of an EPS is tied to usage of the application, DOE identified usage profiles for a variety of applications. Usage profiles for many of the most common applications were developed based on published research and stakeholder comments. Where usage data were lacking, DOE assigned the application a generic usage profile. The nine generic EPS usage profiles DOE used in its analysis are shown in Table 7.7. For EPSs that power BC applications, DOE assigned a usage profile that is consistent with the associated BC usage profile. An example of this is shown in Table 7.8. All usage profiles are shown in appendix 7A, while sources are included in BCEPS_EnergyUse_NOPR.xlsx.

DOE used a single usage profile for each application to calculate unit energy consumption. For most applications the usage profile represents a typical user. However, usage can vary significantly depending on the user. Therefore, for some applications, including notebook computers and video game consoles, DOE developed multiple usage profiles to account for different usage patterns. DOE then calculated a weighted-average usage profile for each of these applications, based on an estimated distribution of user types, and used these to calculate application-specific UECs.

Table 7.7 Generic EPS Usage Profiles

INFREQUENTLY USED (APPLICATION IS MOSTLY TURNED OFF)			
EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Operating	60%	5
	Idle	2%	3
	Sleep/Off	1%	160
No-load	Disconnected from EPS	-	0
Unplugged	Disconnected from EPS	-	0

INFREQUENTLY USED (EPS IS MOSTLY UNPLUGGED)			
EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Operating	60%	5
	Idle	2%	3
	Sleep/Off	1%	0
No-load	Disconnected from EPS	-	0
Unplugged	Disconnected from EPS	-	160

MOSTLY NO-LOAD AND UNPLUGGED			
EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Operating	60%	21
	Idle	2%	21
No-load	Disconnected from EPS	-	63
Unplugged	Disconnected from EPS	-	63

ALWAYS ACTIVE (APPLICATION IS ALWAYS PLUGGED IN AND OPERATING)			
EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Operating	60%	168
No-load	Disconnected from EPS	-	0
Unplugged	Disconnected from EPS	-	0

RARELY CHARGED			
EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Charging	37%	1.4
	Maintenance	17%	2.1
No-load	Disconnected from EPS	-	0
Unplugged	Disconnected from EPS	-	164.5

1 CHARGE PER WEEK (MOSTLY UNPLUGGED)

EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Charging	37%	3
	Maintenance	17%	4
No-load	Disconnected from EPS	-	0
Unplugged	Disconnected from EPS	-	161

2 CHARGES PER WEEK

EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Charging	37%	10
	Maintenance	17%	42
No-load	Disconnected from EPS	-	60
Unplugged	Disconnected from EPS	-	56

2 CHARGES PER WEEK (LOW MAINTENANCE)

EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Charging	37%	10
	Maintenance	17%	14
No-load	Disconnected from EPS	-	11
Unplugged	Disconnected from EPS	-	133

MOSTLY MAINTENANCE

EPS Mode	**Application State**	**Percent of Nameplate Output Power**	**Time per Week (hours)**
Active	Charging	37%	7
	Maintenance	17%	158
No-load	Disconnected from EPS	-	4
Unplugged	Disconnected from EPS	-	0

Table 7.8 Generic EPS Usage Profile for an EPS Powering a BC Application

	[hours/day]					[#/day]
BC Usage Profile	**BC Active**	**BC Maintenance**	**No Battery**	**Unplugged**	**Off**	**Charges**

2 Charges per week	1.4	6.1	8.5	8	0	2/7
EPS Usage Profile	**Active3**	**Active4**	**No-load**	**Unplugged**	**-**	**-**
2 Charges per week	1.4	6.1	8.5	8	-	-

7.1.6 External Power Supply Unit Energy Consumption Values

DOE calculated UEC values at each CSL for the EPSs associated with each application. These application-level UECs are inputs to the LCC analysis and the national impact analysis (NIA).

For each application in product class B, DOE selected a typical EPS nameplate output power(s), based on a market survey of common applications (see BCEPS_Master_Survey.xls for more details). Based on this information, DOE then assigned each application to the representative unit that best matched the nameplate output power of the application’s EPS. Table 7.9 shows how applications were grouped based on nameplate output power. Some applications are common to more than one representative unit. Some notebook computers, for example, are shipped with 120 watt EPSs while others are shipped with 60 watt EPSs. Applications with wide ranging EPS nameplate output powers were split into two or more groups as appropriate.

Table 7.9 External Power Supply Representative Unit and Associated Power Output Range

Representative Unit	Nameplate Output Power	Nameplate Output Voltage	Range of Nameplate Output Powers
	[W]	[V]	[W]
1	2.5	5	0-10.25
2	18	12	10.26-39
3	60	15	40-90
4	120	19	91-250

Once EPSs were sorted into these four groups, DOE calculated UEC values for each application using the nameplate output power of the representative unit based on the usage profile and loading points specific to that application. In this way, DOE could ensure that the LCC analysis weighed the incremental costs for an EPS of a given output power with the energy cost savings for an EPS with that same output power. Because the EPS LCC analysis samples units at the application level, this methodology further ensures that each application’s unique usage profile and loading points are considered in the calculation. Sections 7.1.6.1 through 7.1.6.3 examine application-specific usage profiles for each representative product class.

7.1.6.1 Product Class B: Basic Voltage AC/DC External Power Supplies

Product class B is the largest EPS product class, with over 190 million units shipped in 2009. Representative units with nameplate output powers of 2.5W, 18W, 60W, and 120W were identified and analyzed for this product class. Based on these representative units, this class was subdivided into four segments, and every EPS in this class has been assigned to one of the four segments based on its nameplate output power.

Cordless phones and answering machines (which DOE assumes to be integrated with cordless phones) make up the majority of units in the segment associated with the 2.5 watt representative unit. Cordless phone and answering device EPSs are always in EPS active mode, since the EPS continues to power the base station when the handset is removed. UECs for each of the top ten applications in this segment are shown in Table 7.10.

Table 7.10 Application-Specific Unit Energy Consumption for Product Class B, 2.5 Watt Representative Unit

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
Answering Machines	Residential	14,042,770	4.6	3.0	2.6	2.3	2.1
Cordless Phones	Residential	10,980,070	4.6	3.0	2.6	2.3	2.1
Mobile Phones	Residential	8,481,510	2.6	1.6	1.1	0.9	0.7
Portable Video Game Systems	Residential	6,481,903	2.9	1.8	0.8	0.7	0.3
Beard and Moustache Trimmers	Residential	5,287,500	0.2	0.1	0.1	0.1	0.1
Smartphones	Residential	3,498,855	2.7	1.7	1.1	1.0	0.8
Baby Monitors	Residential	3,400,000	4.1	2.6	1.9	1.7	1.4
Answering Machines	Commercial	2,876,230	4.6	3.0	2.6	2.3	2.1
Cordless Phones	Commercial	2,248,930	4.6	3.0	2.6	2.3	2.1
Shavers	Residential	2,164,000	2.9	1.8	1.3	1.1	0.9
Other Applications		9,011,383	-	-	-	-	-

Notes: Includes all AC/DC basic voltage EPSs with nameplate output power up to 10.25 watts.

LAN equipment represents the highest share of EPS shipments associated with the 18 watt representative unit. Because LAN equipment is always on, energy use is relatively high. DOE performed loading point tests on two pieces of LAN equipment. Both tested units consumed the same amount of energy in active-transmitting mode and active-idle mode. UECs for each of the top ten applications in this segment are shown in Table 7.11.

Table 7.11 Application-Specific Unit Energy Consumption for Product Class B – 18 Watt Representative Unit

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
LAN Equipment	Residential	15,464,294	22.6	17.6	14.7	12.2	7.0
Digital Picture Frames	Residential	9,132,620	29.9	23.2	19.4	16.1	9.3
MP3 Players	Residential	7,853,150	0.6	0.4	0.4	0.3	0.2
Media Tablets	Residential	6,302,424	5.2	3.7	2.9	2.1	1.2
VoIP Adapters	Residential	5,919,000	6.1	4.0	3.0	2.0	1.0
Portable DVD Players	Residential	3,702,700	1.8	1.3	1.0	0.8	0.4
Wireless Charging Stations	Residential	3,496,248	5.2	3.7	2.9	2.1	1.2
LAN Equipment	Commercial	3,167,386	22.6	17.6	14.7	12.2	7.0
Computer Speakers	Commercial	2,623,118	14.2	10.6	8.6	6.8	3.8
Image Scanners	Residential	1,986,603	5.5	3.5	2.5	1.6	0.7
Other Applications		10,609,760	-	-		-	-

Notes: Includes all AC/DC basic voltage Class A EPSs with nameplate output power between 10.25 and 39 watts.

A majority of EPSs in both the third and fourth segments power notebook computers. These segments are associated with the 60 and 120 watt representative units, respectively. These products are used in both the commercial and residential sectors, and DOE assumed that use varies depending on the user. DOE considered two user types for notebook computers based on a report by the Natural Resources Defense Council.[1] The “road warrior” usage profile has significant unplugged time whereas the “desktop replacement” profile has very little unplugged time and more time in active operating modes. DOE incorporated another active-mode state into the notebook profiles by incorporating time playing a DVD.[2]

Video game consoles are the second most common application in the third segment. DOE defined two usage profiles for this application, one for a light user and one for a heavy user. The usage profiles were based on in-home usage audits of video game consoles conducted by The Nielsen Company in 2006. [3] DOE assumed 80 percent of users are light users and 20 percent are heavy users. DOE also incorporated DVD usage for video game consoles. DOE estimated that DVD usage did not vary among user types, and that one-third of video game consoles would be used as a DVD player. As part of the determination analysis, DOE identified loading points for the Xbox 360, which uses a multiple-voltage EPS. DOE applied these same loading points to other video game consoles. UECs for each of the ten applications in the third segment and three applications in the fourth segment are shown in Table 7.12 and Table 7.13, respectively.

Table 7.12 Application-Specific Unit Energy Consumption for Product Class B – 60 Watt Representative Unit

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
Notebooks	Commercial	11,568,975	12.0	10.6	8.9	7.5	4.7
Video Game Consoles	Residential	11,514,798	13.4	11.9	9.9	8.3	5.2
Notebooks	Residential	9,465,525	10.9	9.7	8.1	6.8	4.3
Netbooks	Commercial	4,771,635	8.9	7.9	6.5	5.4	3.4
Netbooks	Residential	3,904,065	8.9	7.9	6.5	5.4	3.4
Ink Jet Imaging Equipment	Residential	3,390,197	13.7	12.0	10.5	9.1	5.7
LED Monitors	Commercial	1,306,098	25.1	21.6	20.3	18.0	11.2
Ink Jet Imaging Equipment	Commercial	694,378	15.5	13.4	12.4	10.9	6.8
LED Monitors	Residential	643,302	15.9	14.0	12.0	10.3	6.4
Sleep Apnea Machines	Residential	300,000	22.5	19.4	17.8	15.7	9.8

Notes: Includes all AC/DC basic voltage Class A EPSs with nameplate output power between 40 and 89 watts.

Table 7.13 Application-Specific Unit Energy Consumption for Product Class B – 120 Watt Representative Unit

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
Notebooks	Commercial	3,856,325	21.2	18.4	15.5	14.8	7.7
Notebooks	Residential	3,155,175	19.3	16.7	14.1	13.4	7.0
Portable O2 Concentrators	Residential	9,000	2.0	1.7	1.5	1.5	0.8

Notes: Includes all AC/DC basic voltage Class A EPSs with nameplate output between 90 and 250 watts.

7.1.6.2 Product Class X: Multiple-Voltage External Power Supplies

The only application that DOE has identified for multiple-voltage EPSs is Microsoft's video game console, the Xbox 360. Its UEC values, by CSL, are displayed in Table 7.14.

Table 7.14 Application-Specific Unit Energy Consumption for Product Class X

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
Video Game Consoles	Residential	7,676,532	123.4	33.1	32.5	27.0	-

7.1.6.3 Product Class H: High Power External Power Supplies

The only application that DOE has identified for high power EPSs is amateur radios. The UEC values for product class H are displayed by CSL in Table 7.15.

Table 7.15 Application-Specific Unit Energy Consumption for Product Class H

Top Applications by Shipments	Sector	Shipments	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
		(Units)	(kWh/year)				
Amateur Radios	Residential	3,000	234.0	89.9	44.3	35.4	21.3

7.2 BATTERY CHARGERS

This section describes battery charger modes, how UEC is calculated, and results for each product class.

7.2.1 Battery Charger Modes

For the purposes of calculating energy consumption, DOE considers a BC to always be in one of the following five states, which are also discussed in chapter 3:

- *Active Mode*: The DOE test procedure for BCs defines active mode as the condition in which the battery charger is connected to a power source; a battery is attached to the charger; and the battery charger is charging a depleted battery, equalizing its cells, or, “performing other one-time or limited-time functions necessary for bringing the battery to the fully charged state.” (42 U.S.C. 6295(gg)(1)(A)(i))

- *Maintenance Mode*: The DOE test procedure for BCs defines maintenance mode as the condition in which the battery charger is connected to mains power and the battery is fully charged, but is still connected to the charger.

- *Standby Mode or No-Battery Mode*: The DOE test procedure for BCs defines no-battery mode as the condition in which the battery charger is connected to mains power and no battery is attached to the charger. DOE revised its BC test procedure to define standby mode as equivalent to no-battery mode for BCs. (74 FR 13318)

- *Off Mode:* For BCs, off mode is the condition in which the charger is connected to mains power, the charger is not connected to the battery, and all switches on the device are in the off position.

- *Unplugged*: The battery charger is disconnected from mains power. No energy is consumed in this mode.

7.2.2 Battery Charger Usage Profiles

The BC usage profiles DOE used in the preliminary analysis made use of the following measures:

(1) *Equivalent Charges per Day (n)*: The number of full charges completed in a day. This is the product of number of the frequency of charging (charges per day divided and days per week) and the depth of discharge of each charge. An application charged once per week from 100 percent depth of discharge would have 1/7 charges per day.
(2) *Total Time in Active and Maintenance Mode ($t_{Active}+t_{Maint}$):* The sum of time spent in active and maintenance modes over 24 hours.
(3) *Time in No-Battery (Standby) Mode (t_{NB}):* The time per day spent in no-battery mode.
(4) *Time in Off Mode (t_{Off}):* The time per day spent in off mode.
(5) *Time Unplugged (t_{UP}):* The time per day spent unplugged.

As with EPSs, usage of a BC is tied to usage of the application. Therefore, DOE gathered usage profiles for a variety of applications. Where usage data were lacking, DOE assigned the application a generic usage profile. The generic BC usage profiles DOE used in the preliminary analysis are shown in Table 7.16.

Application usage depends strongly on the individual user. For most applications, DOE assigned a single usage profile to represent all users. For some applications, DOE developed multiple usage profiles to account for different users. DOE then calculated a weighted-average usage profile based on an estimated distribution of user types. Usage profiles for each application are detailed in Appendix 7A.

Table 7.16 Generic Battery Charger Usage Profiles

Description	Active + Maintenance	No Battery (Standby)	Unplugged	Off	Charges	Source
	Hours per Day				Number per Day	
All Maintenance	24.0	0	0	0	1/50	PG&E for emergency backup systems
Mostly Maintenance	23.5	0.5	0	0	1/7	Based on PG&E for electric housewares
Rarely Charged	0.5	0	23.5	0	1/14	DOE estimate
1 Charge per week (mostly unplugged)	1.0	0	23.0	0	1/7	DOE estimate
2 Charges per week (low maintenance)	3.5	1.5	19	0	2/7	DOE estimate
2 Charges per week	7.5	8.5	8.0	0	2/7	PG&E for MP3 player
5 Charges per week	6.0	7.0	11.0	0	5/7	PG&E for mobile phone
7 Charges per week - light use	21.8	2.2	0	0	1	Based on PG&E for cordless phone
7 Charges per week - heavy use	12.0	12.0	0	0	1	PG&E for wheelchair

7.2.3 Calculating Battery Charger Energy Use

7.2.3.1 General Energy Use Methodology

UEC represents the annual energy consumption of a battery charger. To accurately represent usage in the field, DOE calculates UEC by combining a usage profile with the energy performance characteristics for each energy-consuming mode. For BCs, UEC over a given time period is the sum of:

(1) *Charge Energy Consumption over time (E_{Charge})*: The product of the number of 24-hour charge cycles and the 24-hour charge cycle energy consumption measured in the test procedure, less battery energy;

(2) *Maintenance Mode Energy Consumption (E_{Maint})*: The product of the time spent in maintenance mode and the power drawn while in maintenance mode;

(3) *No Battery (Standby) Mode Energy Consumption (E_{NoBatt})*: The product of the time spent in standby mode and the power drawn while in standby mode; and

(4) *Off Mode Energy Consumption (E_{Off})*: The product of the time spent in off mode and the power drawn while in off mode.

Charge Energy Consumption: Given the 24-hour charge and maintenance energy measurement at each CSL from the test procedure, E_{24}, DOE calculated E_{Charge} by subtracting battery energy, E_{Batt} and excess maintenance energy, over the measurement period. Excess maintenance energy is calculated as maintenance power, P_{Maint}, multiplied by time beyond that spent actively charging, t_{Charge}. Therefore:

$$E_{Charge} = E_{24} - E_{Batt} - [P_{Maint} \times (24 - t_{Charge})]$$

An example E_{Charge} calculation is illustrated in Figure 7.4. In this case, E_{24} is represented by the area under the blue curve, and includes the energy lost in the BC during charge, as well as the battery energy and any excess maintenance mode losses. The excess maintenance mode energy, represented by the area under the red curve, is (P_{Maint} × (24 – t_{Charge})), or in this example, approximately 1.2 W × (24 h – 7.5 h) = 19.8 Wh.

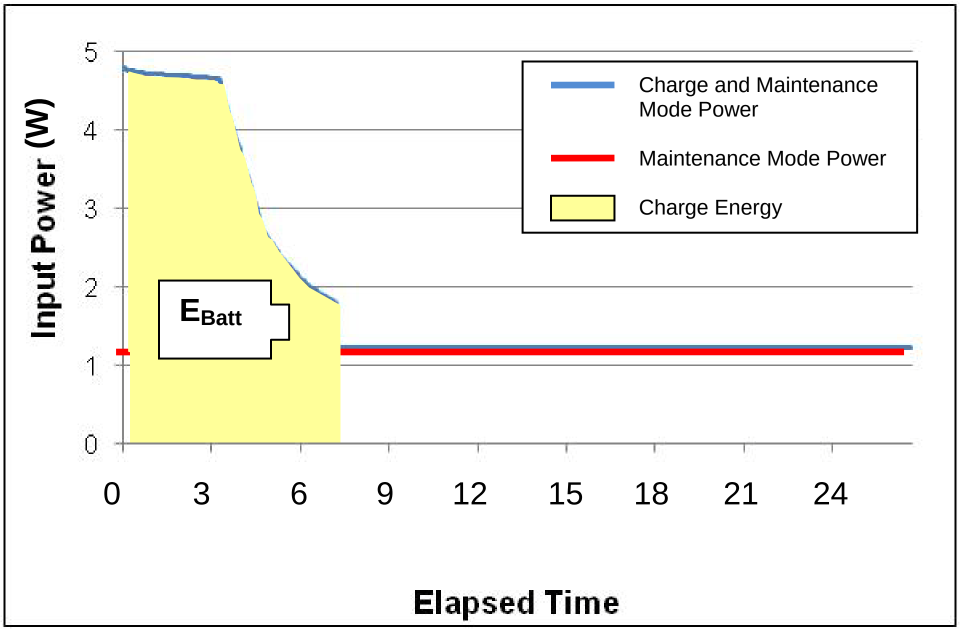


Figure 7.4 Calculating Charge Energy Consumption from 24-Hour Energy

Charge energy over the course of a day, E_{Charge}^{Day} is the product of E_{Charge} and the number of charges per day, *n*:

$$E_{Charge}^{Day} = E_{Charge} \times n$$

Maintenance Mode Energy Consumption: Maintenance mode energy, E_{Maint}, is calculated by multiplying P_{Maint} by the daily amount of time the BC is plugged in and attached to the battery, $t_{Active} + t_{Maint}$, but not charging it. The time the BC is plugged in and attached to the battery and the charges per day are determined by the usage profile, while the time per charge, t_{Charge}, is dictated by the charge rate of the BC itself:

$$E_{Maint} = P_{Maint} \times [t_{Active} + t_{Maint} - (t_{Charge} \times n)]$$

No Battery (Standby) Mode Energy Consumption: No battery (standby) energy, E_{NoBatt} is simply:

$$E_{NoBatt} = P_{NoBatt} \times t_{NoBatt}$$

Off Mode Energy Consumption: Similarly, off-mode energy, E_{Off} is:

$$E_{off} = P_{off} \times t_{off}$$

Given energy consumption in each mode, the complete annual unit energy consumption calculation is represented as:

$$\begin{aligned} UEC = 365 \times (&\left[n \times \left(E_{24} - E_{Batt} - P_{Maint} \times (24 - t_{Charge})\right)\right] \\ &+ \left[P_{Maint} \times \left(t_{Active} + t_{Maint} - (t_{Charge} \times n)\right)\right] + [P_{NoBatt} \times t_{NoBatt}] + [P_{off} \\ &\times t_{off}]) \end{aligned}$$

Or more simply,

$$UEC = 365 \times (E_{Charge}^{Day} + E_{Maint} + E_{NoBatt} + E_{off})$$

7.2.3.1 Modified Energy Use Methodology for Some Slow Chargers

In some cases the methodology described above had to be modified because the performance of the representative BC at a particular CSL did not fit with the application-specific usage profile. For example, mobile phones (the dominant application in product class 2) typically use fast chargers, and their usage profile reflects a fast charging BC. However, CSL 0 in product class 2 is based on a slow charger typically used with small tools and cordless phones. The mobile phone usage profile does not allow enough time for the BC at CSL 0 to make a complete charge.

Because each CSL has an underlying charge time associated with it, a problem arises if it will take longer to charge the battery than the usage profile will allow. That is,

$$t_{Charge}^{CSL} \times n > t_{Active} + t_{Maint}$$

This problem is illustrated by Figure 7.5. BCs at CSLs 1, 2, and 3 complete their charges within the time allotted by the usage profile whereas a BC at CSL 0 takes additional time to complete the charge.

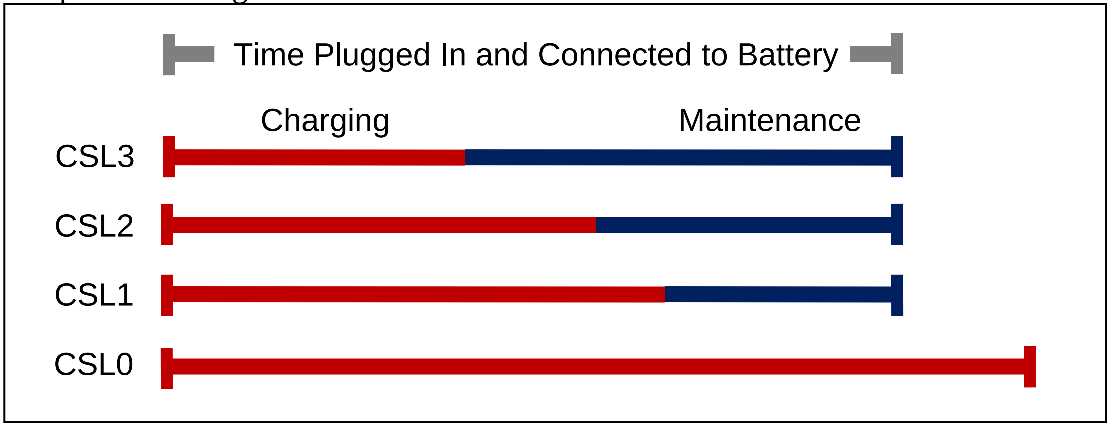


Figure 7.5 Active and Maintenance Time

In order to correctly account for charge energy consumption, it is necessary to allow the BC enough time to complete the charge. To account for the extra time needed, DOE allowed the BC to complete its charge by reducing the time spent unplugged or in no battery mode. The resultant energy consumption in this case is calculated as follows.

Charge Energy Consumption (as before):

$$E_{Charge} = E_{24} - E_{Batt} - \left(P_{Batt} \times \left(24 - t_{Charge}\right)\right)$$

$$E_{Charge}^{Day} = E_{Charge} \times n$$

Maintenance Mode Energy Consumption: Again, this modified methodology was used in cases when the charge time of some slow BCs exceeded the time allocated under the given usage profile for both active and maintenance modes (**$t_{Active} + t_{Maint}$**). No time remained for maintenance mode, resulting in an E_{Maint} of zero.

If: $\quad P_{Maint} \times \left(\left(t_{Active} + t_{Maint}\right) - \left(t_{Charge} \times n\right)\right) \leq 0$

Then: $\mathbf{E_{Maint} = 0}$

No Battery (Standby) Mode Energy Consumption: If the charge time of a slow BC exceeds its allocated time in active and maintenance modes, that excess time must be accounted for. DOE deducted the extra time needed to complete a charge from the time spent unplugged (with zero energy consumption). If the unplugged time provided by the usage profile was insufficient to make up the excess, DOE deducted the time from the no-battery time.

If: $t_{Charge}^{CSL} \times n + t_{NoBatt} \leq 24h$ $\mathbf{t_{Charge}^{CSL} \times n + t_{NoBatt} \leq 24\ h}$
Then: $E_{NoBatt} = P_{NoBatt} \times t_{NoBatt}$ $\mathbf{E_{NoBatt} = P_{NoBatt} \times t_{NoBatt}}$

If $t_{Charge}^{CSL} \times n + t_{NoBatt} > 24h$ $\mathbf{t_{Charge}^{CSL} \times n + t_{NoBatt} > 24\ h}$
Then $E_{NoBatt} = P_{NoBatt} \times (24h - t_{Charge}^{CSL} \times n)$

Since none of the BC usage profiles include any time in off mode, DOE did not adjust the off time.

Off Mode Energy Consumption (as before):

$$E_{off} = P_{off} \times t_{off}$$

Although the use of the modified methodology required a case-by-case modification of the usage profile, DOE considers this appropriate because usage profiles represent the average or typical use of a BC with a given application, while the engineering data and charge time are derived from the representative unit for the product class. While the charge time of the representative unit is intended to represent that of the typical unit within a product class, there will be applications that, on average, require more time to charge (specifically slow chargers at lower CSLs). Using the above methodology DOE was able extend its analytical framework to less typical uses while continuing to model expected user behavior (*i.e.*, if the charger takes longer to charge than expected, the user will leave it plugged in longer).

7.2.4 Battery Charger Unit Energy Consumption Values

As was previously discussed, DOE expresses energy use for each CSL in terms of annual unit energy consumption. DOE recognizes that use varies significantly among the users of a given application. The usage profiles used to calculate annual energy consumption for BCs are intended to represent average use across all consumers. DOE then combined these application-specific usage profiles with mode-specific performance characteristics (E_{24}, E_{Batt}, P_{Maint} , t_{Charge}, P_{NoBatt}, and P_{Off}) to calculate annual energy consumption. These mode-specific performance characteristics were derived in the engineering analysis and first presented in chapter 5. The mode-specific performance characteristics for each CSL and product class can be found in Table 7.17.

Table 7.17 Mode-Specific BC Performance Characteristics

Product Class	CSL	Rated Battery Energy (Wh)	24-Hour Charge Energy (Wh)	Active Charge Time (h)	Maint. Mode Power (W)	No-Battery Mode Power (W)	Off Mode Power (W)
1	0	1.50	26.70	24.00	1.18	0.48	0.00
	1	1.50	19.30	24.00	0.82	0.35	0.00
	2	1.50	10.80	24.00	0.41	0.21	0.00
	3	1.50	5.90	24.00	0.17	0.13	0.00
2	0	3.00	46.50	22.00	1.80	0.70	0.00
	1	2.89	36.88	21.40	1.43	0.29	0.00
	2	1.48	19.70	17.30	0.53	0.04	0.00
	3	2.77	8.15	2.28	0.12	0.08	0.00
	4	3.00	6.91	5.38	0.04	0.05	0.00
3	0	9.47	123.02	1.10	4.54	3.47	0.00
	1	9.74	53.62	8.37	1.83	0.99	0.00
	2	7.61	16.98	0.47	0.26	0.20	0.00
	3	7.61	15.89	0.47	0.26	0.20	0.00
4	0	16.33	167.49	0.60	5.92	2.18	0.00
	1	13.36	52.55	0.90	1.43	1.44	0.00
	2	19.09	39.06	1.51	0.53	0.31	0.00
	3	14.91	27.21	0.60	0.40	0.40	0.00
5	0	830.68	2036.86	12.82	21.18	20.05	0.00
	1	762.06	1647.31	15.85	11.94	11.57	0.00
	2	774.98	1195.50	6.93	8.03	4.18	0.00
	3	800.00	1180.00	8.00	0.00	0.00	0.00
6	0	400.00	891.65	12.82	10.59	10.03	0.00
	1	400.00	786.06	15.85	5.97	5.78	0.00
	2	400.00	560.95	6.93	4.02	2.09	0.00
	3	400.00	536.40	8.00	0.00	0.00	0.00
7	0	3736.06	5884.17	8.58	10.00	0.00	0.00
	1	3725.89	5311.07	8.58	3.31	1.53	0.00
	2	3750.00	4860.00	8.00	2.60	2.00	0.00
8	0	1.90	10.39	2.15	0.32	0.00	0.00
	1	2.15	8.44	1.98	0.24	0.00	0.00
	2	1.62	3.70	2.83	0.07	0.00	0.00
	3	1.62	3.06	2.83	0.04	0.00	0.00
9	0	3.72	48.07	2.90	1.76	0.00	0.00
	1	4.73	13.52	4.50	0.23	0.00	0.00
	2	2.94	8.05	2.94	0.15	0.00	0.00
10	0	70.00	0.00	24.00	2.20	0.00	0.00
	1	70.00	0.00	24.00	0.70	0.00	0.00
	2	70.00	0.00	24.00	0.46	0.00	0.00

	3	70.00	0.00	24.00	0.17	0.00	0.00

DOE calculated UEC at each CSL for each application in each product class. These application-level UECs are inputs to the LCC and NIA. The following sections examine each product class in more detail and include the application-level UECs for the top applications, by shipments, of each BC product class.

7.2.4.1 Battery Charger Product Class 1: Inductive Connection, <100 Wh

This category includes rechargeable toothbrushes and water jets. DOE applied the same usage profile to each application. These products employ a cradle charger and are often left plugged in, however based on a usage profile provided by Philips, DOE assumed that some of these products remain unplugged when not in use. (Philips, No. 41 at p. 2) UECs for each of the two applications in this product class are shown in Table 7.18.

Table 7.18 Application-Specific Unit Energy Consumption for Battery Charger Product Class 1

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
Rechargeable Toothbrushes	Residential	15,000,000	8.7	6.1	3.0	1.3
Rechargeable Water Jets	Residential	100,000	8.7	6.1	3.0	1.3

7.2.4.2 Battery Charger Product Class 2: <4 V Battery, <100 Wh

Mobile phones and smartphones dominate product class 2 with over 100 million unit shipments. DOE based its usage profile for mobile phones on data provided by PG&E (PG&E, No. 30), but assumed that a larger proportion of commercial users than residential users unplug mobile phone battery chargers between charges. UECs for each of the top ten applications in this product class are shown in Table 7.19.

Table 7.19 Application-Specific Unit Energy Consumption for Battery Charger Product Class 2

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3	CSL4
		(Units)	(kWh/yr)				
Mobile Phones	Residential	67,852,080	10.8	7.8	3.9	1.1	1.0
Smartphones	Residential	34,988,550	11.7	8.5	4.4	1.2	1.1
Digital Cameras	Residential	20,022,656	1.0	0.8	0.4	0.1	0.1
Answering Machines	Residential	14,042,770	13.6	10.7	5.7	1.7	1.1
Cordless Phones	Residential	10,980,070	13.6	10.7	5.7	1.7	1.1
Bluetooth Headsets	Residential	10,633,500	7.7	6.2	3.4	1.0	0.6
Portable Video Game Systems	Residential	10,386,000	6.6	4.4	2.1	0.8	0.6
Shavers	Residential	8,656,000	9.5	7.3	3.1	0.9	0.4
Mobile Phones	Commercial	7,539,120	9.9	7.4	3.9	1.0	0.9
Consumer Two-Way Radios	Commercial	7,396,800	13.1	10.1	5.5	1.8	1.5
Other Applications		56,520,151	-	-	-	-	-

7.2.4.3 Battery Charger Product Class 3: 4-10 V Battery, <100 Wh

Product class 3 includes a range of products, such as camcorders, toy ride-on vehicles, and portable DVD players. Many of the BCs in product class 3 (and product class 4) are for power tools. DOE derived usage profiles for power tools by assuming three different divisions:

- The type of power tool (professional, DIY integral, and DIY external);
- The location in which the power tool is used (*e.g.*, residential or commercial buildings); and
- And the type of user (professional or amateur).

Differences between the three types of power tools are explained in chapter 3 of this TSD. As previously explained, use in a residential or commercial setting was analyzed by splitting these applications into “residential” applications and “commercial” applications. Energy prices for each sector are then applied accordingly in the cost-benefit analyses. DOE then assumed that all amateur users use power tools in the residential sector and, on average, charge these power tools infrequently. Professional users, however, may use power tools in a commercial or residential setting depending on where they are contracted to work, and typically charge their tools at least once per day. Commercial power tool UECs are therefore based exclusively on professional use, while residential sector UECs are based on a hybrid of professional and amateur use.

UECs for each of the top ten applications in product class 3 are shown in Table 7.20.

Table 7.20 Application-Specific Unit Energy Consumption for Battery Charger Product Class 3

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/year)			
Camcorders	Residential	4,700,250	0.9	0.3	0.1	0.1
Toy Ride-On Vehicles	Residential	4,044,950	6.7	2.6	0.5	0.4
Portable DVD Players	Residential	3,702,700	6.7	2.7	0.4	0.4
DIY Power Tools (Integral)	Residential	2,220,625	21.5	8.6	1.3	1.3
RC Toys	Residential	2,100,000	1.9	0.8	0.3	0.2
DIY Power Tools (External)	Residential	1,490,156	8.8	3.3	0.7	0.6
Handheld Vacuums	Residential	1,320,000	40.1	16.0	2.5	2.4
LAN Equipment	Residential	1,064,433	39.8	16.0	2.3	2.3
Stick vacuums	Residential	862,785	40.1	16.0	2.5	2.4
DIY Power Tools (External)	Commercial	262,969	26.7	9.6	3.0	2.5
Other Applications		1,291,612	-	-	-	-

7.2.4.4 Battery Charger Product Class 4: >10 V Battery, <100 Wh

Notebook computers make up more than half of the unit shipments in BC product class 4. DOE examined two usage profiles for notebook computers – one with significant maintenance time to represent a “desktop replacement” user, and one with significant unplugged time to represent a user who frequently uses a notebook while it is disconnected from mains. UECs for each of the top ten applications in this product class are shown in Table 7.21.

Table 7.21 Application-Specific Unit Energy Consumption for Battery Charger Product Class 4

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
Notebooks	Commercial	15,425,300	43.9	11.2	5.3	3.1
Notebooks	Residential	12,620,700	46.4	12.0	4.8	3.5
Professional Power Tools	Residential	7,596,875	19.0	5.3	2.5	1.6
Netbooks	Commercial	4,771,635	41.3	10.7	5.4	3.3
DIY Power Tools (External)	Residential	4,470,469	10.9	3.1	1.4	1.0
Professional Power Tools	Commercial	4,090,625	32.6	10.8	6.5	3.7
Netbooks	Residential	3,904,065	42.9	11.0	5.3	3.4
Handheld vacuums	Residential	2,680,000	52.4	12.9	5.1	3.7
Stick Vacuums	Residential	1,751,715	52.4	12.9	5.1	3.7
Robotic Vacuums	Residential	1,000,000	52.8	13.4	5.9	4.0
Other Applications		2,614,298	-	-	-	-

7.2.4.5 Battery Charger Product Class 5: <20 V Battery, 100-3,000 Wh

Toy ride on vehicles make up the majority of shipments in product class 5. UECs for each of the four applications in this product class are shown in Table 7.22.

Table 7.22 Application-Specific Unit Energy Consumption for Battery Charger Product Class 5

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
Toy Ride-On Vehicles	Residential	4,044,950	49.1	33.0	17.5	9.9
Marine / Automotive / RV Chargers	Residential	500,000	198.5	116.2	72.1	7.5
Mobility Scooters	Residential	192,274	358.9	255.9	111.7	97.1
Wheelchairs	Residential	124,543	358.9	255.9	111.7	97.1
Portable O2 Concentrators	Residential	4,500	50.5	41.1	14.8	19.8

7.2.4.6 Battery Charger Product Class 6: ≥20 V Battery, 100-3,000 Wh

Personal transportation equipment dominates product class 6. With the exception of lawn mowers, which are typically used seasonally, most units are charged frequently and spend a significant amount of time in no-battery mode. DOE assumes users do not unplug BCs in product class 6. UECs for each of the five applications in this product class are shown in Table 7.23.

Table 7.23 Application-Specific Unit Energy Consumption for Battery Charger Product Class 6

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
Electric Scooters	Residential	250,000	128.2	89.7	39.3	21.3
Lawn Mowers	Residential	182,143	97.1	57.0	35.0	2.7
Motorized Bicycles	Residential	150,000	128.2	89.7	39.3	21.3
Wheelchairs	Residential	41,514	151.0	113.5	43.2	34.9

7.2.4.7 Battery Charger Product Class 7: >3,000 Wh

Golf cars have the highest battery energies of any application analyzed by DOE. They also have the only BCs DOE found with on/off switches. Given that time when the BC is switched off is functionally equivalent to time spent unplugged, DOE included both modes in its estimate of time in unplugged mode. Commercial golf cars experience much higher use than residential golf cars and therefore have higher annual energy consumption. UECs for this application are shown in Table 7.24.

Table 7.24 Application-Specific Unit Energy Consumption for Battery Charger Product Class 7

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2
		(Units)	(kWh/yr)		
Golf Cars	Commercial	188,294	276.2	209.6	143.5
Golf Cars	Residential	22,326	76.6	41.5	30.0

7.2.4.8 Battery Charger Product Class 8: DC-DC Chargers, <9 V Input

The most common applications that employ USB power (or other 5 V input) are MP3 players and mobile phones. DOE assumes these applications are charged a few times per week and spend a significant amount of time unplugged. UECs for each of the top ten applications in this product class are shown in Table 7.25.

Table 7.25 Application-Specific Unit Energy Consumption for Battery Charger Product Class 8

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
MP3 Players	Residential	36,090,900	1.0	0.8	0.3	0.2
Mobile Phones	Residential	16,963,020	0.9	0.7	0.3	0.2
Digital Cameras	Residential	5,005,664	0.1	0.1	0.0	0.0
Mobile Phones	Commercial	1,884,780	0.9	0.7	0.3	0.2
Camcorders	Residential	1,566,750	0.0	0.0	0.0	0.0
Bluetooth Headsets	Residential	1,181,500	1.6	1.2	0.4	0.3
Personal Digital Assistants	Residential	1,102,500	0.5	0.4	0.1	0.1
Personal Digital Assistants	Commercial	472,500	0.5	0.4	0.1	0.1
E-Books	Residential	440,000	0.5	0.4	0.1	0.1
Digital Cameras	Commercial	263,456	1.0	0.8	0.3	0.2
Other Applications		238,770	-	-	-	-

7.2.4.9

7.2.4.10 Battery Charger Product Class 9: DC-DC Chargers, ≥9 V Input

In-vehicle GPSs are by far the most common applications with BCs charged by 12 V input. DOE assumes these units spend the majority of time unplugged; that is, disconnected from the car's battery. While the car is running, these units are either in maintenance mode or charging. UECs for each of the ten applications in this product class are shown in Table 7.26.

Table 7.26 Application-Specific Unit Energy Consumption for Battery Charger Product Class 9

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2
		(Units)	(kWh/yr)		
In-Vehicle GPS	Residential	9,483,750	0.8	0.3	0.1
Flashlights / Lanterns	Residential	50,000	7.9	1.0	0.7
Medical Nebulizers	Residential	45,000	0.8	0.3	0.1
Portable O2 Concentrators	Residential	4,500	0.8	0.3	0.1

7.2.4.11 Battery Charger Product Class 10: AC-AC, AC Output from Battery

Uninterruptible power supplies are the only application DOE identified in product class 10. They are almost always in maintenance mode. UECs for this application are shown in Table 7.27.

Table 7.27 Application-Specific Unit Energy Consumption for Battery Charger Product Class 10

Top Applications by Shipments	Sector	Shipments	CSL0	CSL1	CSL2	CSL3
		(Units)	(kWh/yr)			
Uninterruptible Power Supplies	Residential	5,064,000	19.3	6.1	4.0	1.5
Uninterruptible Power Supplies	Commercial	2,936,000	19.3	6.1	4.0	1.5

References

---

[1] Natural Resources Defense Council. "Laptop Computers: How Much Energy Do They Use and How Much Energy Can We Save?" August 2003.

[2] TIAX, LLC. "Energy Consumption by Consumer Electronics in U.S. Residences", Final Report to the Consumer Electronics Association, January 2007.

[3] Nielsen Wireless and Interactive Services. "The State of the Console - Video Game Console Usage - Fourth Quarter 2006". 2007.

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducts to evaluate the economic impacts on individual consumers of possible energy conservation standards for battery chargers (BC) and external power supplies (EPS). New standards usually decrease operating costs and increase purchase costs for consumers. This chapter describes the three metrics used in this analysis to determine the impact of standards on individual consumers:

Life-cycle cost (LCC) is the total (discounted) consumer cost over the analysis period including purchase price, operating costs (including energy expenditures), and installation costs.

Payback period (PBP) is the number of years it takes a customer to recover the generally higher purchase price of a more energy-efficient product through the operating cost savings of using the more energy-efficient product. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

Rebuttable payback period is a special case in which the PBP is calculated based on laboratory conditions, specifically DOE test procedure inputs. DOE calculates the aforementioned LCC and PBP using a range of inputs, which are designed to reflect actual conditions.

Sections 8.2 and 8.3 discuss inputs to the LCC and PBP, respectively. Section 8.3.3 presents the rebuttable presumption PBP and section 8.4 presents the results for the LCC and PBP. Key variables and calculations are presented for each metric. DOE performs the calculations discussed here using a series of Microsoft Excel® spreadsheets developed for this rulemaking. Stakeholders are invited to download and examine the spreadsheets, which are available at:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html.

Appendix 8A presents details and instructions for using the spreadsheets. Appendix 8B presents sensitivity results and results using different input scenarios. Appendix 8C presents DOE's application sampling methodology used in the LCC, and Appendix 8D presents further detail on the calculation of residential discount rates.

8.1.1 General Approach for Life-Cycle Cost and Payback Period Analyses

Recognizing that several inputs to the LCC and PBP analysis are either variable or uncertain, DOE incorporates Monte Carlo simulation and probability distributions into its LCC and PBP model. DOE incorporates both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball®, a commercially available add-in program.

The relationship between increasing selling price and increasing efficiency is the predominant influence on the LCC and PBP results. However, other factors related to the characteristics of the consumer using the products also affect the results. Based on the geographic region, sector, and application in which a consumer uses the BC or EPS, factors such as energy prices, sales tax, and energy usage can vary. By using the Monte Carlo simulation and separate sensitivity runs, DOE accounts for this variability. Since many BCs and EPSs are portable, it is possible for consumers to utilize the same product in both a residential and commercial setting. While DOE calculates an LCC for both the residential and commercial sectors, it does not attempt to quantify the extent to which residential consumers use their products in a commercial setting, or vice versa.

For the LCC and PBP analyses, DOE considers variability in the discount rate. DOE also models variability in the electricity price by sector, base case efficiency distribution, product lifetime, sales tax rate, and energy consumption amount by representative unit. By developing samples, DOE can perform the LCC and PBP calculations and account for the variability in these inputs among a variety of consumer and regional data. DOE uses the Energy Information Administration's (EIA) Form 861 from 2008 to develop regional electricity price samples. The LCC and PBP spreadsheets present the results of the analysis as average values, relative to the baseline conditions.

The time period used for the LCC and PBP analyses in this rulemaking is the useful life of the application that the BC or EPS operates. This is because BCs and EPSs are often made specifically for use with particular consumer products, so their lifetimes relate directly to the lifetimes of those products. DOE assumes that once the consumer product has reached the end of its useful life, the user typically discards the associated BC or EPS. Therefore, for each representative unit, DOE has gathered lifetime values for consumer product applications. DOE then samples an application based on market-weighting for each representative unit and uses the mean lifetime associated with that application. In the event that an application lifetime and the associated EPS or BC lifetime do not coincide, DOE will use the EPS or BC lifetime in its analysis.

DOE is conducting the LCC and PBP analyses on the baseline BCs and EPSs from the representative units and product classes ("representative units") identified in Chapter 3. Table 8.1.1 shows the set of 16 representative units that DOE is evaluating in this analysis.

Table 8.1.1 Representative Units and Product Classes Analyzed in the LCC and PBP Analyses

Non-Class A External Power Supply Representative Units
203 Watt Multiple Voltage
345 Watt High-Power
Direct Operation External Power Supply Representative Units
2.5 Watt Regular AC/DC
18 Watt Regular AC/DC
60 Watt Regular AC/DC
120 Watt Regular AC/DC
Battery Charger Representative Product Classes (PC)
PC1 - Low Energy, Inductive
PC2 - Low Energy, Low Voltage
PC3 - Low Energy, Medium Voltage
PC4 - Low Energy, High Voltage
PC5 - Medium Energy, Low Voltage
PC6 - Medium Energy, High Voltage
PC7 - High Energy
PC8 - DC-DC, <9V Input
PC9 - DC-DC, ≥9V Input
PC10 - Low Energy, AC Out

There are a number of end-use applications ("applications") that use EPSs and BCs from each representative unit and BC product class (PC) outlined in Table 8.1.1, and oftentimes the applications are very different. This is because many of the same EPS or BC units can be used for a variety of applications. Since many of the inputs to the LCC model are dependent on the particular application, such as product lifetime, DOE considers an array of popular applications when evaluating each representative unit and BC product class. Further detail on these applications and DOE's methodology for selecting inputs can be found in appendix 8C. DOE considered LCC and PBP results for specific applications as a subgroup analysis. Additional detail on application-specific results can be found in chapter 11.

8.1.2 Overview of LCC and PBP Inputs

As mentioned earlier, the LCC represents the total consumer expense over the analysis period, including purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounts future operating costs to the time of purchase and sums them over the analysis period. There is no "residual value" for a BC or EPS, since it is often discarded along with the consumer product that it operates. The PBP represents the number of years it takes customers to recover the purchase price of more energy-efficient equipment through lower operating costs. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during the operation of the BC or EPS, otherwise known as the operating cost.

The primary inputs for establishing the life-cycle cost and payback period are:

Manufacturer Selling Price (MSP): As discussed in Chapter 5, the MSP is the final price that manufacturers sell a product for, including the total cost to produce the product and any markups the manufacturer applies. The MSP does not account for any distribution or retail markups, taxes or installation.

Markups: DOE then applies a series of markups to the MSP to convert it to a price that would be paid by the actual end-use consumer.

Sales Tax: DOE then applies sales tax to convert the end user product price to a final product price including sales tax. Chapter 6 describes the sales tax markup in detail.

Installation Cost: DOE considers installation costs to be zero for BCs and EPSs because installation would typically entail a consumer simply unpacking the BC or EPS from the box it was sold in and connecting the device to mains power and its associated product or battery. Because the cost of this "installation" (which may be considered temporary, as intermittently used devices might be unplugged for storage) is not quantifiable in dollar terms, DOE considers the installation cost to be zero.

Disposal Cost: DOE considers disposal cost to be zero for BCs and EPSs.

The primary inputs for calculating the operating cost include the following:

Unit Energy Consumption (in kWh/year): The annual site energy consumed by the BC or EPS at each efficiency level. See Chapter 7 for details of how DOE determines the unit energy consumption (UEC).

Maintenance Costs: The incremental cost of repurchasing a lithium ion battery rather than a nickel-based battery. DOE applies this cost to CSL 2 and CSL 3 of certain BC applications where the application lifetime is expected to exceed the battery lifetime.

Electricity Prices: DOE uses the average price per kilowatt-hour (i.e., $/kWh) paid by customers. DOE determines electricity prices using national average residential and commercial electricity prices for the sample calculation. For the Monte Carlo distribution, DOE uses average residential and commercial values for 13 regions and large states. DOE develops all electricity price inputs using 2008 EIA data.

Electricity Price Trends: DOE uses the EIA's *Annual Energy Outlook 2010 (AEO2010)*[i] and projections from the Lieberman-Warner Climate Security Act of 2007[ii] to forecast electricity prices. For the results presented in this chapter, DOE uses the *AEO2010* reference case to forecast future electricity prices.

Start Year: The year in which the BC or EPS and its associated product are purchased. For the LCC and PBP analysis, DOE uses 2013 as the start year for all products.

Lifetime: The total years in operation after which the consumer retires the BC or EPS from service, along with the product it operates.

Discount Rate: The rate at which DOE discounts future expenditures to establish their value in the year of purchase (2013).

Figure 8.1 depicts the relationships between the installed cost and the operating cost inputs for the calculation of the LCC and PBP. In this figure, the yellow boxes indicate the inputs, the green boxes indicate intermediate calculated values, and the blue boxes indicate the analysis outputs (the LCC and PBP).

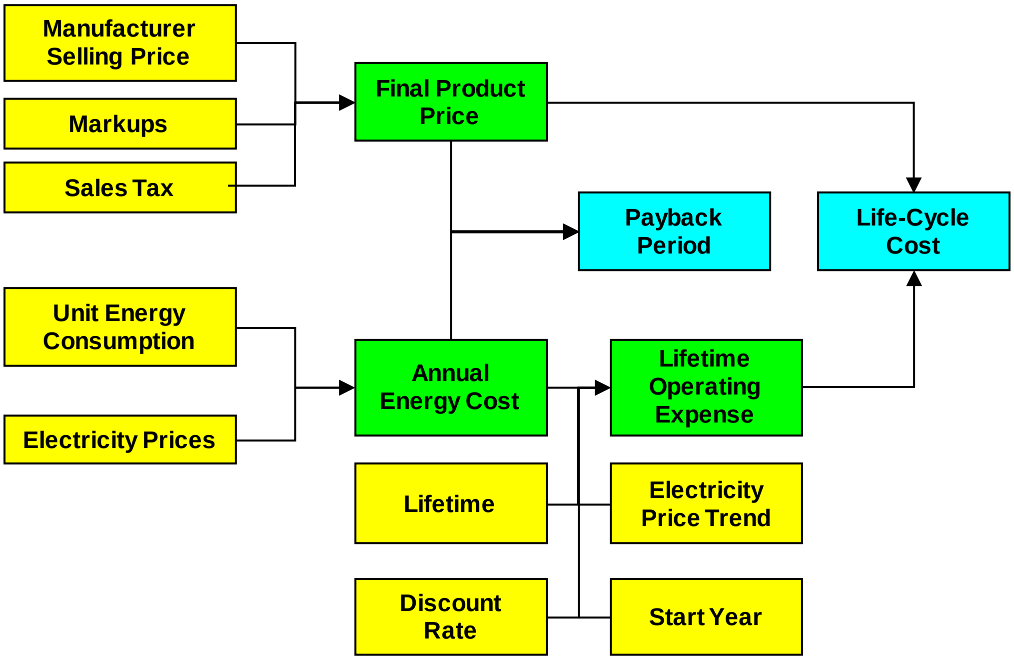


Figure 8.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.2 summarizes the input values that DOE uses to calculate the LCC and PBP for BCs and EPSs. Each row summarizes the total installed cost inputs and operating costs, including the lifetime, discount rate, and electricity price trend. DOE characterizes several of the inputs with probability distributions that capture the input's uncertainty and/or variability in the Monte Carlo analysis. Table 8.1.2 lists how these inputs changed from the Preliminary Analysis to the Notice of Proposed Rulemaking (NOPR) analysis.

Table 8.1.2 Summary Information of Inputs for the Life-Cycle Cost and Payback Period Analyses

Inputs	September 2010 Preliminary Analysis	Changes for the Proposed Rule
Manufacturer Selling Price	Derived from the Engineering Analysis through manufacturer interviews (BCs and EPSs) and test/teardown results (BCs only).	Used same methodology, but conducted additional test/teardowns and interviews.
Markups	Considered various distribution channel pathways for different applications. Applied a reduced "incremental" markup to the portion of the product price exceeding the baseline price.	Used same methodology with additional data sources. See chapter 6 of the TSD for details.
Sales Tax	Derived weighted-average tax values for each Census division and large State from data provided by the Sales Tax Clearinghouse.	Updated the sales tax using the latest information from the Sales Tax Clearinghouse.
Installation Cost	Assumed to be zero.	No change.
Maintenance Cost	Assumed to be zero.	Included the cost of repurchasing a battery that fails within the application lifetime. Accounted for the incremental cost of a lithium ion battery over a nickel chemistry battery, only for Candidate Standard Level (CSL) 2 or higher.
Unit Energy Consumption	Determined for each application based on estimated loading points and usage profiles (for EPSs), and battery characteristics and usage profiles (for BCs).	Used same methodology with additional data sources. See chapter 7 of the TSD for details.
Electricity Prices	Price: Based on EIA's 2008 Form EIA-861 data. Variability: Regional energy prices determined for 13 regions.	Price: No change. The 2008 Form EIA-861 is the most current source available. DOE also considered subgroup analyses using electricity prices for low-income consumers and top tier marginal price consumers. Variability: No change.
Electricity Price Trends	Forecasted with EIA's Annual Energy Outlook Early Release 2010.	Updated with EIA's Annual Energy Outlook 2010.
Lifetime	Determined for each application based on multiple data sources.	Used same methodology with additional data sources. See chapter 3 of the TSD for details.
Discount Rate	Residential: Approach based on the finance cost of raising funds to purchase and operate BCs or EPSs either through the financial cost of any debt incurred (based on the Federal Reserve's Survey of Consumer Finances data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007) or the opportunity cost of any equity used. Time-series data was based on arithmetic means from 1979-2009. Commercial: Derived discount rates using the cost of capital of publicly-traded firms based on data from Damodaran Online, the Value Line Investment survey, and the Office of Management and Budget (OMB) Circular No. A-94.	Residential: DOE updated the calculations to consider the geometric means for all time-series data from 1980-2009. Commercial: DOE updated the risk-free rate to use a 40-year average return on 10-year treasury notes, as reported by the U.S. Federal Reserve. DOE updated the equity risk premium to use the geometric average return on the S&P 500 over a 40-year time period.
Sectors Analyzed	All reference case results used the residential sector inputs. Commercial sector results were presented in Appendix 8B as a sensitivity analysis.	All reference case results represent a weighted average of the residential and commercial sectors.
Base Case Market Efficiency Distribution	All market efficiency distributions were constant across representative units and product classes. Distributions were derived from test results.	Where possible, DOE derived market efficiency distributions for specific applications within a representative unit or product class.

Sections 8.2 and 8.3 discuss the inputs depicted in Table 8.1.2.

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition

The LCC is the total customer cost over the life of a product, including total installed costs and operating costs. Future operating costs are discounted to the analysis start year (2013) and summed over the analysis period (the lifetime for each respective representative unit or scaled BC product class). The LCC is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N} \left(\frac{OC_t}{(1+r)^t} \right)$$

Eq. 8.1

where

LCC = life-cycle cost ($),
IC = total installed cost ($),
N = analysis period,
$\sum$ = sum over the analysis period, from year 1 to year N,
OC = operating cost ($),
r = discount rate,
t = year for which operating cost is being determined,

DOE expresses all the costs in its LCC and PBP analyses in 2010 dollars. There are no replacement costs, disposal costs, or residual value associated with BCs or EPSs, so they are absent from the equation above.

8.2.2 Total Installed Cost Inputs

The total installed cost to the customer is defined by the following equation:

$$IC = FPP + INST$$

Eq. 8.2

where

IC = total installed cost, expressed in dollars,

FPP = final product price (i.e., customer price for the product only, including sales tax), expressed in dollars, and

$INST$ = installation cost or the customer price to install products, expressed in dollars. This cost is assumed to be zero for all BCs and EPSs.

In the product price determination (Chapter 6), DOE develops end user product prices and sales taxes to derive final product prices. Total installed costs are determined using:

- End user Product Price ($), and
- Sales Tax ($).

The end user product price is the average purchase price a consumer pays before sales tax for BCs and EPSs. Since consumers often do not purchase BCs or EPSs individually, but rather as a component of the product they operate, the end user product price for a BC or EPS is derived as a component of the larger purchase price for the product it is purchased with. The markups applied to the final product are carried over for the BC or EPS component. The sales tax represents state and local sales taxes applied to the end user product price. It is a multiplicative factor that increases the end user product price. DOE calculates the total installed cost for the BCs and EPSs analyzed based on the following equation:

$$\begin{aligned} IC &= FPP \\ &= PRICE \times MU_{TAX} \end{aligned}$$

Eq. 8.3

where

IC = total installed cost,
FPP = final product price,
$PRICE$ = end user product price, and
MU_{TAX} = sales tax mark up

Chapter 6 provides detail on the end user product price and sales tax.

8.2.3 Operating Cost Inputs

The operating cost represents the costs incurred in the operation of the BC or EPS. Table 8.2.1 lists the inputs for operating costs. The lifetime, discount rate, and compliance date of the standard are required to determine the operating cost and for establishing the operating cost present value. The maintenance costs are added to annual operating costs to account for the repurchase of batteries within the application’s service life. The electricity consumption for the baseline and other efficiency levels examined enable comparison of standards’ operating costs.

Table 8.2.1 Inputs for Operating Costs

Unit Energy Consumption
Maintenance Cost
Electricity Prices
Electricity Price Trends
Discount Rate
Lifetime

The UEC is the estimated energy that a BC or EPS consumes during normal use over the course of a year. Electricity prices used in the analysis are the price per kilowatt-hour in cents or dollars (e.g., \$/kWh) paid by each customer for electricity. DOE uses electricity price trends to forecast electricity prices for future year analysis. These trends with the electricity price and annual UEC are used to calculate the energy cost in each year, which is the operating cost. DOE defines operating cost by the following equation:

$$OC = (E_{cons} \times EP \times EPT) + MC$$

Eq. 8.4

where

OC = operating costs,
E_{cons} = annual energy consumed,
EP = electricity price,
EPT = electricity price trend factor relative to 2010, and
MC = maintenance costs.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs for BCs and EPSs.

8.2.4 Unit Energy Consumption

BCs and EPSs are unique appliances because they are always used in conjunction with other products of interest. Most BCs and EPSs are packaged with particular products; thus, consumers usually do not buy the BC or EPS directly. Instead, for example, consumers obtain an EPS for a video game system when buying the video game system itself. Thus, although the LCC and PBP analysis uses the consumer purchase prices of BCs and EPSs, in reality those prices are a “hidden” portion of the prices that consumers pay for the products of interest.

Because BCs and EPSs are used in conjunction with other products, their energy consumption is directly related to the usage of those other products as well as the technologies that the BC or EPS utilizes. The energy consumption of the analyzed BCs and EPSs is assessed in further detail in chapter 7, and the technologies of the analyzed BCs and EPSs are assessed in chapter 3.

The energy use characterization (Chapter 7) details how DOE determines the UEC for baseline and standards-compliant products. The UEC varies with the product efficiency. That is, the energy consumption associated with standards-level products (i.e., products with efficiencies greater than baseline products) is less than the consumption associated with baseline products. As such, the UEC decreases with higher improved efficiency. An important input to determining the energy consumption is the total hours per year that the product is in operation in the different load states available to the product. With this information, the UEC can be calculated as a function of its efficiency.

For the LCC and PBP analysis, DOE utilizes different UECs for each efficiency level of each representative unit and scaled BC product class. Since each representative unit and scaled BC product class encompasses multiple product applications, each with its own distinct usage profile and energy consumption levels, DOE uses a shipment-weighted average UEC for each representative unit and scaled BC product class analyzed in the LCC and PBP analysis for the sample calculation. For the Monte Carlo simulation analyses, DOE samples an application for each representative unit and scaled BC product class and uses the UECs associated with that application. Appendix 8C contains a complete listing of the application inputs associated with each representative unit and scaled BC product class, including the UECs associated with each efficiency level for the applications considered and the methodology for sampling these UECs.

8.2.5 Maintenance Costs

DOE recognizes that the service life of a BC or EPS typically exceeds that of the consumer product with which it is designed to operate. Thus, a consumer would not typically incur repair or maintenance costs for a BC or EPS. If a BC or EPS does fail, DOE expects that consumers would typically discard the EPS and purchase a replacement.

However, DOE does account for maintenance costs for the replacement of batteries that are marginally more expensive at higher CSLs in several BC product classes. In certain applications, DOE expected that the battery would need to be replaced within the service life of the BC. Because higher CSLs utilize lithium ion batteries, which are marginally more expensive than nickel based batteries, DOE accounted for a marginal cost to replace batteries at CSL 2 or higher. DOE only applied this marginal cost increase to applications where the application service life was expected to exceed the battery lifetime based on usage data. In these instances, DOE applied the maintenance cost in the year that the batteries would be repurchased, and discounted the value to 2010$. Table 8.2.2 lists the affected applications and the marginal increase in battery replacement cost over a nickel-based battery chemistry.

Table 8.2.2 Marginal Maintenance Costs for Lithium Ion Battery Replacement

Product Class (PC)	Application	Marginal Replacement Cost [2010$]
PC 3 – Low Energy, Medium Voltage	Commercial DIY Power Tools (External Battery)	0.22
PC 4 – Low Energy, High Voltage	Commercial DIY Power Tools (External Battery)	0.28

DOE calculated the marginal replacement cost of a lithium ion battery over a nickel-based battery chemistry similarly in the LCC analysis as was done in the engineering analysis.

In this calculation, DOE only considered the incremental cost to a consumer of purchasing a lithium ion based battery rather than a nickel-based battery. Further information can be found in chapter 5.

8.2.6 Electricity Prices

DOE estimates electricity prices for residential and commercial consumers in each of the 13 regions and large states by using EIA Form 861 data.[iii] Table 8.2.3 lists the 13 geographic regions and large states. The EIA Form 861 data are published annually and include annual electricity sales in kilowatt hours; revenues from electricity sales; and number of consumers for the residential and commercial sectors for every utility serving final consumers. The calculation of average electricity prices proceeds in two steps:

1) For each utility, estimate an average residential and commercial price by dividing the residential or commercial revenues by residential or commercial sales.

2) Calculate a regional average price, weighting each utility with customers in a region by the number of residential or commercial consumers served in that region.

The calculation uses the most recent available EIA data at the time the analysis was conducted, from 2008. Table 8.2.3 shows the results for each geographic region. Because DOE conducted the LCC and PBP analyses in 2010$, it needed to convert all electricity prices into 2010$. To perform the necessary monetary conversion, DOE uses the consumer price index (CPI) to convert the electricity prices from 2008$ to 2010$. As described in the following section on electricity price trends, DOE normalizes energy prices to 2010. Therefore, to forecast energy prices for any given future year, DOE establishes energy prices for 2010. In Table 8.2.3, DOE uses data from the *AEO2010* to estimate the electricity prices for 2010. DOE uses the CPI to adjust for inflation, and then multiplies the electricity price in 2008 by the ratio of the price in 2010 to that in 2008, as reported in the *AEO2010*, so as to convert the electricity price to a 2010 estimate.

Table 8.2.3 Electricity Prices by Census Division, 2010

Census Division	Electricity Prices,* 2010	
	Residential	**Commercial**
	2010$/kWh	*2010$/kWh*
New England	$0.166	$0.145
Middle Atlantic	$0.124	$0.104
East North Central	$0.100	$0.085
West North Central	$0.083	$0.069
South Atlantic	$0.097	$0.081
East South Central	$0.088	$0.085
West South Central	$0.091	$0.081
Mountain	$0.093	$0.079
Pacific	$0.099	$0.091
New York State	$0.181	$0.160
California	$0.130	$0.115
Texas	$0.123	$0.114
Florida	$0.110	$0.093
U.S. Weighted Average	**$0.112**	**$0.097**

* DOE converts dollars to 2010$ by multiplying costs in 2008$ by the ratio of 2010 CPI (217.9) to 2008 CPI (215.3). DOE converts the price for 2008 to the price in 2010 by multiplying the 2008 price by the ratio of the average *AEO* electricity price in 2010 to the average *AEO* electricity price in 2008.

8.2.7 Electricity Price Trend

The electricity price trend projects the future cost of electricity to 2035. DOE calculates the LCC and PBP using three separate projections from *AEO2010*: reference, low economic growth, and high economic growth. The *AEO2010* contains electricity price projections for each of these three scenarios.

DOE also considers an electricity price projection using a carbon cap and trade scenario based upon the Lieberman-Warner Climate Security Act of 2007. This scenario illustrates an elevated electricity price projection based on emissions regulations as outlined in the EIA's S.2191 report accompanying the Act.

These four cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets, while the carbon cap and trade scenario illustrates the possible effects of emissions regulations. DOE normalizes these four scenarios to the 2010 electricity price, and then uses that electricity price factor to scale the 2010 electricity prices. Figure 8.2 and Figure 8.3 show the residential and commercial electricity price trends, respectively, based on the three *AEO2010* projections and the carbon cap and trade scenario projection. The LCC results presented in this chapter are based on the *AEO2010* reference case.

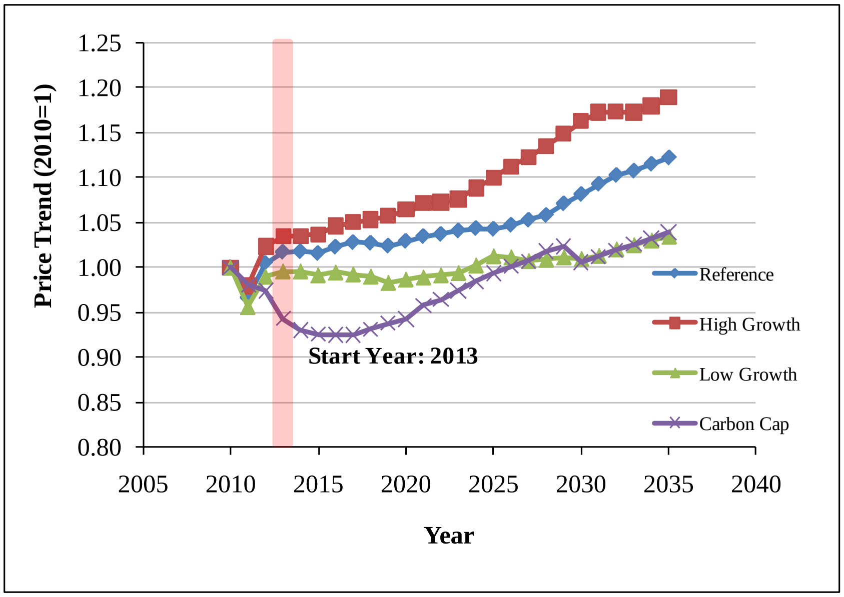


Figure 8.2 Residential Sector Electricity Price Trend

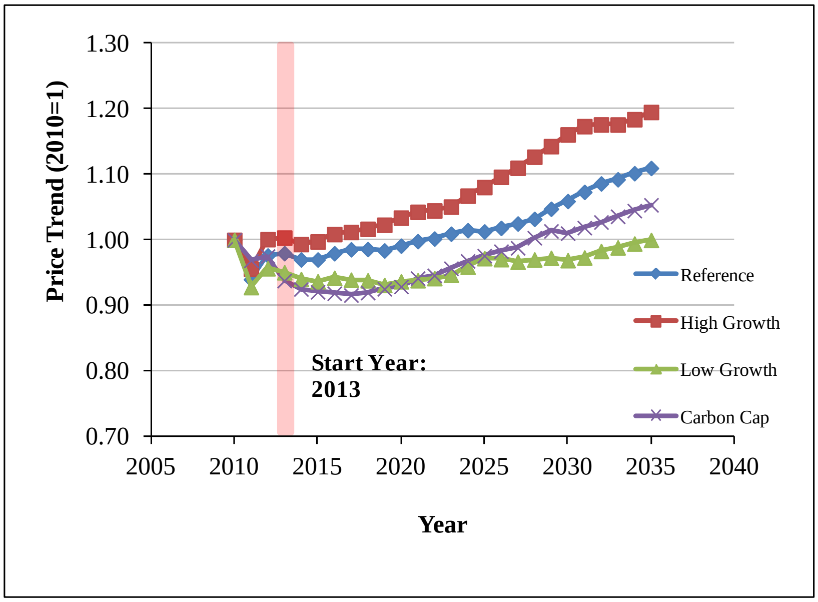


Figure 8.3 Commercial Sector Electricity Price Trend

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in both the LCC spreadsheets and the LCC results tables in this chapter.

8.2.8 Gasoline Prices and Trends

For BCs powered by automotive power sources (scaled BC product class 9), DOE calculated consumer energy cost savings using gasoline prices rather than electricity prices. DOE obtained yearly gasoline prices and projections from the *AEO2010*, which expressed prices per gallon of gasoline. DOE converted these prices into dollars per kilowatt-hour to project the total gasoline cost for each UEC.

DOE converted the gasoline prices to dollars per kilowatt-hour by using an energy equivalence conversion factor and an automobile energy conversion efficiency estimate. An estimate of 33.705 kWh/gallon of gasoline was used to estimate fully-efficient conversion of energy.[iv] From this estimate, DOE applied an average automobile energy conversion efficiency of 21-percent, which represents the typical efficiency in converting gasoline to electric power.[v] Using these figures, DOE estimates 7.08kWh/gallon when powering a BC through an automotive power source. DOE then converted the *AEO2010* gasoline price estimates (expressed as dollars per gallon) into dollars per kilowatt-hour. The resulting gasoline prices per kilowatt-hour are expressed in Figure 8.4.

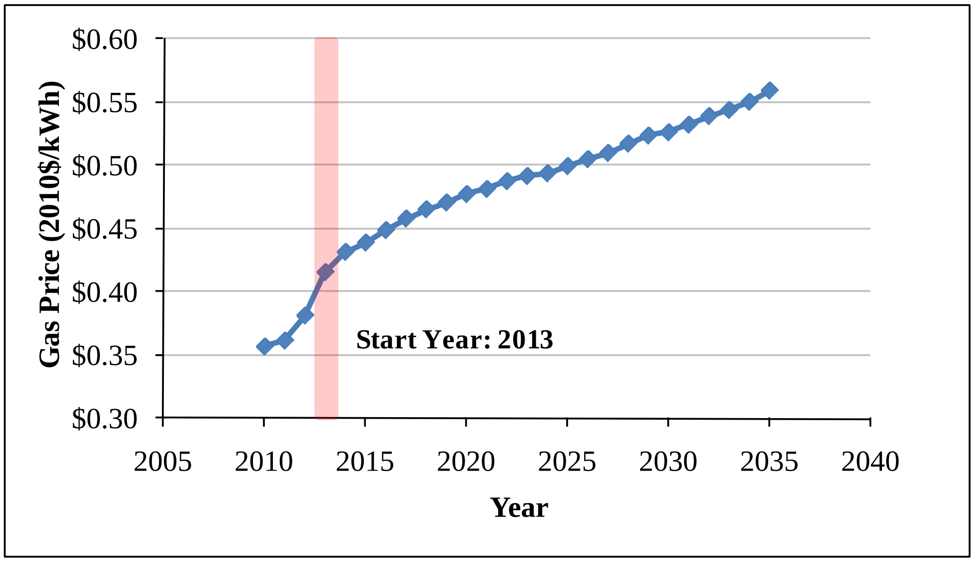


Figure 8.4 Gasoline Prices for Years 2010 to 2035

8.2.9 Lifetime

DOE considers the lifetime of a BC or EPS to be from the moment it is purchased for end-use up until the time when it is permanently retired from service. Because the typical BC or EPS is purchased for use with a single associated application, DOE assumes that it will remain in service for as long as the application does. Since there are multiple applications with different lifetimes for a single representative unit or scaled BC product class, a shipment-weighted average lifetime is calculated from the relevant applications for that representative unit or scaled BC product class in the Sample Calculation. The Monte Carlo simulation analysis samples a lifetime from the relevant applications for each representative unit or scaled BC product class. Since each application has its own lifetime estimate, this provides a distribution of lifetime estimates for a given representative unit or scaled BC product class. Further detail on this application sampling methodology can be found in Appendix 8C. Chapter 3 of this TSD contains the lifetimes for the selected applications and the methodology for deriving these estimates.

Even though many of the technology options to improve BC and EPS efficiencies may result in an increased useful life for the BC or EPS, the lifetime of the BC or EPS is still directly tied to the lifetime of its associated application. Even if an EPS or BC has a lifetime that exceeds the lifetime of its application, the typical consumer will not use the EPS or BC once the application has been discarded. For this reason, the baseline and standard level designs for the LCC and PBP analyses all use the same lifetime estimate. Further detail on product lifetimes and how they relate to applications can be found in chapter 3 of this TSD.

8.2.10 Discount Rate

The discount rate is the rate at which DOE discounts future expenditures to establish their present values. In the LCC analysis, DOE derives the discount rates separately for residential and commercial consumers. For residential consumers, DOE estimates the discount rate by looking across all possible debt or asset classes that might be used to purchase BCs or EPSs. For the commercial consumers, DOE estimates the cost of capital for commercial companies by examining both debt and equity capital, and develops an appropriately weighted average of the cost to the company of equity and debt financing.

8.2.10.1 Residential Discount Rate

DOE's approach for the residential discount rate involves identifying all possible debt or asset classes that might be used to purchase BCs or EPSs, including household assets that might be affected indirectly.[1] DOE does not include debt from primary mortgages and equity of assets considered non-liquid (such as retirement accounts), since these would likely not be used to finance BC or EPS purchases. DOE estimates the average shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using the Federal Reserve's *Survey of Consumer Finances* (*SCF*) data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007.[vi] Table 8.2.4 shows the average shares of each considered class. DOE uses the mean share of each class across the seven survey years (18 years) as the basis for estimating household financing of BCs and EPSs.

---

[1] An indirect effect would arise if a household sold assets to pay off a loan or credit card debt that might have been used to finance the actual EPS or BC purchase.

Table 8.2.4 Average Percentage Shares of Household Debt and Equity Types

Type	1989 SCF %	1992 SCF %	1995 SCF %	1998 SCF %	2001 SCF %	2004 SCF %	2007 SCF %	Mean %
Home Equity Loans	2.2	1.9	0.9	1.0	1.2	2.9	2.5	1.8
Credit Cards	0.0	2.2	2.6	2.2	1.7	2.0	2.5	1.9
Other Installment Loans	3.1	1.8	1.4	1.7	1.1	1.4	1.2	1.7
Other Residential Loans	0.0	7.0	5.3	4.4	3.1	5.9	7.3	4.7
Other Line of Credit	1.2	0.6	0.4	0.0	0.3	0.5	0.3	0.5
Checking Accounts	6.3	4.8	4.9	4.0	3.7	4.3	3.5	4.5
Savings and Money Market	20.9	19.3	14.3	13.1	14.5	15.4	13.3	15.8
Certificate of Deposit (CD)	15.8	12.0	9.5	7.1	5.5	6.0	6.6	8.9
Savings Bond	2.4	1.7	2.2	1.1	1.2	0.9	0.7	1.5
Bonds	15.0	12.6	10.7	7.1	8.0	8.6	6.8	9.8
Stocks	24.4	24.7	26.4	37.7	38.1	28.4	29.3	29.8
Mutual Funds	8.7	11.4	21.3	20.5	21.6	23.7	26.0	19.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

DOE estimates interest or return rates associated with each type of equity and debt. The data source for the interest rates for loans, credit cards, and lines of credit is the Federal Reserve Board's *SCF* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007. The top half of Table 8.2.5 shows the average nominal interest rates in each year and the inflation rates used to calculate real rates (using the Fisher formula).[2] For home equity loans, DOE calculates effective interest rates using a tax adjustment since interest on such loans is tax deductible. The bottom half of the table shows the average effective real interest rates in each year and the mean rate across all the years. Since the interest rates for each debt carried by households in these years were established over 18 years, DOE believes they are representative of rates that may be in effect in 2013.

---

[2] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1.

Table 8.2.5 Average Nominal and Real Interest Rates for Household Debt Classes

Type	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	2007 SCF	Mean
Nominal Interest Rates %								
Home Equity Loans	8.4	6.2	7.0	6.8	6.0	3.6	5.8	6.2
Credit Cards*	-	-	14.1	14.0	13.9	11.1	12.4	13.1
Other Installment Loans	8.4	7.5	8.5	7.6	8.3	8.1	8.8	8.2
Other Residential Loans	9.8	8.9	8.3	8.0	7.7	6.0	6.4	7.9
Other Line of Credit	14.4	12.5	11.6	11.6	9.4	7.6	9.6	11.0
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	2.85	
Real Interest Rates %								
Home Equity Loans	4.5	3.8	4.8	5.4	3.7	1.5	3.5	3.9
Credit Cards*	-	-	11.0	12.1	10.9	8.4	9.6	10.4
Other Installment Loans	4.6	5.7	6.5	6.4	6.3	6.1	6.8	6.1
Other Residential Loans	4.6	5.6	5.3	6.1	4.7	3.2	3.4	4.7
Other Line of Credit	9.3	9.3	8.4	9.7	6.2	4.9	6.7	7.8

*No interest rate data available for credit cards in 1989 or 1992.

To account for variation among new households, DOE samples a rate for each household from a distribution of rates for each of the above debt classes. DOE develops a probability distribution of interest rates for each debt class based on the *SCF* data. Appendix 8D presents the probability distribution of interest rates for each debt class that DOE used in the LCC and PBP analyses.

Similar rate data are not available from the *SCF* for the asset classes, so DOE derives data for these classes from national historical data. The interest rates associated with certificates of deposit (CDs),[vii] savings bonds,[viii] and bonds (AAA corporate bonds) [ix] are from Federal Reserve Board time-series data 1980-2009. DOE assumes rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984-2009.[x] The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 1980-2009.[xi] The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1980 to 2009. DOE adjusts the nominal rates to real rates using the annual inflation rate in each year. Average nominal and real interest rates for the classes of assets are shown in Table 8.2.6. Since the interest and return rates for each asset type cover a range of time, DOE believes they are representative of rates that may be in effect in 2013.

Table 8.2.6 Average Nominal and Real Interest Rates for Household Equity Types

Type	Average Nominal Rate %	Average Real Rate %
Checking Accounts	--	--
Savings and Money Market	5.3	2.3
CDs	6.2	2.4
Savings Bonds	8.2	4.4
Bonds	8.3	4.5
Stocks	11.1	7.2
Mutual Funds	10.5	6.6

To account for variation among new households, DOE samples a rate for each household from a distribution of rates for each of the above asset types. DOE develops a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. Appendix 8D presents the probability distribution of interest rates for each asset type that DOE used in the LCC and PBP analysis.

Table 8.2.7 summarizes the mean real effective rates of each type of equity or debt. DOE determines the average share of each debt and asset using *SCF* data for 1989, 1992, 1995, 1998, 2001, 2004, and 2007. Each year of SCF data provides the debt and asset shares for U.S. households. DOE averages the debt and asset shares over the seven years of survey data to arrive at the shares shown below. The average rate across all types of household debt and equity, weighted by the shares of each class, is 5.1 percent.

Table 8.2.7 Shares and Interest or Return Rates Used for Household Debt and Equity Types

Type	Average Share of Household Debt Plus Equity* %	Mean Effective Real Rate** %
Home Equity Loans	1.8	3.9
Credit Cards	1.9	10.4
Other Installment Loans	1.7	6.1
Other Residential Loans	4.7	4.7
Other Line of Credit	0.5	7.8
Checking Accounts	4.5	0.0
Savings and Money Market Accounts	15.8	2.3
CDs	8.9	2.4
Savings Bonds	1.5	4.4
Bonds	9.8	4.5
Stocks	29.8	7.2
Mutual Funds	19.1	6.6
Total/Weighted-Average Discount Rate	100.0	**5.1**

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

8.2.10.2 Commercial Discount Rate

Most companies use both debt and equity capital to fund investments; for most companies, therefore, the cost of capital is the weighted average of the cost to the firm of equity and debt financing.[xii]

DOE estimates the cost of equity financing using the Capital Asset Pricing Model (CAPM). The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a firm. For example, the cost of equity financing tends to be high when a firm faces a large degree of systematic risk, and the cost tends to be low when the firm faces a small degree of systematic risk.

The degree of systematic risk facing a firm and the subsequent cost of equity financing are determined by several variables, including the risk coefficient of a firm (beta, or *B*), the expected return on risk-free assets (R_f), and the additional return expected on assets facing average market risk (known as the equity risk premium, or ERP). The beta indicates the degree of risk associated with a given firm, relative to the level of risk (or price variability) in the overall stock market. Betas usually vary between 0.5 and 2.0. A firm with a beta of 0.5 faces half the risk of other stocks in the market; a firm with a beta of 2.0 faces twice the overall stock market risk.

Following this approach, the cost of equity financing for a particular company is by the equation:

$$\boldsymbol{k_e = R_f + (\beta \times ERP)}$$

Eq. 8.5

where

k_e = the cost of equity for a company, expressed in dollars,
R_f = the expected return of the risk-free asset, expressed in dollars,
β = the risk coefficient, and
ERP = the expected equity risk premium, expressed in dollars.

The cost of debt financing (k_d) is the yield or interest rate paid on money borrowed by a company (raised, for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk and excludes deductions for taxes.

DOE estimates the cost of debt for companies by adding a risk adjustment factor to the current yield on long-term corporate bonds (the risk-free rate). This procedure is used to estimate current and future company costs to obtain debt financing. The adjustment factor is based on indicators of company risk, such as credit rating or variability of stock returns.

The discount rate of companies is the weighted average cost of debt and equity financing, less expected inflation. DOE estimates the discount rate using the equation:

$$\boldsymbol{k = k_e \times w_e + k_d \times w_d}$$

Eq. 8.6

where

k = the (nominal) cost of capital,
k_e and k_d = the expected rates of return on equity and debt, respectively, and
w_e and w_d = the proportion of equity and debt financing, respectively.

The real discount rate deducts expected inflation from the nominal rate.

The expected return on risk-free assets, or the risk-free rate, is defined by the 40-year average return on 10-year treasury notes, as reported by the U.S. Federal Reserve.[xiii] The ERP represents the difference between the expected (average) stock market return of the S&P 500 over a 40-year time period and the risk-free rate. As Table 8.2.8 shows, DOE uses an ERP estimate of 3.1-percent, which it calculated from the risk-free rate described above and S&P 500 returns from the Damodaran Online website (a private website associated with New York University's Stern School of Business, which aggregates information on corporate finance, investment, and valuation).[xiv]

DOE calculates an expected inflation of 1.6-percent from the average of the projected change in gross domestic product (GDP) prices in the *Economic Report of the President.*[xv] DOE obtained the cost of debt, percent debt financing, and systematic firm risk from the Damodaran Online website. Table 8.2.8 shows average values across all public companies considered in the analysis. However, the cost of debt, percent debt financing, and systematic firm risk vary by sector.

Table 8.2.8 Variables Used to Estimate Company Discount Rates

Variable	Symbol	Average Value %	Source
Risk-Free Asset Return	R_f	6.9	U.S. Federal Reserve
Equity Risk Premium	ERP	3.1	U.S. Federal Reserve; Damodaran Online
Expected Inflation	R	1.6	2010 Economic Report of the President
Cost of Debt (After Tax)	k_d	6.6	Damodaran Online
Percent Debt Financing	w_d	28.5	Damodaran Online
Systematic Firm Risk	B	1.2	Damodaran Online

In the commercial sector, BCs and EPSs are purchased and owned by commercial companies, industrial companies and the Government. DOE uses a sample of 6,721 companies drawn from these owner categories to represent BC and EPS purchasers. It took the sample from the list of companies included in the Value Line investment survey[xvi] and listed on the

Damodaran Online website. DOE obtained the cost of debt, the firm beta, the percent of debt and equity financing, and the equity risk premium from Damodaran Online.

DOE estimates the cost of debt financing for these companies from the long-term Government bond rate (risk-free rate) and the standard deviation of the stock price. For Government-office-type owners, the discount rate represents an average of the Federal rate and the State and local bond rate. DOE drew the Federal rate directly from the U.S. Office of Management and Budget discount rate for investments in Government building energy efficiency.[xvii] DOE estimates the State and local discount rate from the interest rate on State and local bonds between 1980 and 2009.[viii] DOE uses this information to estimate the weighted-average cost of capital for the sample of companies included in the company database.

The cost of capital may be viewed as the discount rate that should be used to reduce the future value of typical company project cash flows. It is a nominal discount rate, since anticipated future inflation is included in both stock and bond expected returns. Deducting expected inflation from the cost of capital provides estimates of the real discount rate by ownership category (see Table 8.2.9). The mean real discount rate for these companies varies between 3.3-percent (Government offices) and 7.9-percent (industrial companies).

Table 8.2.9 Real Discount Rates by BC and EPS Ownership Category

Ownership Category	**SIC Codes***	**Mean Real Discount Rate %**	**Standard Deviation %**	**Number of Observations**
Industrial Companies	1 – 4	7.9	1.0	3,856
Commercial Trade	5	7.8	0.9	505
Commercial Finance, Insurance & Real Estate	6	7.2	1.3	1,510
Commercial Services	7 – 8	7.7	0.8	850
Government Offices	N/A	3.3	1.6	N/A

* SIC Codes refer to the U.S. Standard Industrial Classification system.
Source: Navigant Consulting, Inc. calculations based on firms sampled from the Damodaran Online website.

DOE's approach for estimating the cost of capital provides a measure of the discount rate spread as well as the average discount rate. DOE infers the discount rate spread by ownership category from the standard deviation, which ranges between 0.8-percent and 1.6-percent (Table 8.2.9).

To estimate the share of each ownership category in total commercial sector purchases of BCs and EPSs, DOE uses the share of each category in total paid employees. DOE uses the most current data reported by the U.S. Census Bureau to see the number of employees by industry, [xviii] for the Federal government, [xix] and for State and Local governments.[xx] DOE uses the number of employees as a proxy for the share of each ownership category because the prevalence of most BCs and EPSs will vary depending on the number of individual users for a given device. Table 8.2.10 presents the estimated shares of commercial BC and EPS purchases by ownership category.

Table 8.2.10 Estimated Share of BC and EPS Purchases by Ownership Category in Commercial Sector

Ownership Category	Percent (%)
Industrial Companies	23.3
Commercial Trade	12.8
Commercial Finance, Insurance & Real Estate	6.4
Commercial Services	43.6
Government Offices	13.9

Source: U.S. Census Bureau.

DOE estimates discount rate distributions for the different sectors as a weighted average of the distributions for the different ownership types. Table 8.2.11 summarizes the weighted average real discount rates in the residential and commercial sectors.

Table 8.2.11 Average Real Discount Rate by Sector

Sector	Discount Rate %
Residential	5.1
Commercial	7.1

8.2.11 Product Energy Efficiency in the Base Case

For purposes of conducting the LCC analysis, DOE analyzed candidate standard levels relative to a base case (*i.e.*, a case without new federal energy conservation standards). This requires an estimate of the distribution of product efficiencies in the base case *(i.e.*, what consumers would have purchased in 2013 in the absence of federal standards). Rather than analyzing the impacts of a particular standard level assuming that all consumers will purchase products at the baseline efficiency level, DOE conducted the analysis by taking into account the breadth of product energy efficiencies that consumers are expected to purchase under the base case.

As discussed in section 8.1.1, DOE's approach for conducting the LCC analysis for BCs and EPSs relied on developing samples of consumers that use each of the products, and using a Monte Carlo simulation technique to perform the LCC calculations on the consumers in the sample. DOE assigned each consumer in the sample a unique product energy efficiency taken from the estimated base case distribution of product energy efficiencies in the compliance year. The energy efficiency distributions used for each application are presented in chapter 3 of the TSD. The applications assigned to each representative unit and scaled BC product class, and their respective energy efficiency distribution, is explained in further detail in Appendix 8C.

DOE calculated the efficiency distributions by evaluating tested efficiency data for each representative unit and BC product class and comparing it to data research on each application. Where sufficient data was available, DOE analyzed product efficiencies for specific applications and subsets of applications within a product class. The tested efficiencies were compared to the proposed compliance curves for each CSL and binned accordingly. DOE assumed that the current averages with slight adjustments for the pending California BCs standards (as described in chapter 3) are reasonable to use as a base case for 2013. DOE also assumed a modest improvement in EPS efficiency from 2010 to 2013. This is because Europe recently passed efficiency standards requiring EPSs to meet the EISA level (CSL 0), and the efficiency requirement is set to rise to Energy Star 2.0 (CSL 1) by April 2011. DOE assumes this will impact the American market by shifting EPS efficiencies higher by year 2013. Further detail on this analysis can be found in chapter 9 of the TSD.

Table 8.2.12 through Table 8.2.14 shows the application-weighted efficiency distributions for each representative unit and product class. The LCC and PBP analysis used the efficiency distribution specific to each application during the Monte Carlo simulations. Further detail on these application-specific efficiency distributions can be found in Appendix 8C.

Table 8.2.12 Base Case Energy Efficiency Market Shares for Non-Class A External Power Supplies in 2013

Representative Unit	**Market Share (%)**				
	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
203 Watt Multiple Voltage	5	95	0	0	0
345 Watt High-Power	50	50	0	0	0

Table 8.2.13 Base Case Energy Efficiency Market Shares for Direct Operation External Power Supplies in 2013

Representative Unit	**Market Share (%)**				
	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
2.5 Watt	42	49	6	2	0
18 Watt	19	52	18	10	0
60 Watt	19	63	17	1	0
120 Watt	26	53	18	3	0

Table 8.2.14 Base Case Energy Efficiency Market Shares for Battery Chargers in 2013

Product Class (PC)	**Market Share (%)**				
	CSL 0	**CSL 1**	**CSL 2**	**CSL 3**	**CSL 4**
PC1: Low E, Inductive	**78**	**11**	**11**	**0**	**0**
PC2: Low E, Low V	**18**	**22**	**57**	**3**	**0**
PC3: Low E, Medium V	**17**	**62**	**21**	**0**	**0**
PC4: Low E, High V	**9**	**39**	**52**	**0**	**0**
PC5: Medium E, Low V	**28**	**52**	**7**	**13**	**0**
PC6: Medium E, High V	**36**	**29**	**22**	**13**	**0**
PC7: High E	**44**	**57**	**0**	**0**	**0**
PC8: DC-DC, <9V Input	**50**	**40**	**10**	**0**	**0**
PC9: DC-DC, ≥9V Input	**25**	**50**	**25**	**0**	**0**
PC10: Low E, AC Out	**87**	**0**	**0**	**13**	**0**

8.2.12 Compliance Date of Standard

The compliance date is the date when a new standard becomes operative, i.e., the date by which BC and EPS manufacturers must manufacture products that comply with the standard. DOE's publication of a final rule in this standards rulemaking is scheduled for completion in July 2011. The compliance date for amended EPS standards is July 1, 2013. (42 U.S.C.

6295(u)(3)(D)(i)(II)(bb) The compliance date for new EPS and BC standards is also targeted to be July 1, 2013. DOE calculates the LCCs for all consumers as if each would purchase a new product in the year the standard takes effect (2013). However, DOE bases the cost of the equipment on the most recent available data; all dollar values are expressed in 2010$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

The PBP is the amount of time it takes the consumer to recover the assumed higher purchase cost of a more energy-efficient product as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (i.e., from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a “simple” PBP, because it does not take into account changes in operating cost over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent.

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC}$$

Eq. 8.7

where

PBP = payback period in years,
ΔIC = difference in the total installed cost between the more efficient standard level product (efficiency levels 1, 2, etc.) and the baseline (efficiency level 0) product, and
ΔOC = difference in annual operating costs.

PBPs are expressed in years. PBPs greater than the life of the product mean that the increased total installed cost of the more efficient product is not recovered in reduced operating costs over the lifetime of that product. Because all BC and EPS designs in the LCC and PBP analyses save energy and thus yield a positive ΔOC, PBPs that are negative or equal to zero indicate that the total installed cost of the equipment that meets the higher EL is less than that of the baseline.

8.3.2 Inputs

The data inputs to the PBP calculation are the total installed cost of the product to the customer for each candidate standard level (CSL) and the annual (first year) operating costs for each CSL. The only input to the total installed cost is the final product price since the installation cost is assumed to be zero for BCs and EPSs. The inputs to the operating costs are the BC’s or EPS’s UEC and the cost of electricity. The PBP calculation uses the same inputs as the LCC calculation described in section 8.2, except that electricity price trends are not required.

Since the PBP is a “simple” (undiscounted) PBP, the required electricity cost is only for the year in which a new energy conservation standard is to take effect—in this case, 2013. The electricity price DOE uses in the PBP calculation is the price projected for 2013, expressed in 2010$, but not discounted to 2010. DOE does not use discount rates in the PBP calculation.

8.3.3 Rebuttable Presumption Payback Period

Section 325(o)(2)(B)(iii) of EPCA establishes a rebuttable presumption that a standard for BCs or EPSs is economically justified if the Secretary finds that “the additional cost to the consumer of purchasing a product complying with an energy conservation standard level will be less than three times the value of the energy. . . savings during the first year that the consumer will receive as a result of the standard, as calculated under the applicable test procedure . . . .” (42 U.S.C. 6295(o)(2)(B)(iii)) This rebuttable presumption test is an alternative path to establishing economic justification, as compared to consideration of the seven factors set forth in 42 U.S.C. 6295(o)(2)(B)(i)(I)-(VII).

For EPSs and BCs, energy savings calculations in the LCC and PBP analyses use both the relevant test procedures as well as the relevant usage profiles. Because DOE calculates payback periods in a methodology consistent with the rebuttable presumption test for EPSs and BCs in the LCC and payback period analyses, DOE is not performing a stand-alone rebuttable presumption analysis, as it is already embodied in the LCC and PBP analyses.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents LCC results for each BC and EPS representative unit and product class. This section uses the terms “positive LCC savings” and “negative LCC savings.” When a standard results in “positive LCC savings,” the life cycle cost of the standards-compliant BC or EPS is less than the life-cycle cost of the baseline BC or EPS and the consumer will benefit. A consumer is adversely affected when a standard results in “negative LCC savings” (i.e., when the life-cycle cost of the standards-compliant BC or EPS is higher than the life-cycle cost of the baseline BC or EPS). As mentioned previously, DOE characterized the uncertainty and variability of many of the inputs to the analysis with probability distributions and then used a Monte Carlo simulation technique to perform the LCC and PBP calculations. DOE calculated the average LCC and LCC savings and the median[3] and average PBP for each of the CSLs.

DOE calculated LCC savings and PBPs at each efficiency level relative to the base case products that it assigned to the consumers. For some consumers, DOE assigned base case products that are more energy efficient than some of the standard levels. If a consumer was assigned a product energy efficiency that is greater than or equal to the energy efficiency of the standard level under consideration, the LCC calculation reveals that this consumer is not impacted by an increase in product energy efficiency to the standard level, and will experience LCC savings of $0. For that reason, the average LCC impacts are not equal to the difference

---

[3] DOE notes that it presents the median payback period in its results tables to reduce the effect of outliers on the data; however, DOE would like to clarify that it does not eliminate the outliers from the data.

between the LCC of a specific standard level and the LCC of the baseline products. The PBP calculations, however, only consider users who would be affected by the standard.

This section presents LCC and PBP results for a combination of the residential and commercial sectors, where each sector's inputs were sampled based on the application shipments within that sector. The calculations use the energy price forecast in the Reference case of the *AEO2010*. Appendix 8B presents results using the energy price forecasts in the Low, High, and Carbon Cap and Trade growth cases, as well as results for high-usage and low-usage users.

In the subsections below, DOE presents figures showing the distribution of LCCs in the base case for each representative unit and BC product class. Also presented below are figures showing the distribution of LCC impacts and the distribution of PBPs at the CSL selected for the proposed standard level. The distributions of LCCs are presented as frequency charts that show the distribution of LCCs with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

8.4.1 Non-Class A External Power Supply Results

DOE conducted a life-cycle cost analysis on two representative units for Non-Class A (NCA) EPSs: (1) 203 watt multiple voltage EPSs, and (2) 345 watt high-power EPSs. As discussed in chapter 5, DOE leveraged its analysis of these units from the *Determination Concerning the Potential for Energy Conservation Standards for Non-Class A External Power Supplies* published on November 3, 2009 to derive cost-efficiency relationships. (74 FR 56928) For these units, DOE had to normalize data across several sources. For this reason, the MSPs for the 203 watt multiple voltage EPS are expressed as an incremental cost increase over the baseline level, where the baseline MSP is assigned a value of $0. As a result, the average installed prices for this product class are not indicative of the total installed cost at each CSL, and thus the average LCC results are also not indicative of the total life-cycle cost for each CSL. However, the LCC savings, PBP calculations, and percentage of consumers with a net cost or net benefit are unaffected by using these MSPs since they consider the incremental change from one CSL to the other. The MSPs for the 345 watt high-power EPS are not incremental MSPs, but rather represent the complete MSP for the EPS at a given CSL.

8.4.1.1 Base Case LCC Distributions

Figure 8.5 and Figure 8.6 show the frequency charts for the base case LCC for the two Non-Class A EPS representative units. Since the base case considers the different efficiency levels at which consumers currently purchase products, the base case LCC distribution is composed of several standards-levels. If all consumers purchased products at CSL 0 in the base case, then the LCC distribution would be composed entirely of the LCC at CSL 0. However, the LCC distribution in the base case shows the LCC results in proportion to how many users currently purchase products at each standards-level (CSLs 0 through 4).

To find the appropriate distribution of LCCs in the base case, the total LCC was calculated for each standards-level considered (CSLs 0 through 4). Then these distributions were weighted by the market shares for each standards-level in the base case, as discussed in section

8.2.11. The combined chart shows the aggregated LCC distribution across all CSLs in the base case.

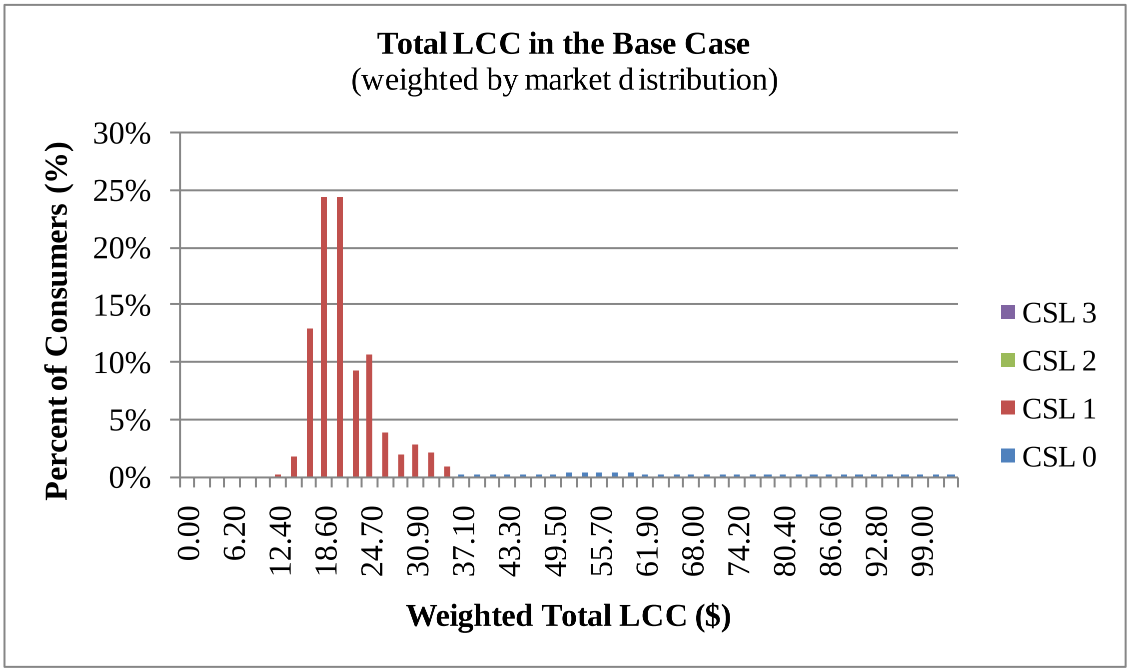


Figure 8.5 203W Multiple Voltage Non-Class A External Power Supplies: Base Case LCC Distribution

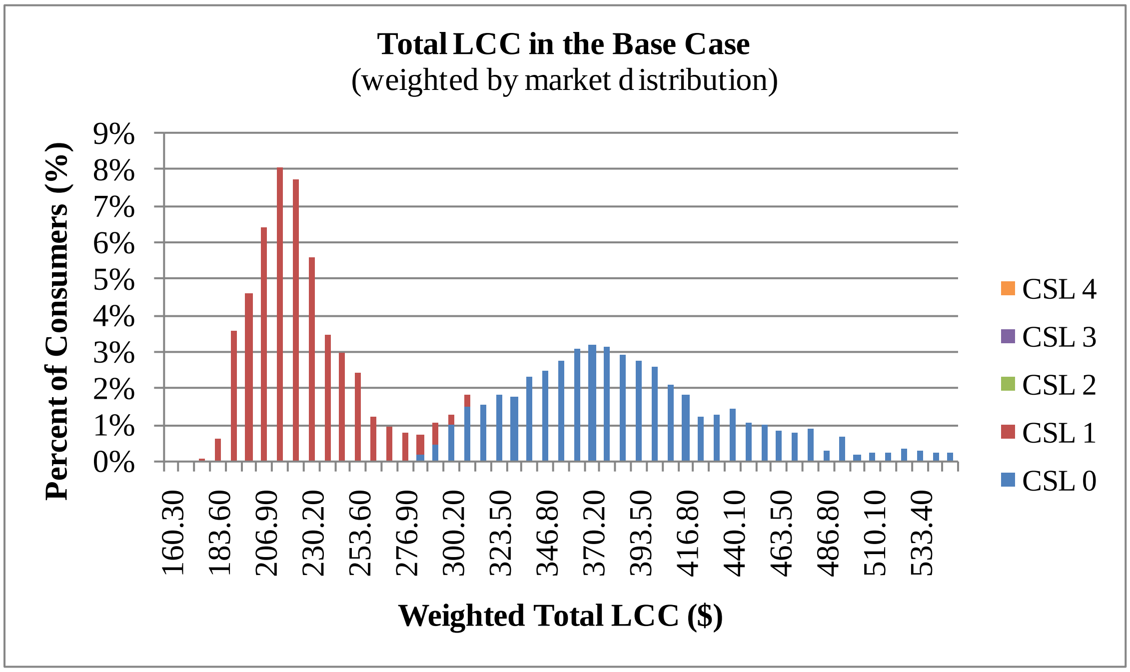
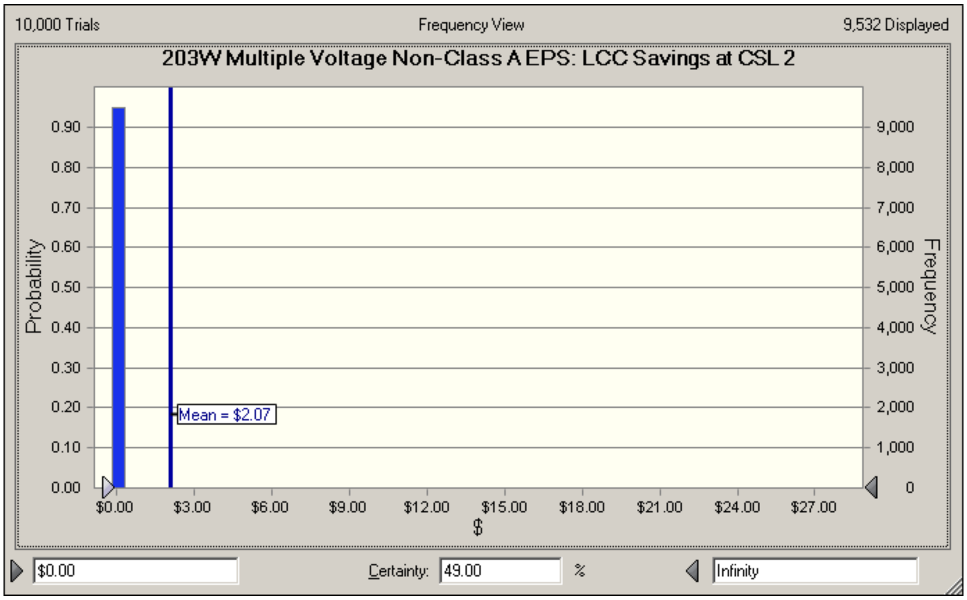


Figure 8.6 345W High-Power Non-Class A External Power Supplies: Base Case LCC Distribution

8.4.1.2 203W Multiple Voltage Non-Class A External Power Supplies

Figure 8.7 and Figure 8.8 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 2. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

For the 203W multiple voltage representative unit, the distribution of LCC savings is atypical compared to most other representative units. A majority of consumers (over 90 percent) experience LCC impacts that are approximately zero. This explains the large spike at $0 in the figure. This is because 95 percent of the market currently purchases at CSL 1, which differs from CSL 2 in total LCC by only $0.01. As a result, many consumers experience positive or negative LCC savings by a few cents. However, 5 percent of consumers currently purchase 203W multiple voltage EPSs at the baseline level. These consumers experience extremely positive LCC savings when switching to CSL 2, which increases the mean LCC savings to $2.07. Due to the scale of the y-axis, these consumers do not appear in the figure.

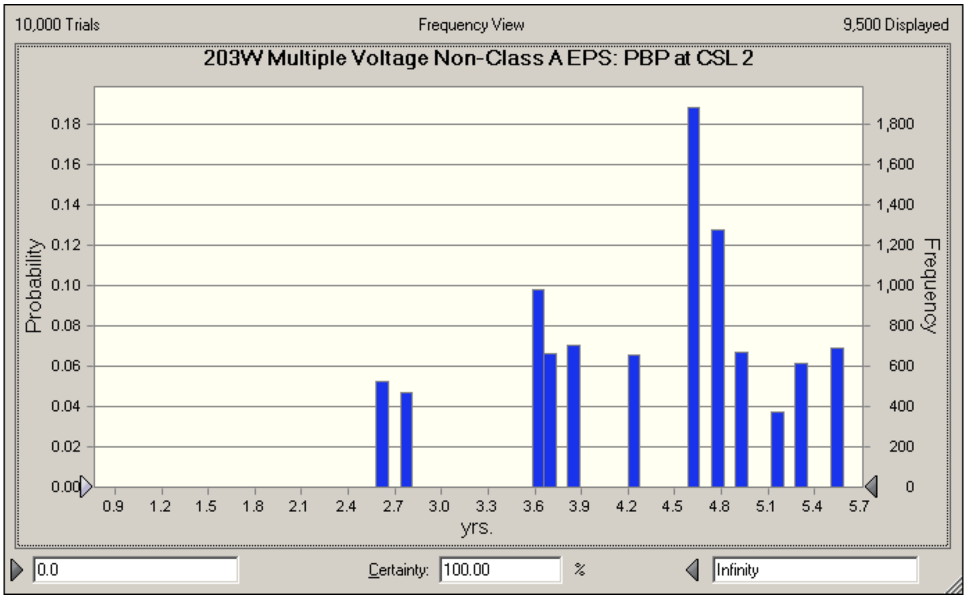


$0.00

Certainty: 49.00 %

Infinity

Figure 8.7 203W Multiple Voltage Non-Class A External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 2



0.0

Certainty: 100.00 %

Infinity

Figure 8.8 203W Multiple Voltage Non-Class A External Power Supplies: Distribution of PBPs at CSL 2

Table 8.4.1 summarizes the LCC and PBP results for the 203W Multiple Voltage NCA EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 203W Multiple Voltage NCA EPSs, CSL 2 has the highest average LCC savings, and a median PBP of 4.7 years. While 51 percent of consumers experience a net cost at CSL 2, nearly all these consumers experience a cost of only a few additional cents. This is because 95 percent of consumers currently purchase these BCs at CSL 1, which has an average LCC that is nearly identical to the average LCC of CSL 2. When these consumers shift to CSL 2, they experience positive or negative LCC savings that approximate $0.00. The other 5 percent of consumers that currently purchase at the baseline (CSL 0), will experience significant LCC savings from switching to CSL 2, which increases the weighted average LCC savings to $2.07 for CSL 2. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.1 LCC and PBP Results for 203W Multiple Voltage Non-Class A External Power Supplies

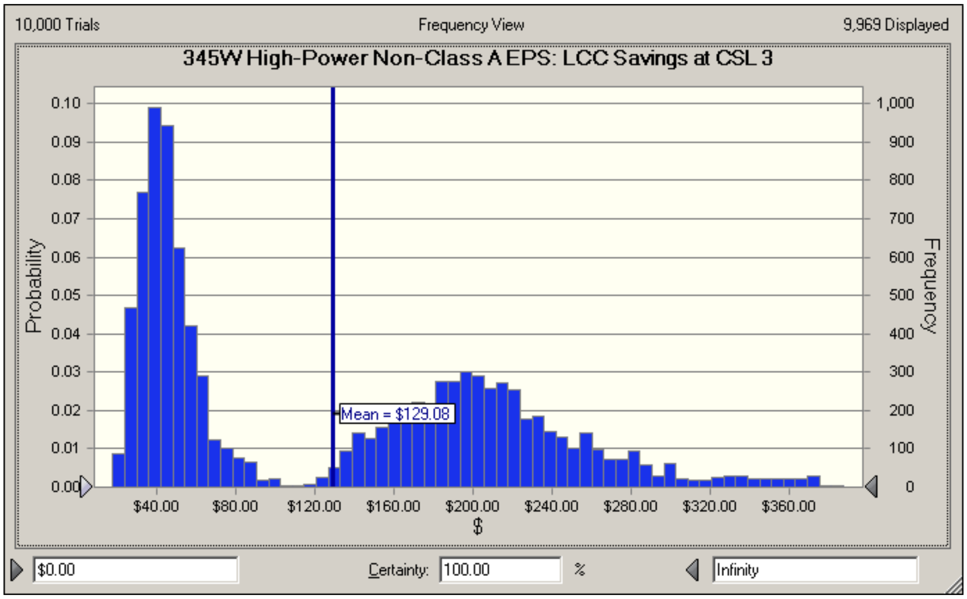
			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* *%*	No Load Power *W*	Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	82.4	12.330	0.00	61.09	61.09	-	-	-	-	-
1	86.4	0.400	3.81	16.40	20.21	2.05	0.0	95.0	5.0	0.4
2	86.4	0.300	4.12	16.07	20.20	2.07	51.0	0.0	49.0	4.7
3	88.5	0.300	11.97	13.38	25.35	-3.09	95.0	0.0	5.0	13.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

8.4.1.3 345W High-Power Non-Class A External Power Supplies

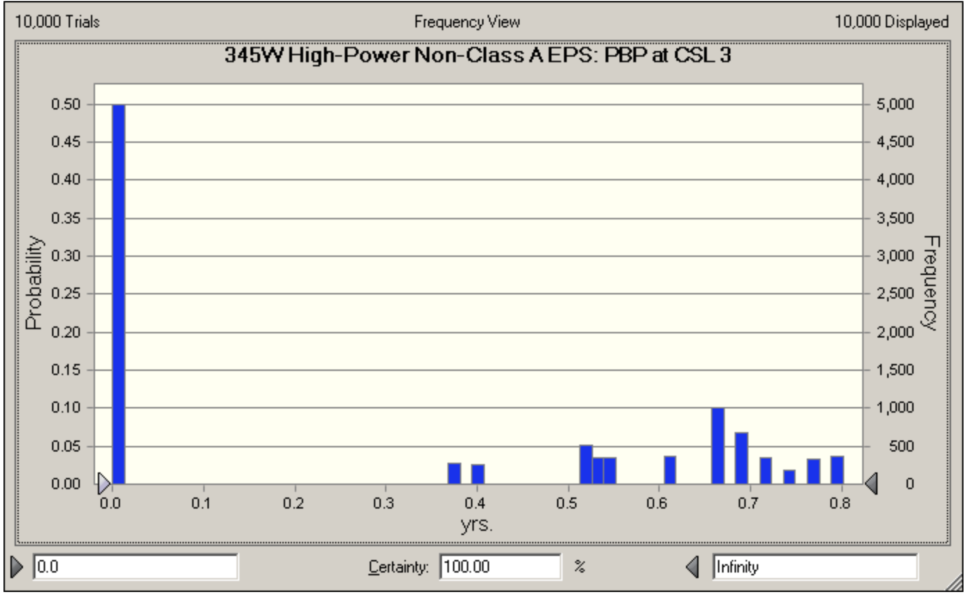
Figure 8.9 and Figure 8.10 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 100.00 % Infinity

Figure 8.9 345W High-Power Non-Class A External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 3

The PBP distribution for the 345W High-Power representative unit shows a large spike at the value of 0.0 years. This is because the installed price at CSL 0 is greater than the installed price at CSL 3. Therefore, all consumers who currently purchase a baseline 345W EPS (i.e., 50 percent of the market) will save money by switching to a less-costly CSL 3 EPS, experiencing an immediate (0.0 year) payback. The other 50 percent of consumers currently purchase at CSL 1, which is less costly than CSL 3. These consumers will not have an immediate payback, but are represented by the payback distribution in Figure 8.10.



0.0 Certainty: 100.00 % Infinity

Figure 8.10 345W High-Power Non-Class A External Power Supplies: Distribution of PBPs at CSL 3

Table 8.4.2 summarizes the LCC and PBP results for the 345W High-Power NCA EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 345W High-Power NCA EPSs, all CSLs have positive LCC savings. CSL 3 has the greatest LCC savings, and a median PBP of 0.2 years. CSLs 1, 2, and 3 all have a smaller installed cost than the baseline (CSL 0), so consumers currently purchasing at the baseline (50 percent of the population) experience an immediate payback by switching to a BC at one of these standard levels. However, the remaining 50 percent of consumers currently purchase at CSL 1, and thus do not experience an immediate payback when switching to CSL 2 or 3. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.2 LCC and PBP Results for 345W High-Power Non-Class A External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	62.4	15.430	176.82	210.53	387.35	-	-	-	-	-
1	81.3	6.010	139.30	80.88	220.19	83.76	0.0	50.0	50.0	0.0
2	84.6	0.500	139.30	39.82	179.13	124.82	0.0	0.0	100.0	0.0
3	87.5	0.500	143.00	31.86	174.87	129.08	0.0	0.0	100.0	0.2
4	92.0	0.266	191.81	19.18	210.98	92.96	16.9	0.0	83.1	2.5

* “Eff.” stands for “efficiency level.”

8.4.2 Direct Operation External Power Supply Results

DOE conducted a life-cycle cost analysis on four representative units for Direct Operation EPSs at different levels of output power: 2.5 watts, 18 watts, 60 watts, and 120 watts. As discussed in chapter 5, DOE determined the cost-efficiency relationship for these representative units primarily from manufacturer interviews, supplemented with data from DOE’s own efficiency tests and cost teardowns (tests/teardowns). For the data from manufacturer interviews, DOE aggregated the results from various manufacturers. As a result, DOE had to normalize the MSP values across manufacturers. For this reason, the MSPs are expressed as an incremental cost increase over the baseline level, where the baseline MSP is assigned a value of $0. As a result, the average installed prices for Direct Operation EPSs are not indicative of the total installed cost at each CSL, and thus the average LCC results are also not indicative of the total life-cycle cost for each CSL. However, the LCC savings, PBP calculations, and percentage of consumers with a net cost or net benefit are unaffected by using these MSPs since they consider the incremental change from one CSL to the other.

8.4.2.1 Base Case LCC Distributions

Figure 8.11 through Figure 8.14 show the frequency charts for the base case LCC for the four Direct Operation EPS representative units. Since the base case considers the different efficiency levels at which consumers currently purchase products, the base case LCC distribution is composed of several standards-levels. If all consumers purchased products at CSL 0 in the base case, then the LCC distribution would be composed entirely of the LCC at CSL 0. However, the LCC distribution in the base case shows the LCC results in proportion to how many users currently purchase products at each standards-level (CSLs 0 through 4).

To find the appropriate distribution of LCCs in the base case, the total LCC was calculated for each standards-level considered (CSLs 0 through 4). Then these distributions were weighted by the market shares for each standards-level in the base case, as discussed in section 8.2.11. The combined chart shows the aggregated LCC distribution across all CSLs in the base case.

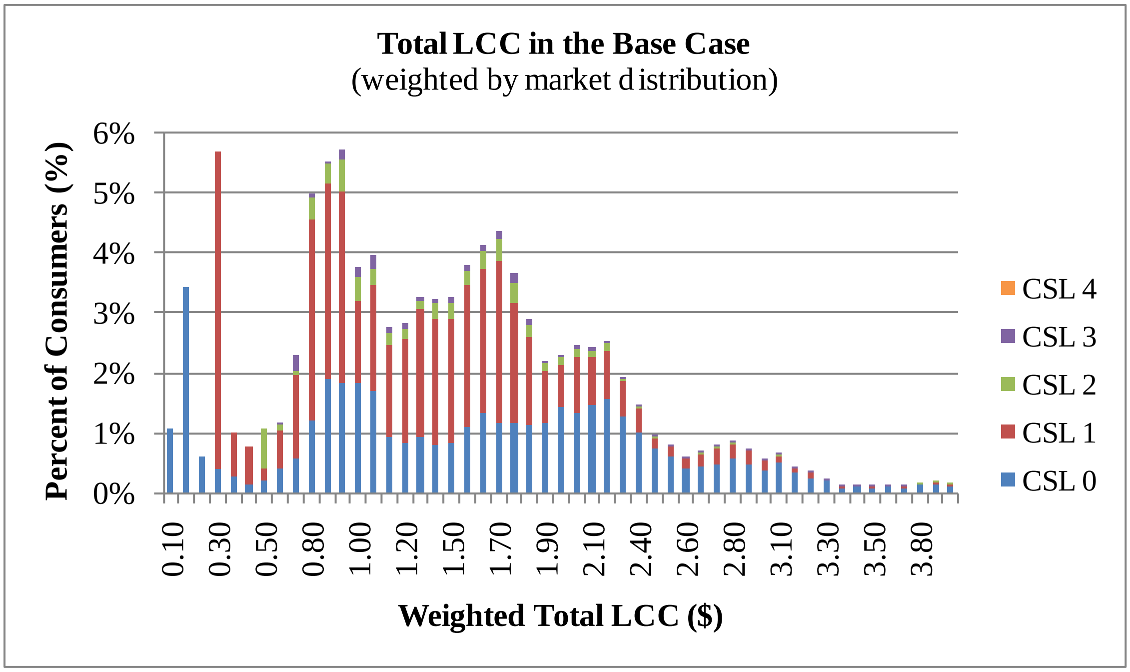


Figure 8.11 2.5W Regular AC/DC External Power Supplies: Base Case LCC Distribution

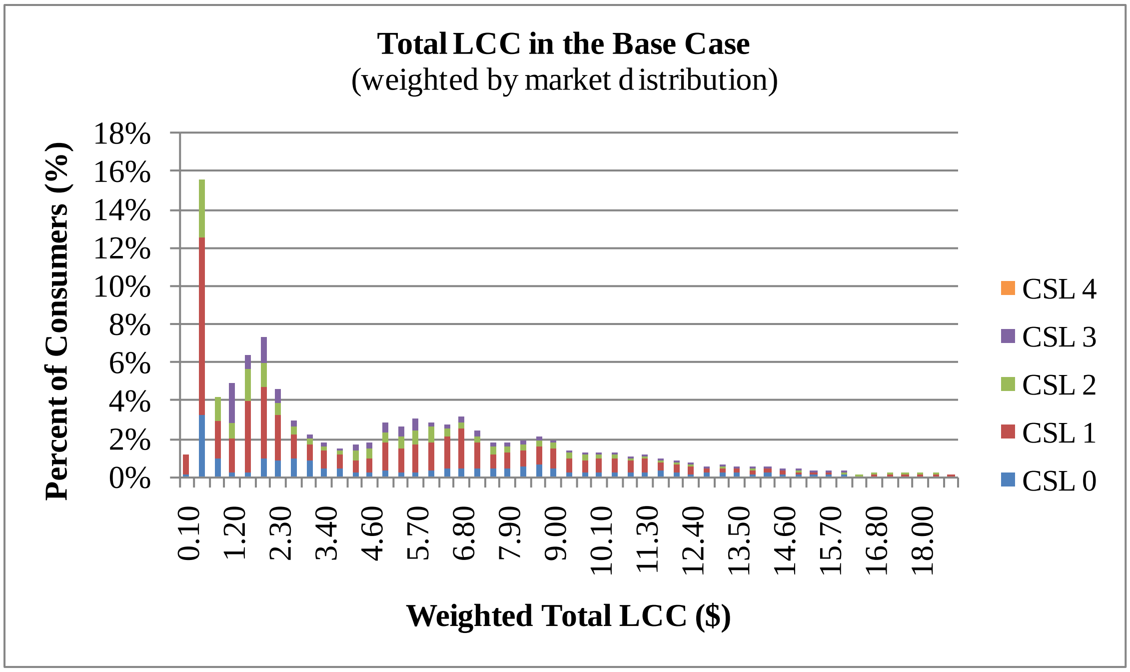


Figure 8.12 18W Regular AC/DC External Power Supplies: Base Case LCC Distribution

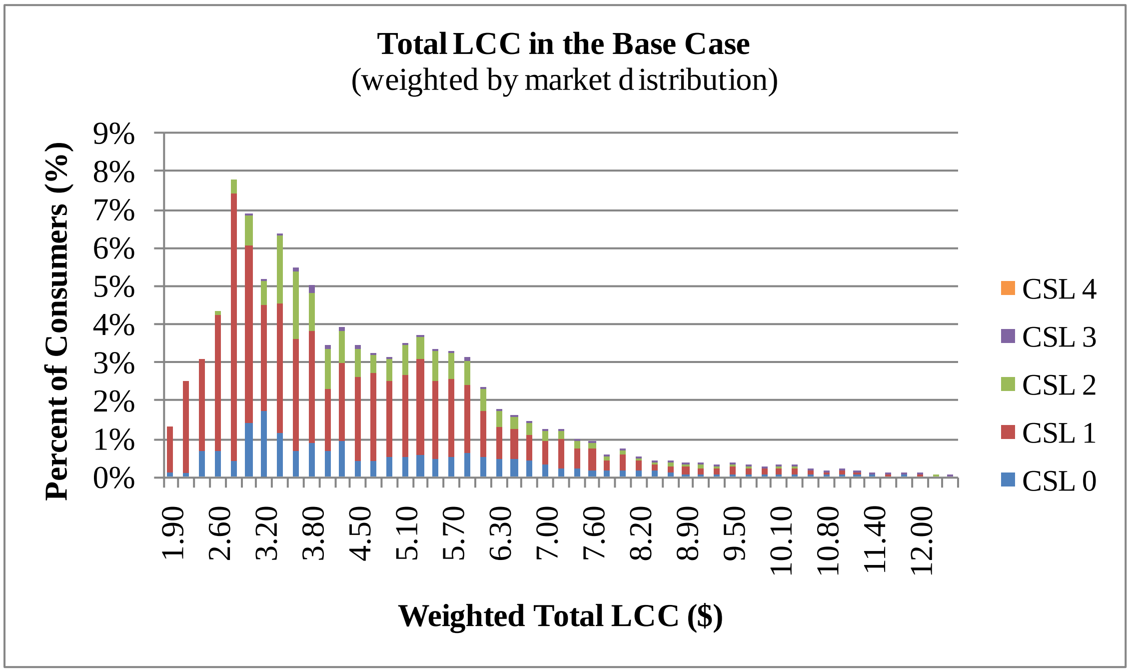


Figure 8.13 60W Regular AC/DC External Power Supplies: Base Case LCC Distribution

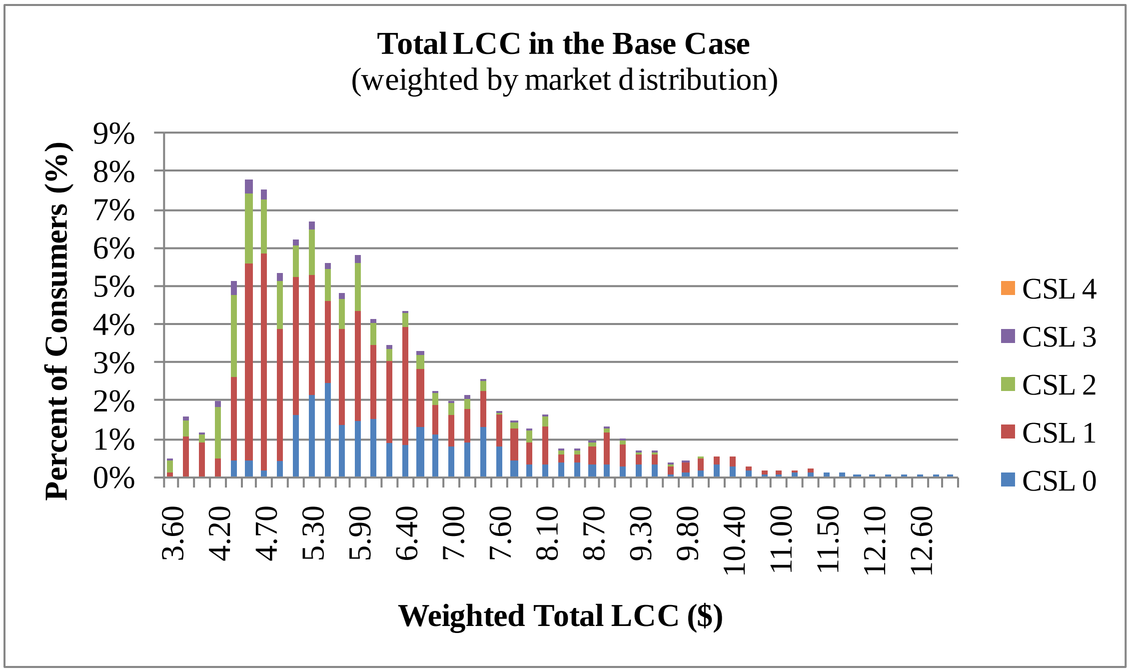
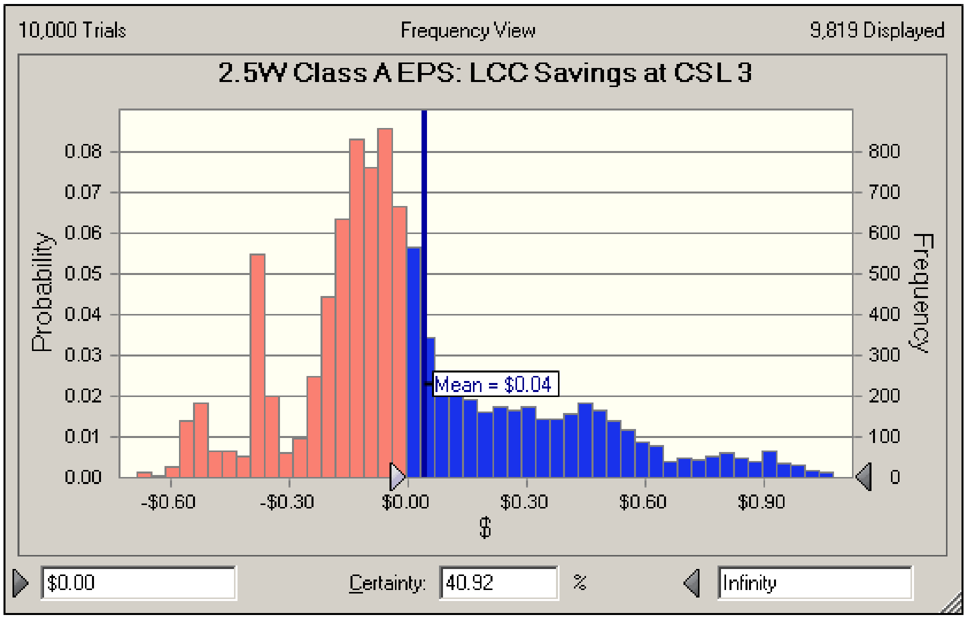


Figure 8.14 120W Regular AC/DC External Power Supplies: Base Case LCC Distribution

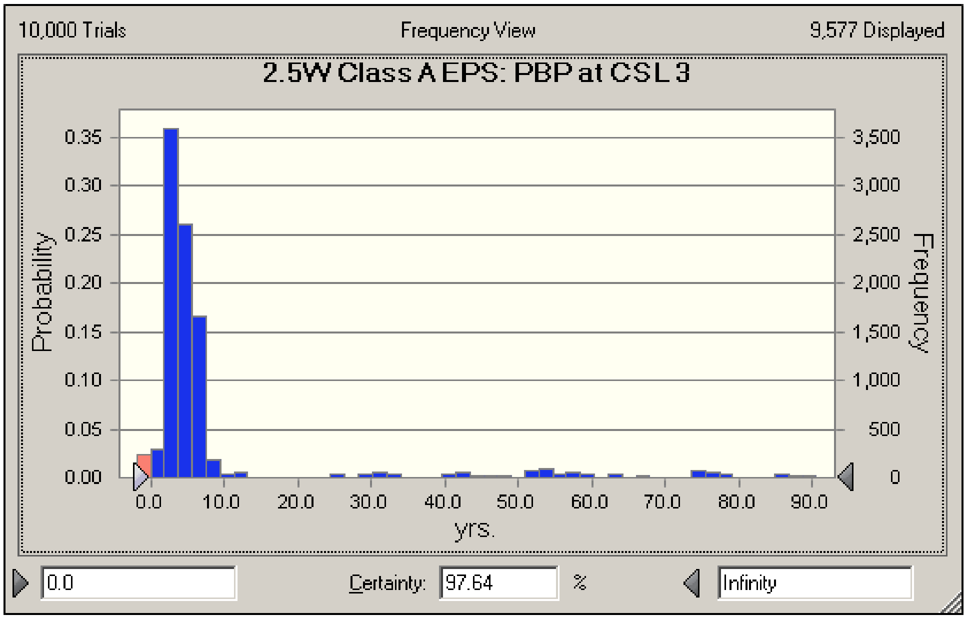
8.4.2.2 2.5W Regular AC/DC External Power Supplies

Figure 8.15 and Figure 8.16 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 40.92 % Infinity

Figure 8.15 2.5W Regular AC/DC External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 3



0.0 Certainty: 97.64 % Infinity

Figure 8.16 2.5W Regular AC/DC External Power Supplies: Distribution of PBPs at CSL 3

Table 8.4.3 summarizes the LCC and PBP results for the 2.5W EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 2.5W EPSs, every CSL has positive LCC savings. CSL 1 has the greatest LCC savings, with a median PBP of 1.6 years. CSL 3 has LCC savings of $0.04, and 59.1 percent of consumers experience negative LCC savings at this standards level. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.3 LCC and PBP Results for 2.5W Regular AC/DC External Power Supplies

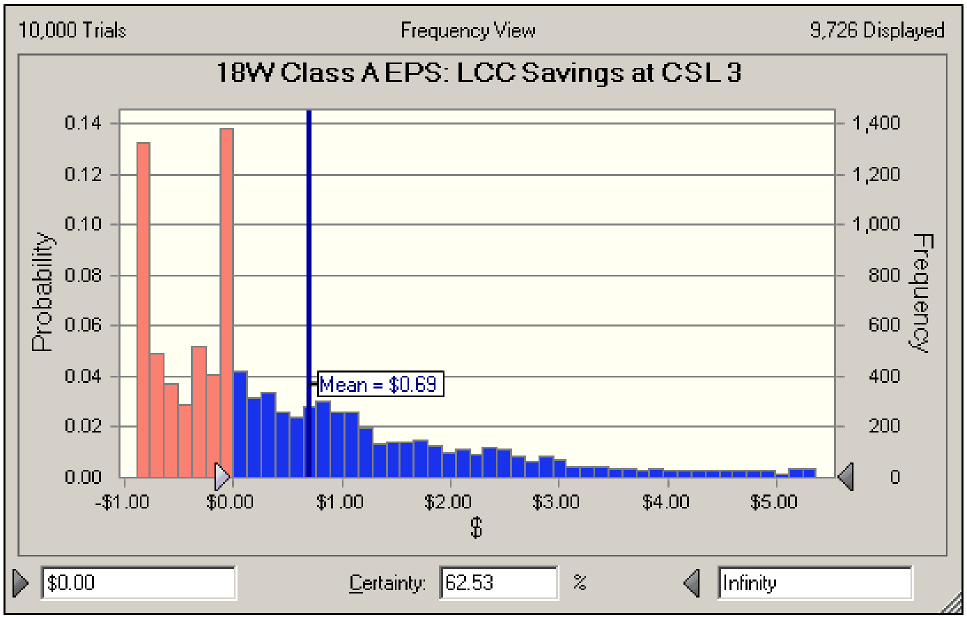
			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	58.3	0.500	0.00	1.55	1.55	-	-	-	-	-
1	67.9	0.300	0.22	1.01	1.23	0.15	5.5	57.6	36.9	1.6
2	71.0	0.130	0.48	0.80	1.28	0.10	45.9	8.3	45.8	3.5
3	73.5	0.100	0.65	0.69	1.34	0.04	59.1	2.4	38.6	4.3
4	74.8	0.039	0.75	0.62	1.37	0.02	61.3	0.0	38.7	4.3

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

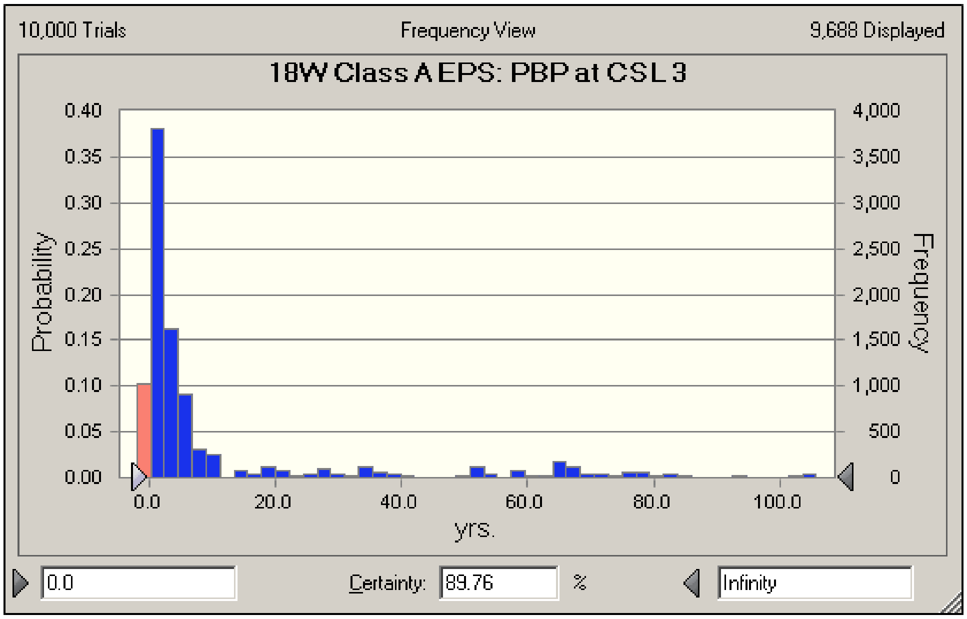
8.4.2.3 18W Regular AC/DC External Power Supplies

Figure 8.17 and Figure 8.18 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 62.53 % Infinity

Figure 8.17 18W Regular AC/DC External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 3



0.0 Certainty: 89.76 % Infinity

Figure 8.18 18W Regular AC/DC External Power Supplies: Distribution of PBPs at CSL 3

Table 8.4.4 summarizes the LCC and PBP results for the 18W EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 18W EPSs, CSL 3 is the highest CSL with positive LCC savings. CSL 3 has LCC savings of $0.69 and a median PBP of 3.1 years. At this standards level, the majority of consumers either experience a net benefit (52.3 percent) or no impact (10.2 percent). Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.4 LCC and PBP Results for 18W Regular AC/DC External Power Supplies

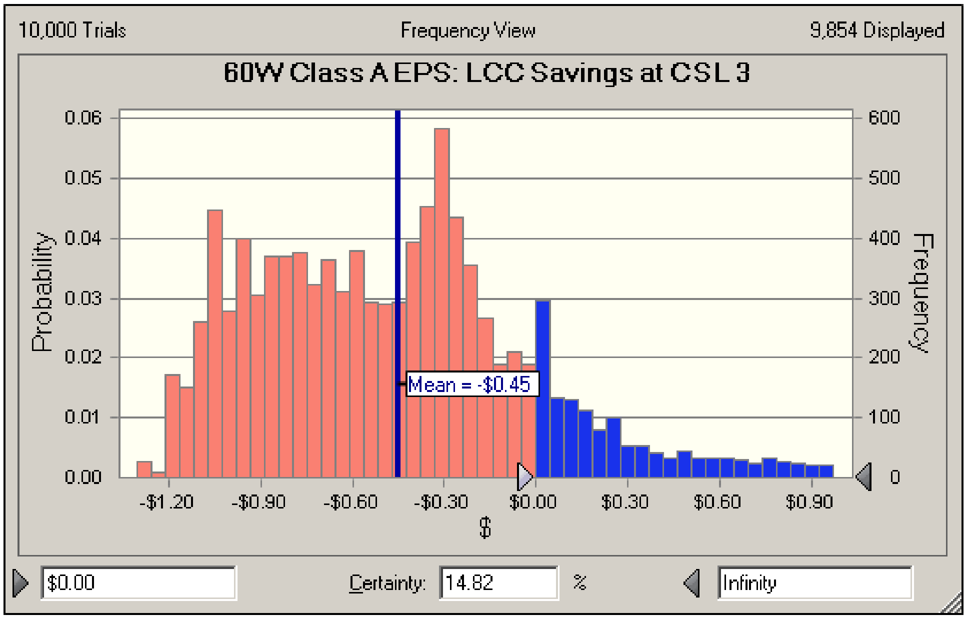
			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	76.0	0.500	0.00	5.83	5.83	-	-	-	-	-
1	80.3	0.300	0.00	4.45	4.45	0.28	0.0	80.5	19.6	0.0
2	83.0	0.200	0.24	3.66	3.90	0.68	16.7	28.5	54.9	1.2
3	85.4	0.100	0.90	2.98	3.88	0.69	37.5	10.2	52.3	3.1
4	91.1	0.039	4.06	1.69	5.76	-1.19	74.4	0.0	25.6	8.1

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

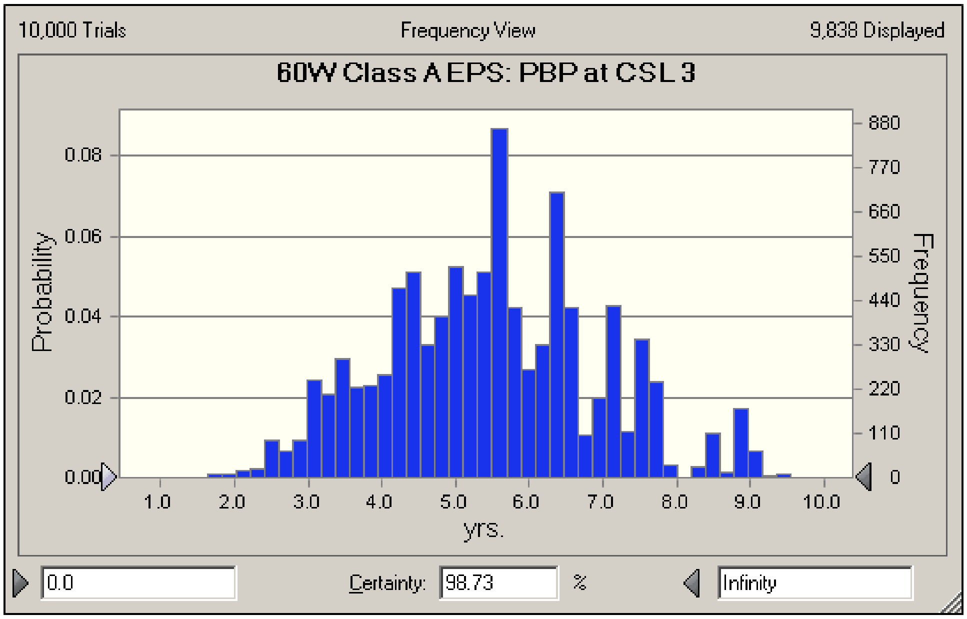
8.4.2.4 60W Regular AC/DC External Power Supplies

Figure 8.19 and Figure 8.20 show the distribution of LCC savings and PBPs for DOE’s proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled “Certainty” at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 14.82 % Infinity

Figure 8.19 60W Regular AC/DC External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 3



0.0 Certainty: 98.73 % Infinity

Figure 8.20 60W Regular AC/DC External Power Supplies: Distribution of PBPs at CSL 3

Table 8.4.5 summarizes the LCC and PBP results for the 60W EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 60W EPSs, CSL 1 is the only CSL with positive LCC savings. CSL 3 has negative LCC savings of -$0.45 and a median PBP of 5.4 years. At CSL 3, 85.2 percent of consumers experience negative LCC savings, while 1.3 percent have no impact and 13.6 percent experience a net benefit. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.5 LCC and PBP Results for 60W Regular AC/DC External Power Supplies

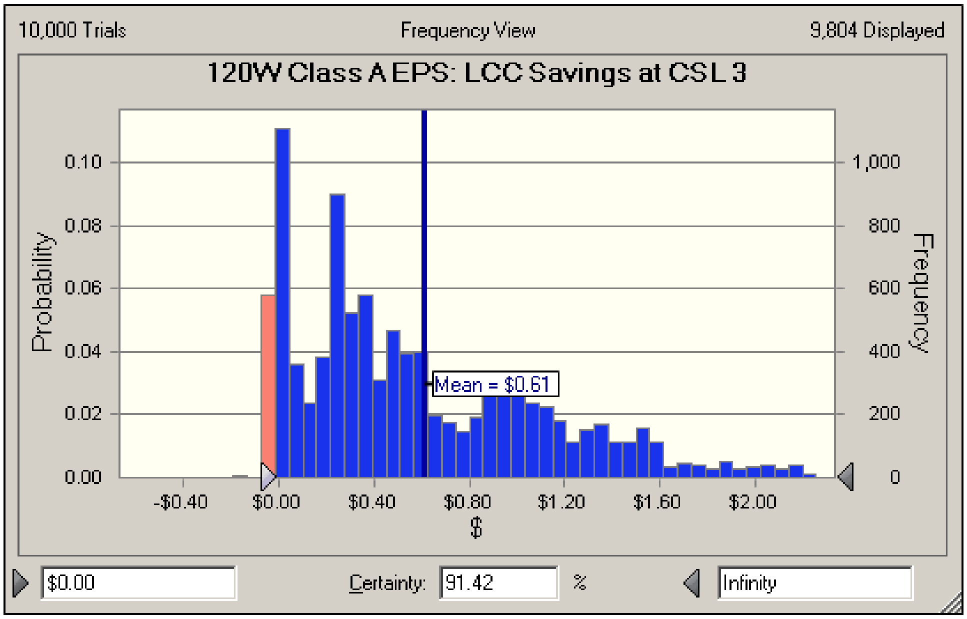
			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	85.0	0.500	0.00	4.82	4.82	-	-	-	-	-
1	87.0	0.500	0.00	4.24	4.24	0.09	0.0	81.4	18.7	0.0
2	87.0	0.200	1.19	3.59	4.78	-0.33	73.7	18.0	8.3	6.3
3	88.0	0.073	1.86	3.04	4.90	-0.45	85.2	1.3	13.6	5.4
4	92.2	0.050	3.93	1.90	5.83	-1.38	92.8	0.0	7.2	6.4

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

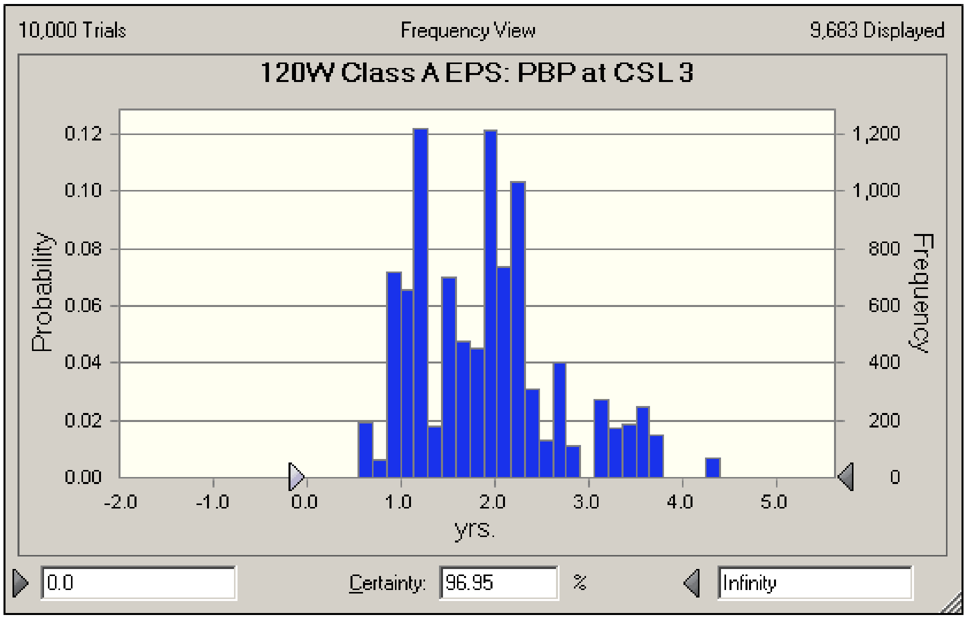
8.4.2.5 120W Regular AC/DC External Power Supplies

Figure 8.21 and Figure 8.22 show the distribution of LCC savings and PBPs for DOE’s proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled “Certainty” at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 91.42 % Infinity

Figure 8.21 120W Regular AC/DC External Power Supplies: Distribution of Life-Cycle Cost Impacts at CSL 3



0.0 Certainty: 96.95 % Infinity

Figure 8.22 120W Regular AC/DC External Power Supplies: Distribution of PBPs at CSL 3

Table 8.4.6 summarizes the LCC and PBP results for the 120W EPS. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For 120W EPSs, CSL 3 is the highest CSL with positive LCC savings. A CSL 3, consumers experience LCC savings of $0.61 on average and the median PBP is 1.9 years. At CSL 3, the majority of consumers either experience a net benefit (88.4 percent) or no impact (3.0 percent). Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.6 LCC and PBP Results for 120W Regular AC/DC External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	85.0	0.500	0.00	6.68	6.68	-	-	-	-	-
1	87.0	0.500	0.00	5.79	5.79	0.23	0.0	74.2	25.8	0.0
2	88.0	0.230	0.44	4.88	5.32	0.60	0.1	21.2	78.7	1.4
3	88.4	0.210	0.63	4.67	5.30	0.61	8.6	3.0	88.4	1.9
4	93.5	0.089	8.98	2.43	11.41	-5.49	100.0	0.0	0.0	9.1

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

8.4.3 Battery Charger Results

DOE conducted a life-cycle cost analysis on all ten BC product classes. As discussed in chapter 5, DOE based the majority of its BC engineering analysis on results from tests and teardowns. However, for two of the BC product classes (PC1 and 10), DOE relied on data from manufacturer interviews to perform its engineering analysis. Unlike the preliminary analysis, DOE is only presenting one set of engineering data and LCC results for each BC product class. PC 1 and 10 uses manufacturer interview data, while PC 2 through 9 use test/teardown data.

Unlike the EPSs discussed previously, the MSPs for each efficiency level considered in the BC analysis represent the total MSP attributable to a battery charger, not the incremental MSP over a baseline level. As such, the average installed prices can be interpreted as the total battery charger installed cost at each CSL, and the total life-cycle cost is representative of the actual cost associated with the BC. The LCC savings, PBP calculations, and percentage of consumers with a net cost or net benefit are unaffected by the type of MSP used, and thus remain accurate.

8.4.3.1 Base Case LCC Distributions

Figure 8.23 through Figure 8.32 show the frequency charts for the base case LCC for the ten BC product classes. Since the base case considers the different efficiency levels at which consumers currently purchase products, the base case LCC distribution is composed of several standards-levels. If all consumers purchased products at CSL 0 in the base case, then the LCC distribution would be composed entirely of the LCC at CSL 0. However, the LCC distribution in the base case shows the LCC results in proportion to how many users currently purchase products at each standards-level (CSLs 0 through 4).

To find the appropriate distribution of LCCs in the base case, the total LCC was calculated for each standards-level considered (CSLs 0 through 4). Then these distributions were weighted by the market shares for each standards-level in the base case, as discussed in section 8.2.11. The combined chart shows the aggregated LCC distribution across all CSLs in the base case.

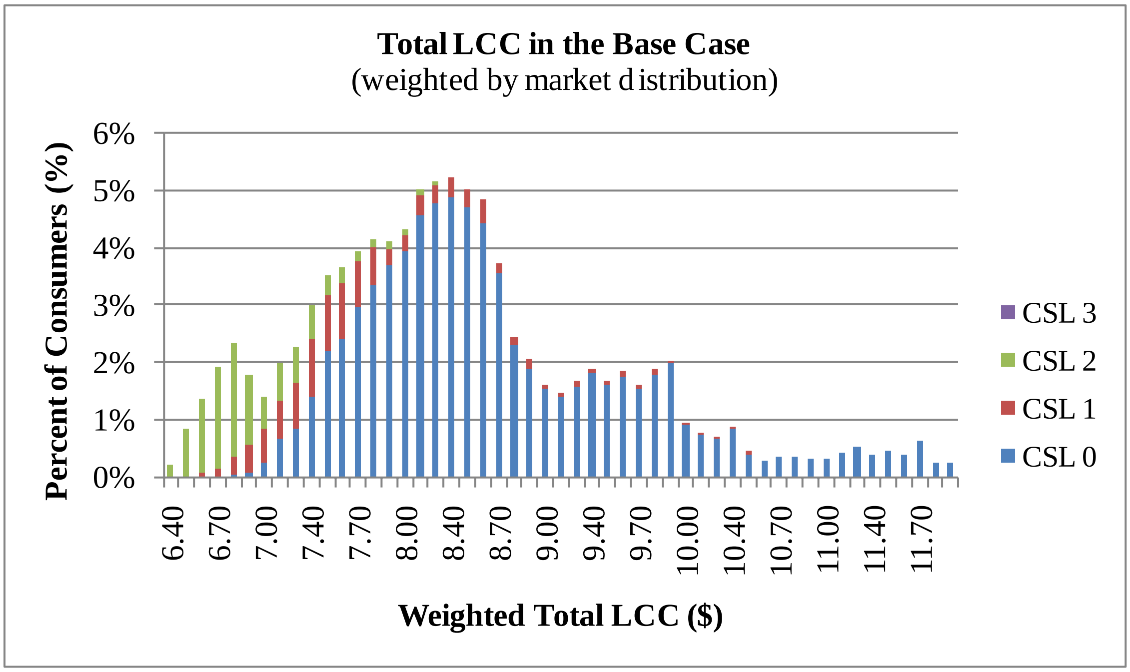


Figure 8.23 PC1 Low Energy, Inductive Battery Charger: Base Case LCC Distribution

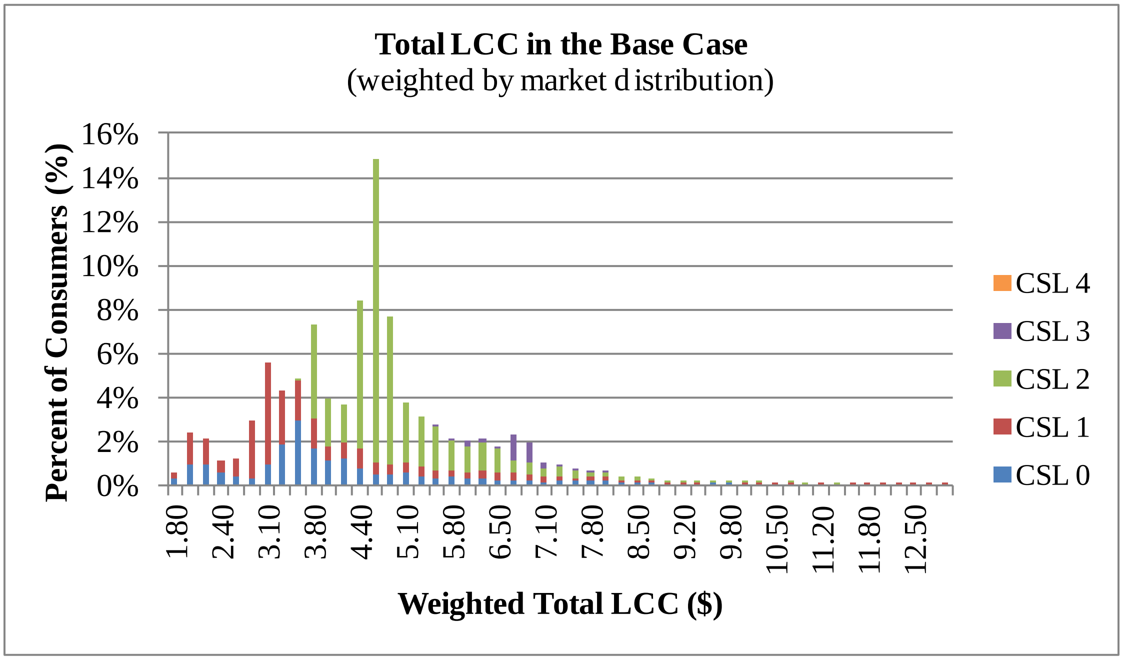


Figure 8.24 PC2 Low Energy, Low Voltage Battery Charger: Base Case LCC Distribution

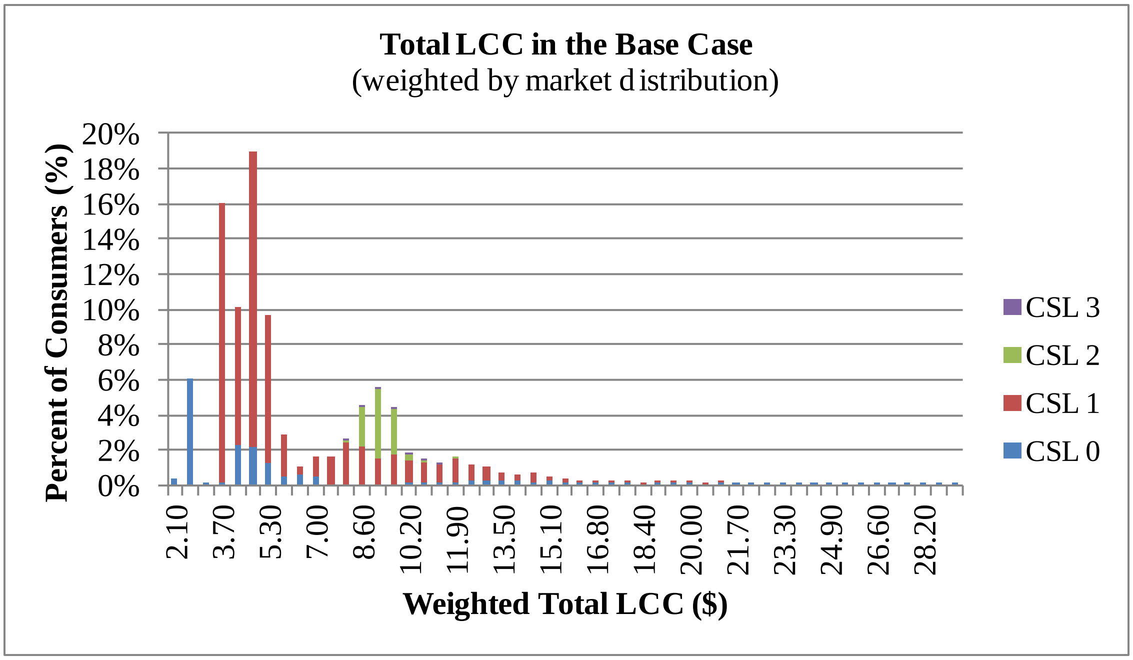


Figure 8.25 PC3 Low Energy, Medium Voltage Battery Charger: Base Case LCC Distribution

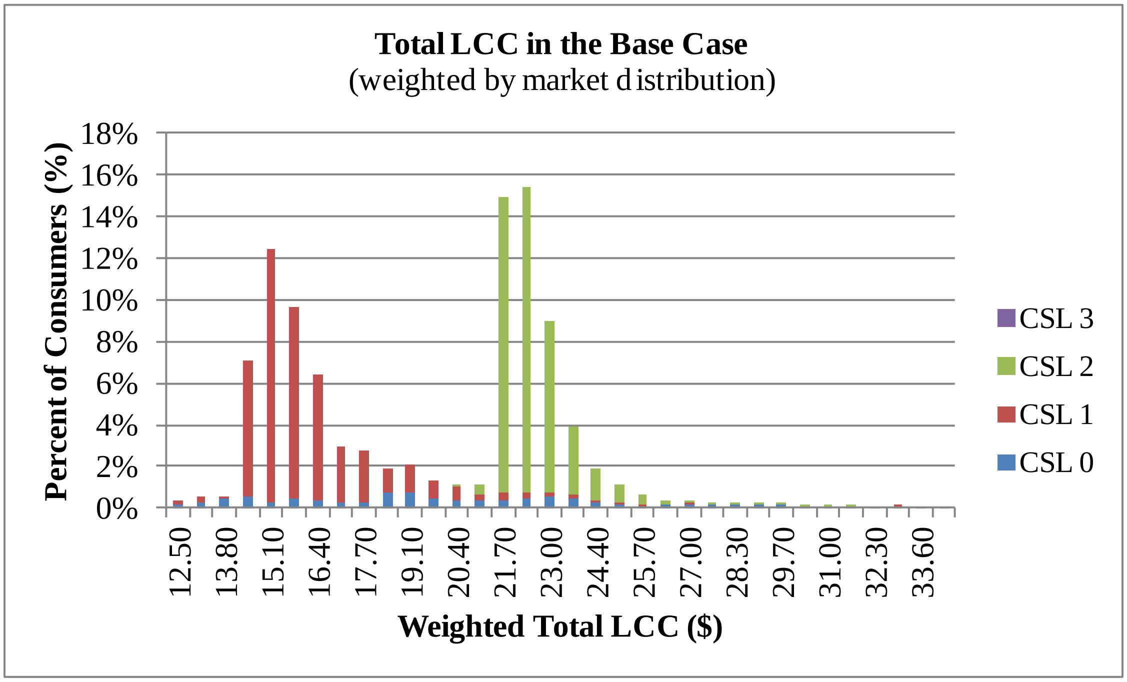


Figure 8.26 PC4 Low Energy, High Voltage Battery Charger: Base Case LCC Distribution

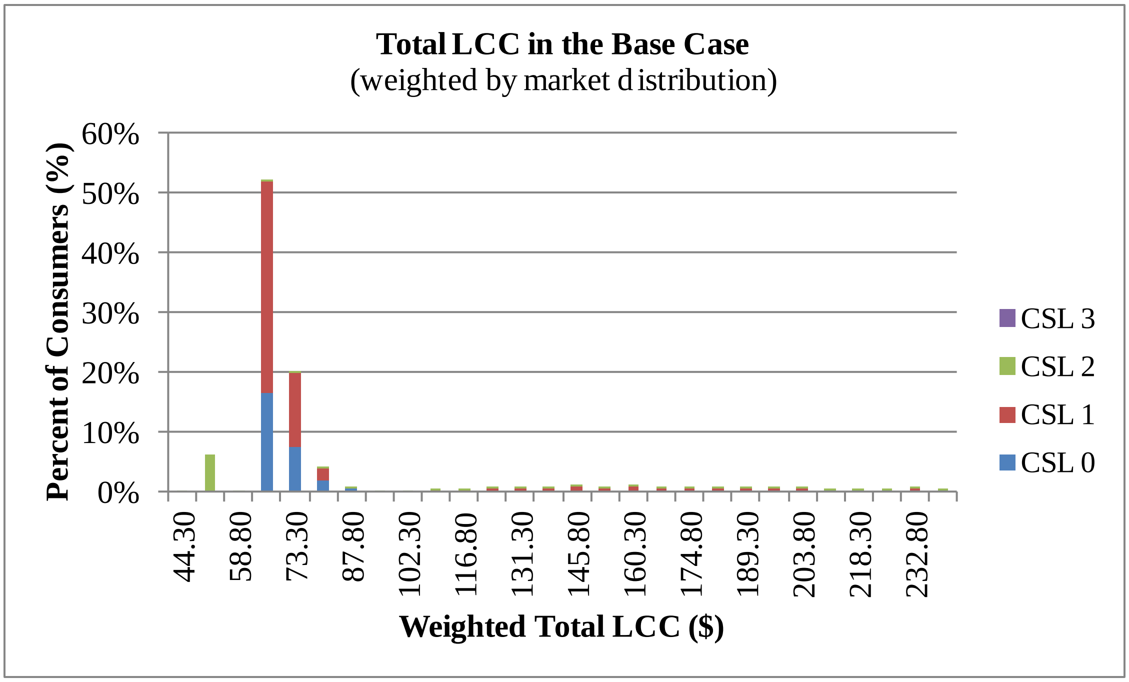


Figure 8.27 PC5 Medium Energy, Low Voltage Battery Charger: Base Case LCC Distribution

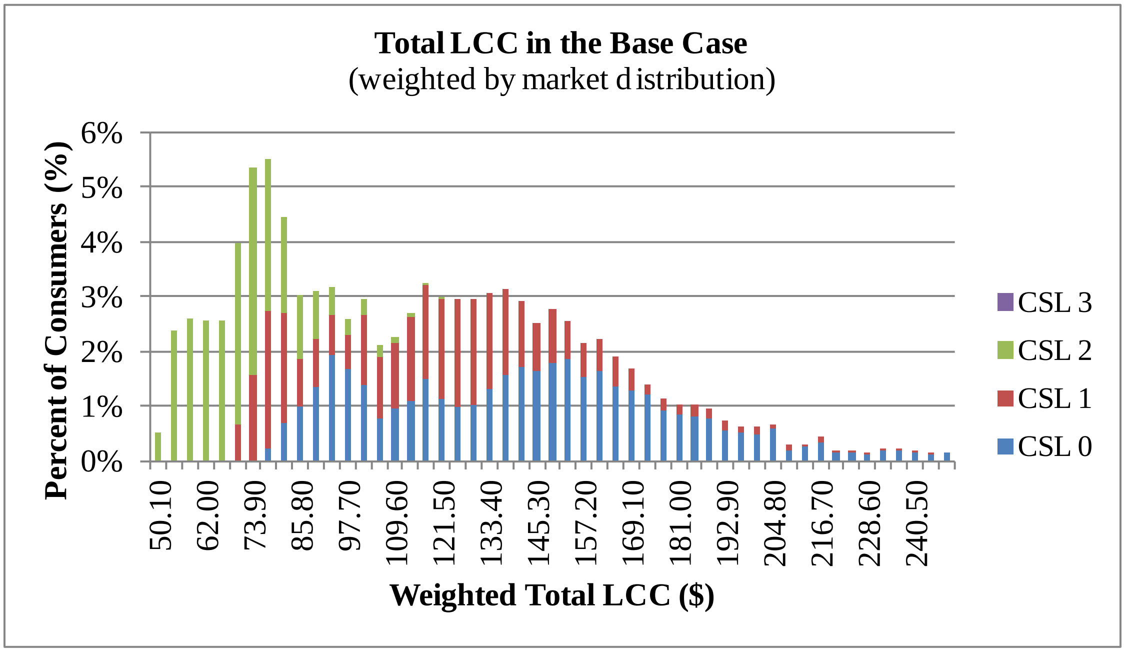


Figure 8.28 PC6 Medium Energy, High Voltage Battery Charger: Base Case LCC Distribution

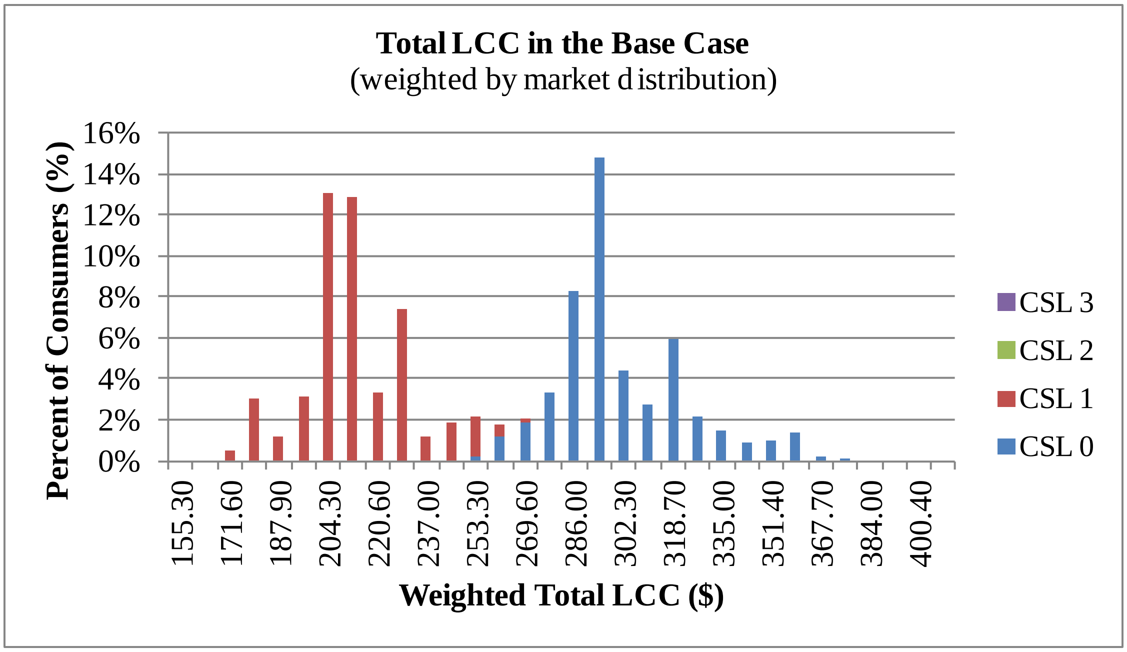


Figure 8.29 PC7 High Energy Battery Charger: Base Case LCC Distribution

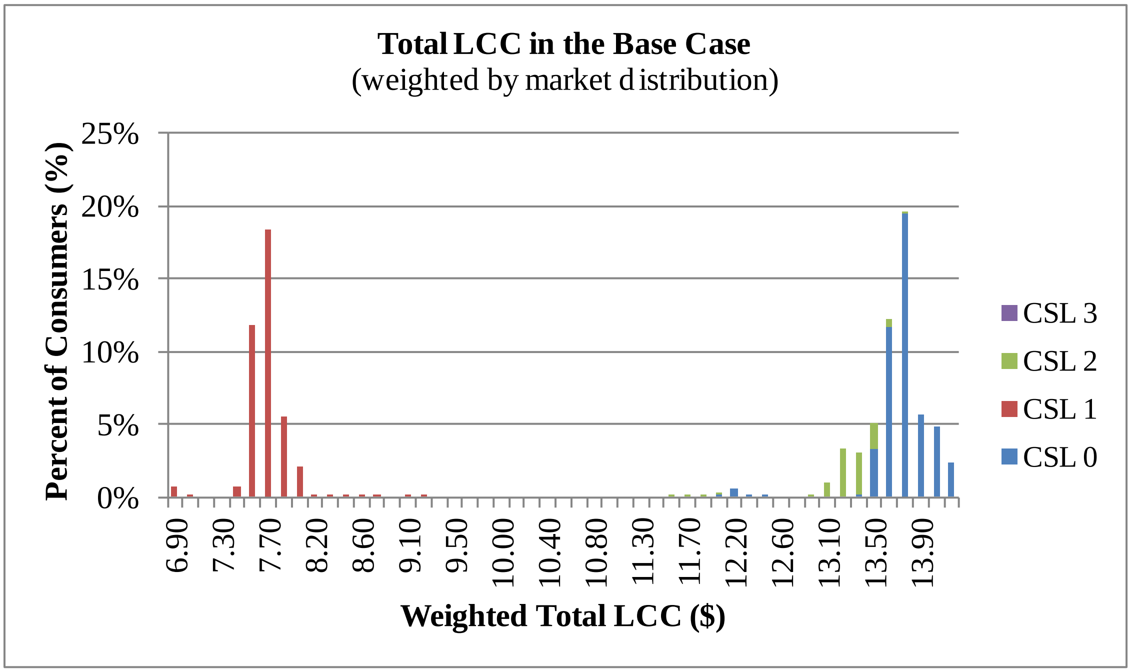


Figure 8.30 PC8 DC-DC, <9V Input Battery Charger: Base Case LCC Distribution

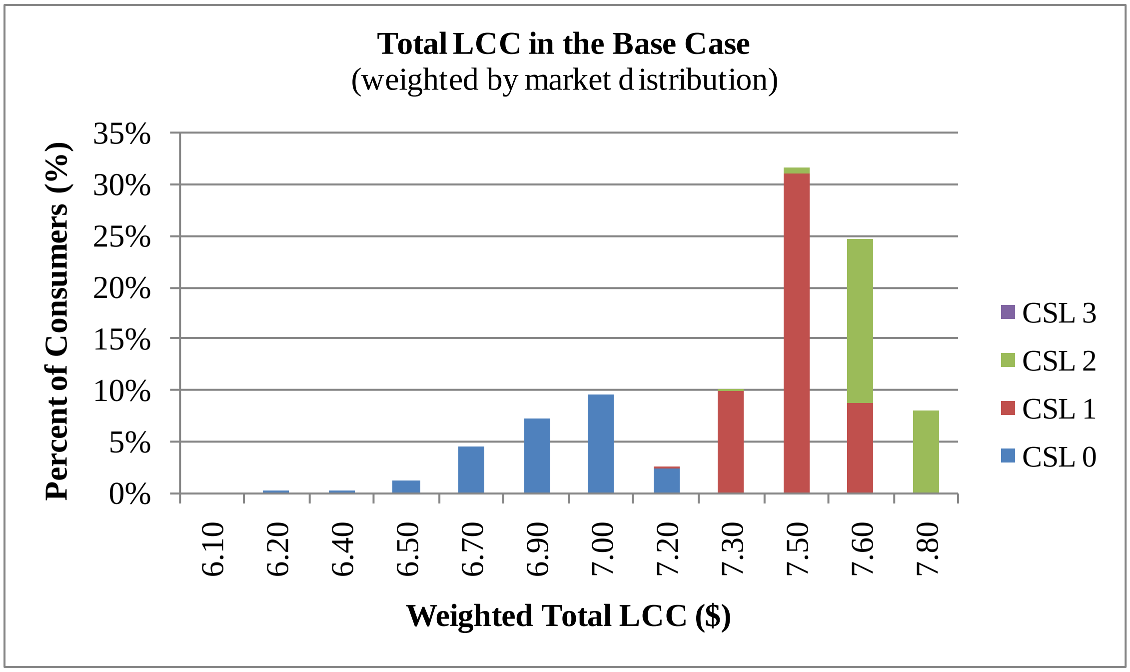


Figure 8.31 PC9 DC-DC, ≥9V Input Battery Charger: Base Case LCC Distribution

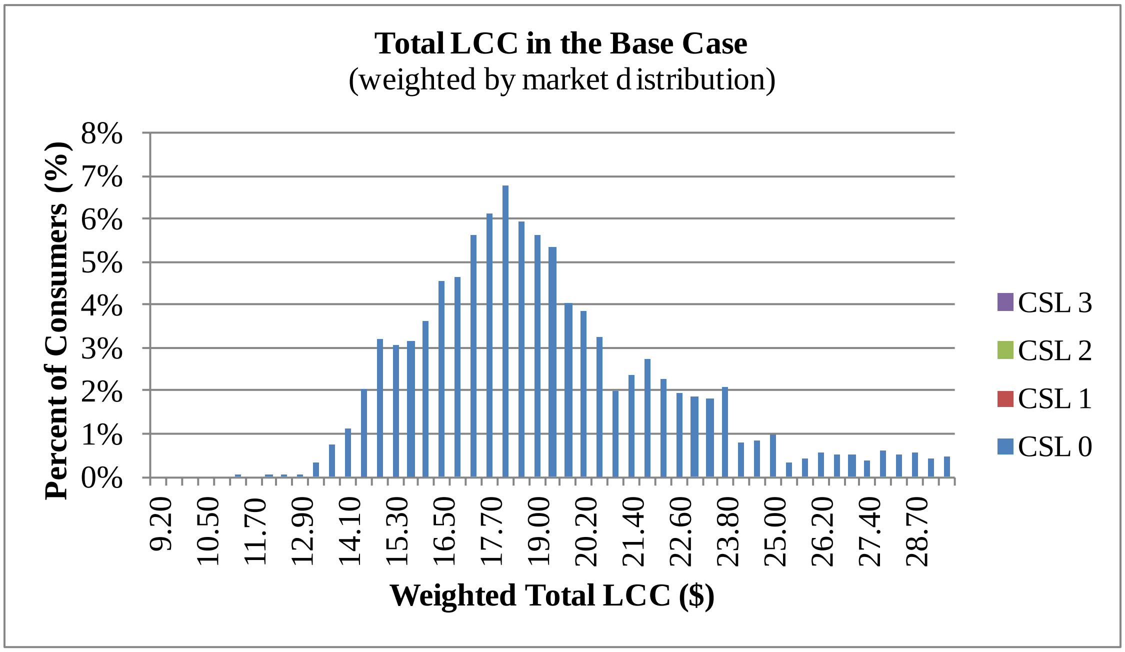
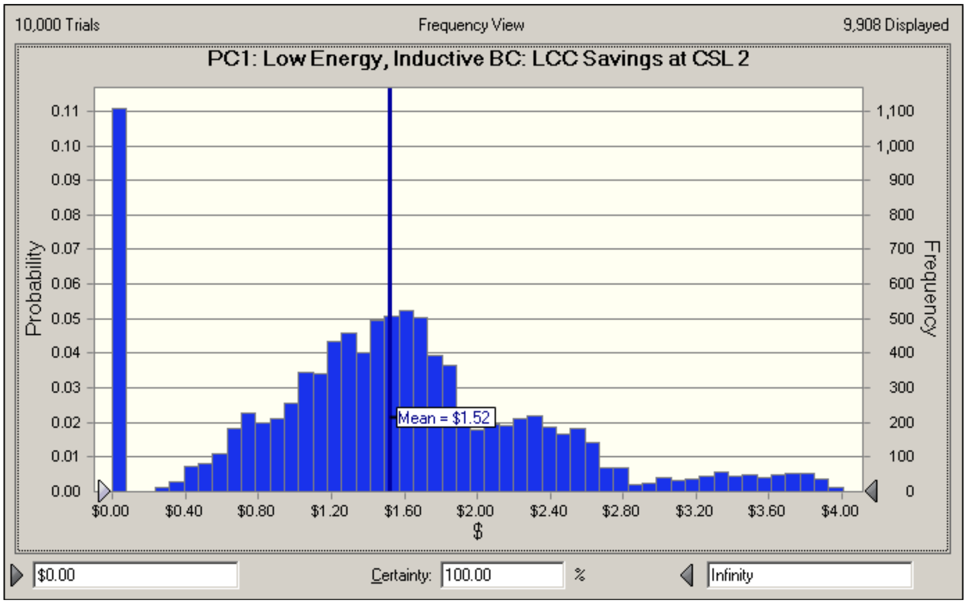


Figure 8.32 PC10 Low Energy, AC Out Battery Charger: Base Case LCC Distribution

8.4.3.2 PC1 Low Energy, Inductive Battery Chargers

DOE did not have sufficient test/teardown data to perform an LCC analysis of the low energy, inductive product class. All LCC and PBP results for this product class are presented using manufacturer data.

Figure 8.33 and Figure 8.34 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 2. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

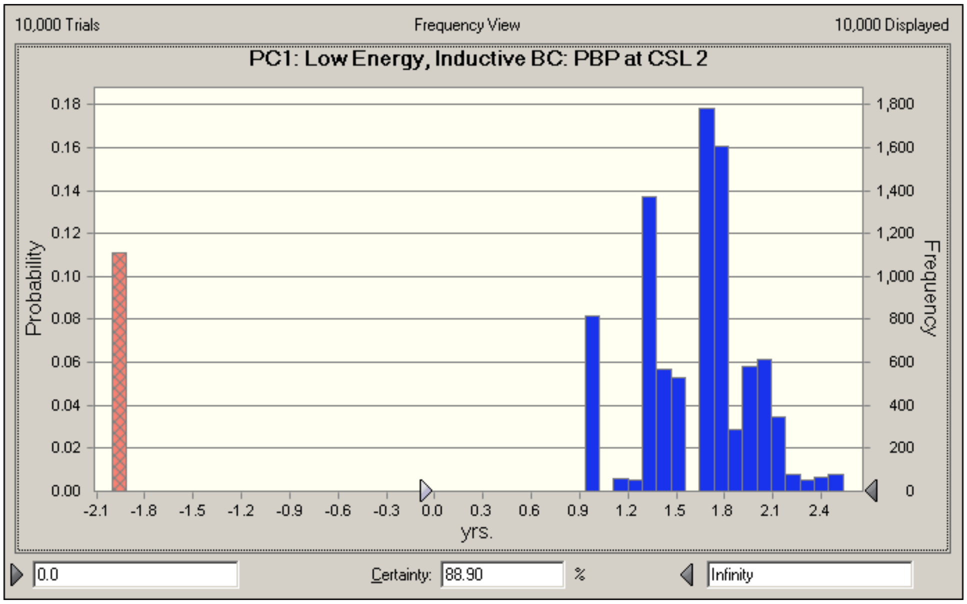


$0.00

Certainty: 100.00 %

Infinity

Figure 8.33 PC1 Low Energy, Inductive Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 2



0.0

Certainty: 88.90 %

Infinity

Figure 8.34 PC1 Low Energy, Inductive Battery Chargers: Distribution of PBPs at CSL 2

Table 8.4.7 summarizes the LCC and PBP results for low energy, inductive BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For low energy, inductive BCs, CSL 2 is the highest CSL with positive LCC savings and also represents the CSL with the greatest LCC savings. At CSL 2, all consumers either experience a net benefit (88.9 percent of consumers) or no impact (11.1 percent of consumers). Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.7 LCC and PBP Results for PC1 Low Energy, Inductive Battery Chargers

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	8.7	4.39	4.32	8.71	-	-	-	-	-
1	6.1	4.72	3.02	7.74	0.76	0.0	22.2	77.8	1.2
2	3.0	5.38	1.50	6.88	1.52	0.0	11.1	88.9	1.7
3	1.3	10.63	0.64	11.27	-2.87	98.2	0.0	1.8	8.5

8.4.3.3 PC2 Low Energy, Low Voltage Battery Chargers

Figure 8.35 and Figure 8.36 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 1. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

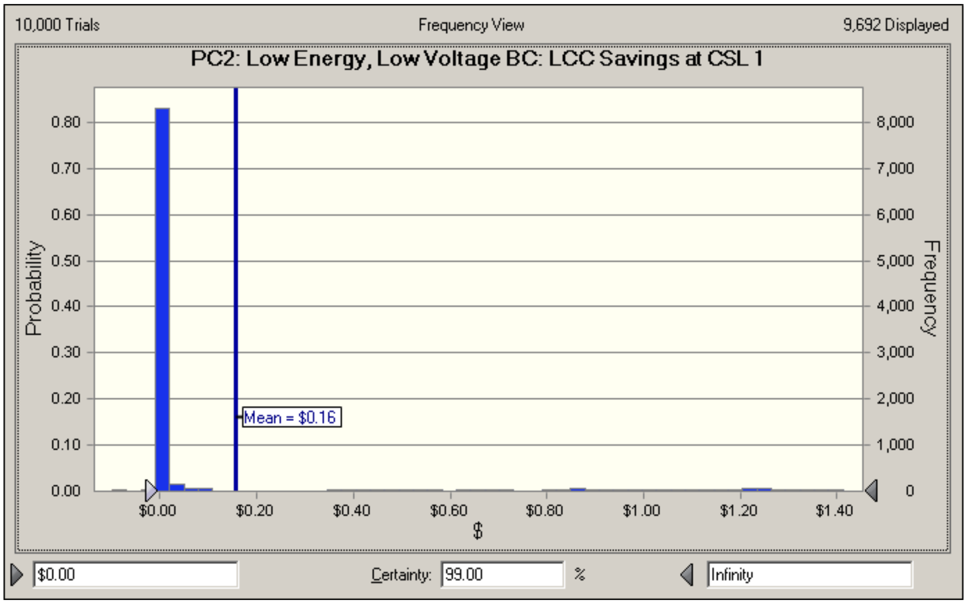


Figure 8.35 PC2 Low Energy, Low Voltage Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 1

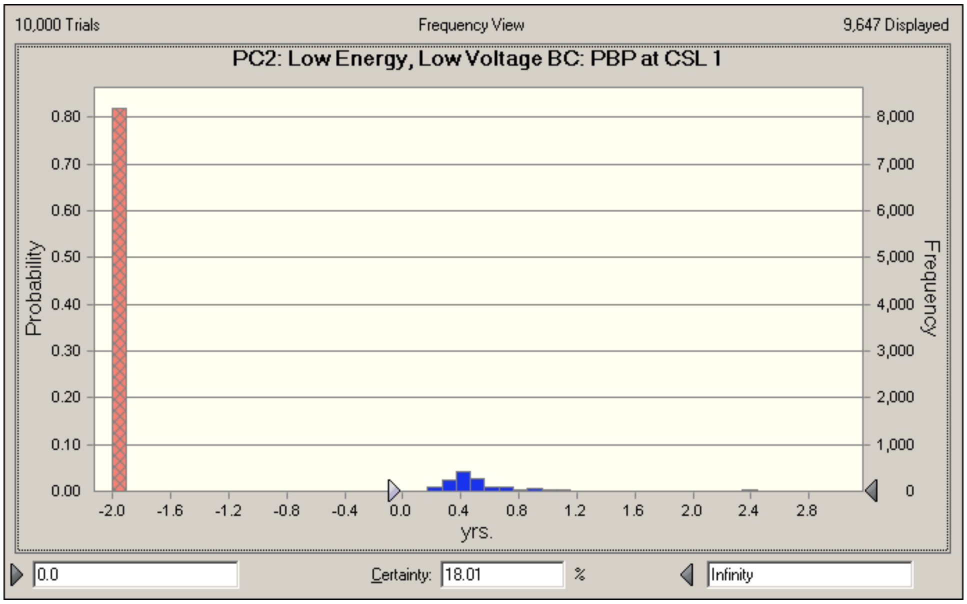


Figure 8.36 PC2 Low Energy, Low Voltage Battery Chargers: Distribution of PBPs at CSL 1

Table 8.4.8 summarizes the LCC and PBP results for low energy, low voltage BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

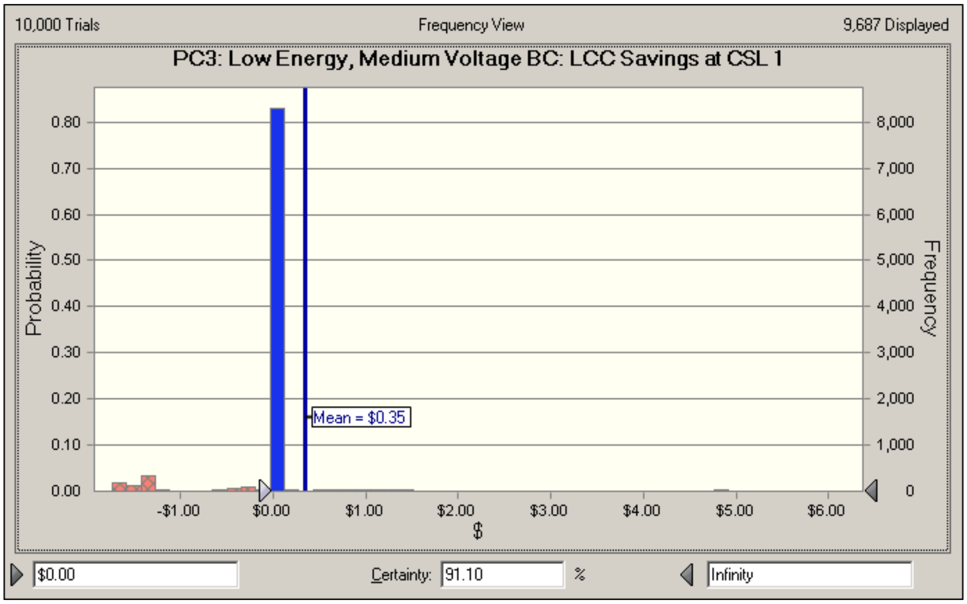
For low energy, low voltage BCs, CSL 1 is the highest CSL with positive LCC savings and also represents the CSL with the greatest LCC savings. The majority of consumers (82.0 percent) experience no impact at CSL 1, but of those impacted, the majority (17.0 percent) experience positive LCC savings. The median PBP for consumers impacted by a standard set at CSL 1 is 0.5 years. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.8 LCC and PBP Results for PC2 Low Energy, Low Voltage Battery Chargers

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	8.7	1.42	3.11	4.53	-	-	-	-	-
1	6.5	1.55	2.35	3.90	0.16	1.0	82.0	17.0	0.5
2	2.9	3.68	1.17	4.86	-0.12	26.8	60.1	13.1	5.2
3	1.0	6.25	0.34	6.59	-1.81	87.1	2.9	10.0	8.5
4	0.8	9.07	0.25	9.32	-4.54	96.8	0.0	3.2	16.9

8.4.3.4 PC3 Low Energy, Medium Voltage Battery Chargers

Figure 8.37 through Figure 8.38 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 1. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00

Certainty: 91.10 %

Infinity

Figure 8.37 PC3 Low Energy, Medium Voltage Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 1

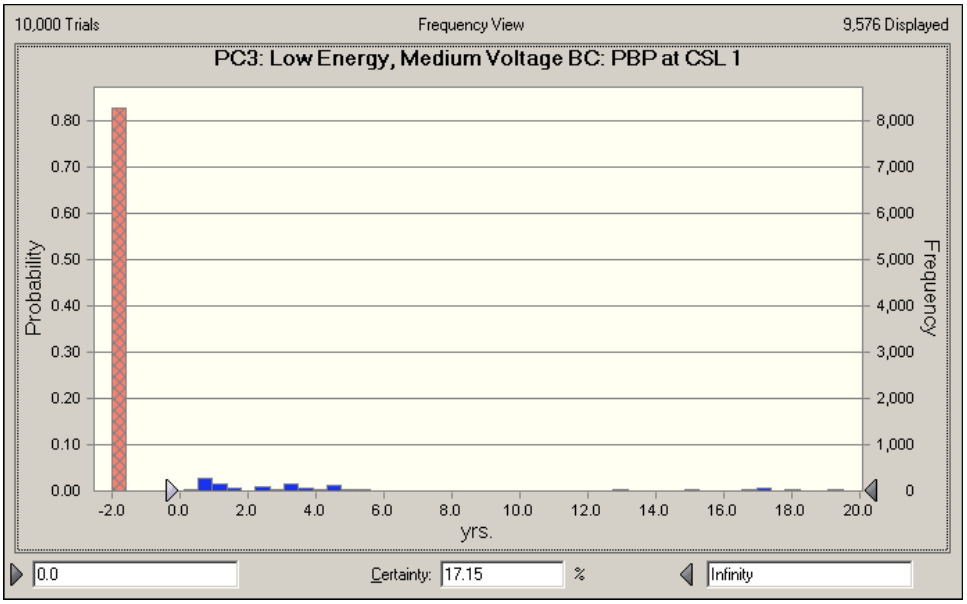


Figure 8.38 PC3 Low Energy, Medium Voltage Battery Chargers: Distribution of PBPs at CSL 1

Table 8.4.9 summarizes the LCC and PBP results for low energy, medium voltage BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For low energy, medium voltage BCs, CSL 1 has both the greatest LCC savings and represents the highest CSL with positive LCC savings. At CSL 1, the majority of consumers (82.8 percent) experience no impact, while the population of consumers who are impacted is relatively evenly split between having a net cost or net benefit. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

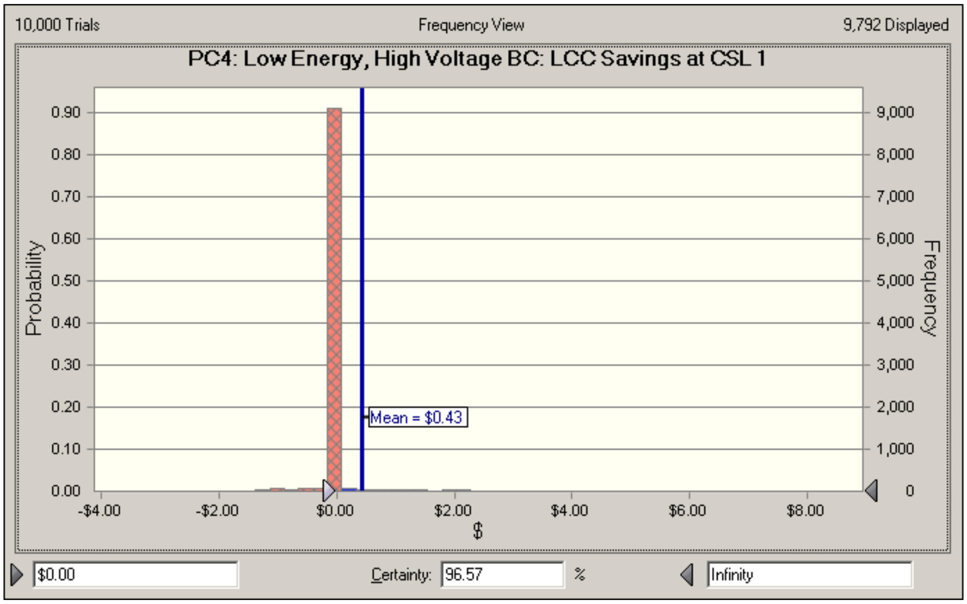
Table 8.4.9 LCC and PBP Results for PC3 Low Energy, Medium Voltage Battery Chargers

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	11.9	1.79	5.94	7.72	-	-	-	-	-
1	4.7	3.51	2.35	5.87	0.35	8.9	82.8	8.3	3.9
2	0.8	8.51	0.39	8.90	-2.12	65.8	20.9	13.3	21.9
3	0.8	8.56	0.37	8.94	-2.15	85.8	0.0	14.2	21.5

8.4.3.5 PC4 Low Energy, High Voltage Battery Chargers

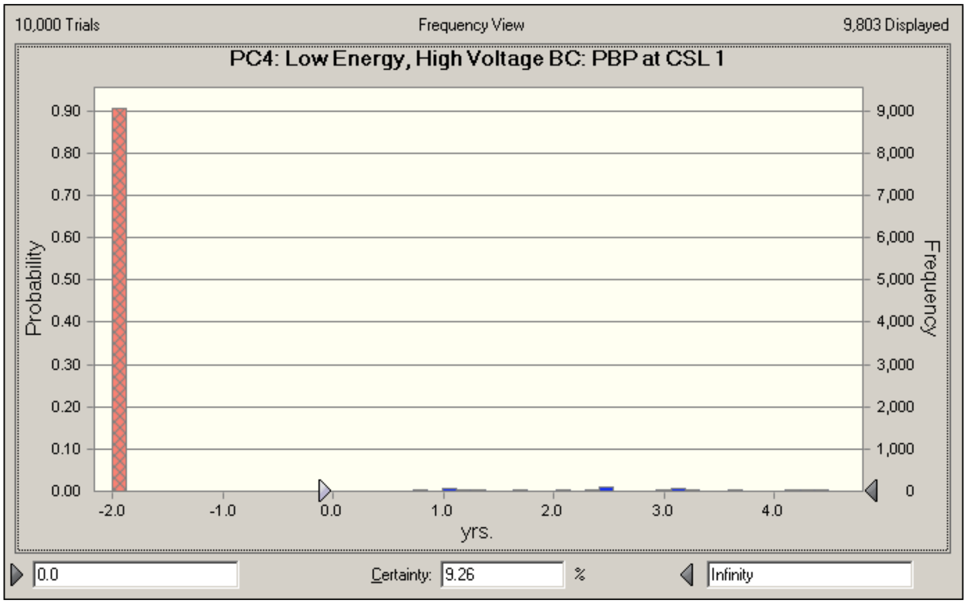
Figure 8.39 and Figure 8.40 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 1. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

For low energy, high voltage BCs, the distribution of LCC savings is atypical compared to most other product classes. A majority of consumers (nearly 90 percent) are not impacted by a standard level set at CSL 1 because they already purchase BCs at this efficiency level or higher. This explains the large spike at $0 in the figure. Of the consumers who are impacted at CSL 1, a majority experience negative LCC impacts, but the mean LCC savings is positive because some consumers experience large positive LCC savings. Due to the scale of the y-axis, these consumers do not appear in the figure.



$0.00 Certainty: 96.57 % Infinity

Figure 8.39 PC4 Low Energy, High Voltage BC: Distribution of Life-Cycle Cost Impacts at CSL 1



0.0 Certainty: 9.26 % Infinity

Figure 8.40 PC4 Low Energy, High Voltage BC: Distribution of PBPs at CSL 1

Table 8.4.10 summarizes the LCC and PBP results for low energy, high voltage BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For low energy, high voltage BCs, CSL 1 has the greatest LCC savings, and represents the highest CSL with positive LCC savings. At this CSL, the majority of consumers (90.7 percent) experience no impact. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard. Of those consumers impacted, the majority (3.4 percent) experience negative LCC savings. However, the 4.6 percent of consumers with positive LCC savings experience larger magnitudes of savings than those who face an LCC cost, which yields a positive weighted average LCC savings at CSL 1. The differences in LCC savings are largely attributable to the specific applications sampled within PC4. Further detail on application-specific LCC results can be found in chapter 11 of the TSD.

Table 8.4.10 LCC and PBP Results for PC4 Low Energy, High Voltage Battery Chargers

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	37.7	8.04	13.94	21.98	-	-	-	-	-
1	9.9	12.24	3.63	15.87	0.43	3.4	90.7	5.8	3.0
2	4.6	20.65	1.64	22.29	-2.73	46.4	51.5	2.2	13.8
3	3.0	28.61	1.09	29.70	-10.14	98.2	0.0	1.8	37.6

8.4.3.6 PC5 Medium Energy, Low Voltage Battery Chargers

Figure 8.41 and Figure 8.42 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 2. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

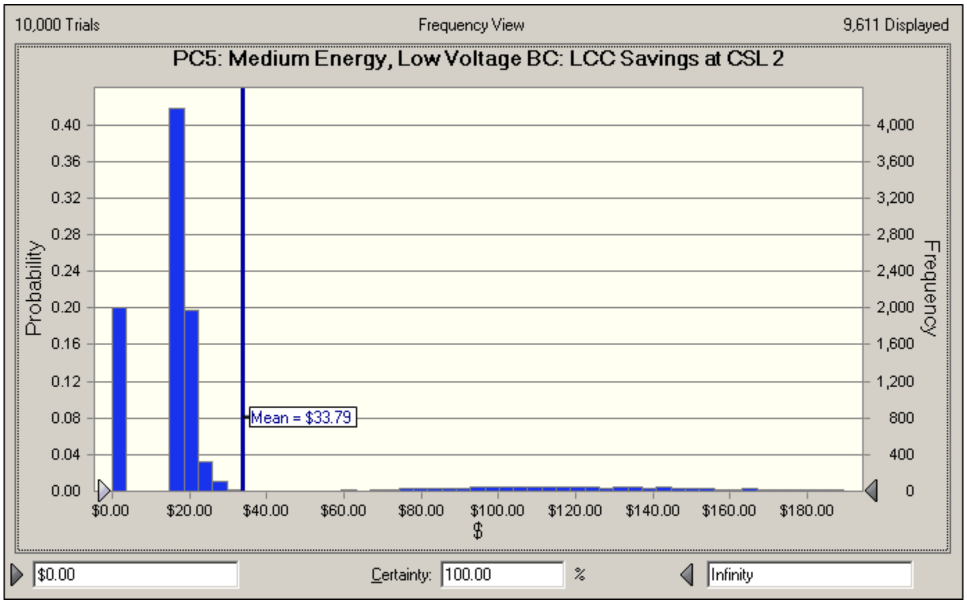
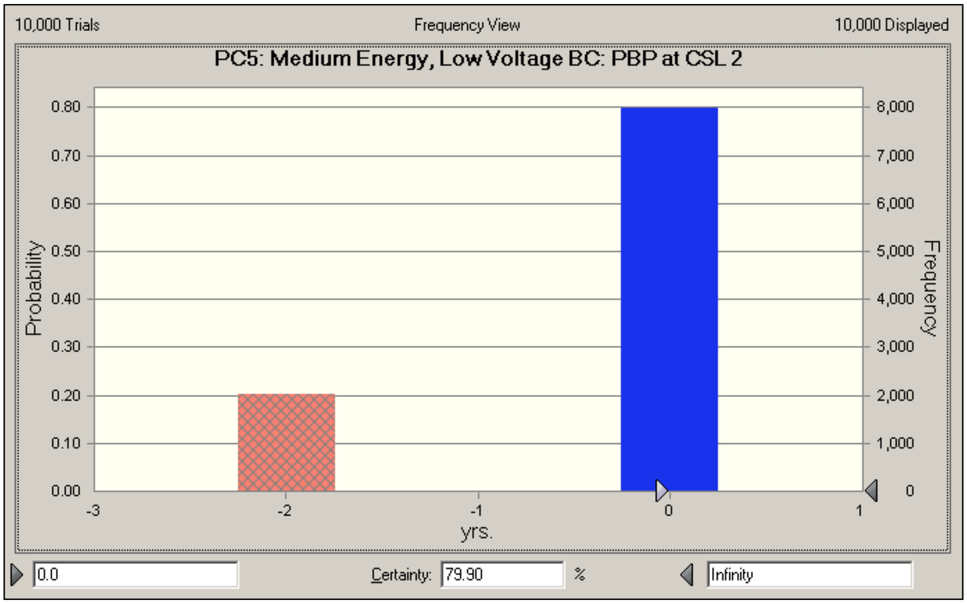


Figure 8.41 PC5 Medium Energy, Low Voltage BC: Distribution of Life-Cycle Cost Impacts at CSL 2

The PBP distribution for PC5 Medium Energy, Low Voltage BCs is split between two options (-2.0 and 0.0) because at this standards level all consumers are either not impacted (-2.0) or they have an immediate payback (0.0). At CSL 2, 8.2 percent of consumers are not impacted. The remaining 91.8 percent of consumers have an immediate payback at CSL 2 because the installed cost at CSL 2 is below the installed cost of both CSL 0 and CSL 1. Therefore, any consumer shifting from CSL 0 or CSL 1 to a CSL 2 BC will save money and have an immediate payback.



0.0

Certainty: 79.90 %

Infinity

Figure 8.42 PC5 Medium Energy, Low Voltage BC: Distribution of PBPs at CSL 2

Table 8.4.11 summarizes the LCC and PBP results for medium energy, low voltage BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

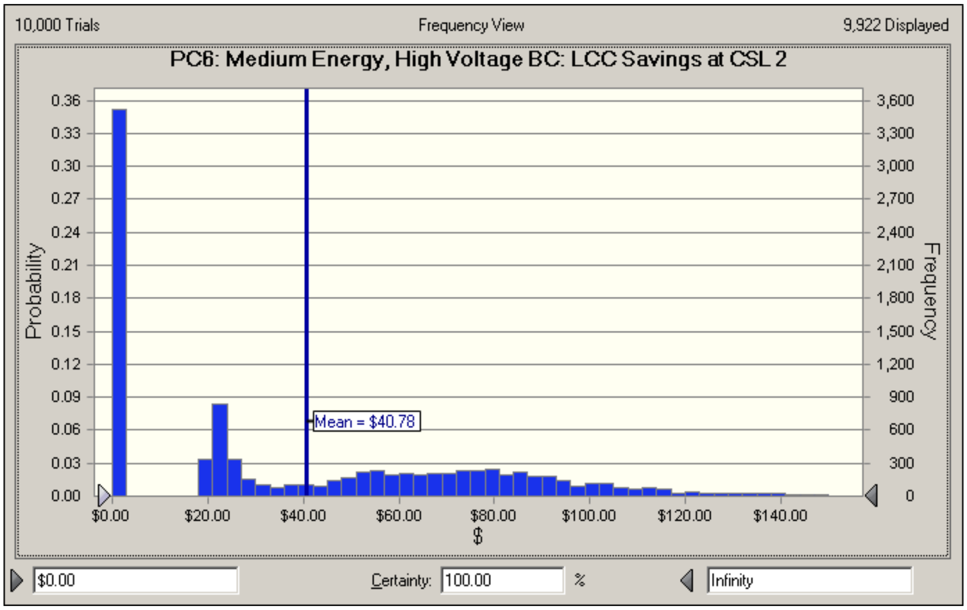
For medium energy, low voltage BCs, CSL 2 has the greatest LCC savings and an immediate (0.0 year) PBP. This is because all consumers either experience no impact or a net benefit at this CSL. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard. The installed price at CSL 2 is below that of CSL 0 and CSL 1, so any consumer shifting from these CSLs to CSL 2 will save money and experience an immediate payback.

Table 8.4.11 LCC and PBP Results for PC5 Medium Energy, Low Voltage Battery Chargers

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	84.6	46.61	55.43	102.03	-	-	-	-	-
1	56.1	51.40	36.55	87.95	9.69	1.3	72.0	26.8	1.7
2	29.3	39.57	18.95	58.51	33.79	0.0	20.1	79.9	0.0
3	15.4	207.82	9.65	217.47	-104.58	78.6	13.0	8.4	53.4

8.4.3.7 PC6 Medium Energy, High Voltage Battery Chargers

Figure 8.43 and Figure 8.44 show the distribution of LCC savings and PBPs for DOE’s proposed standard level of CSL 2. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled “Certainty” at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



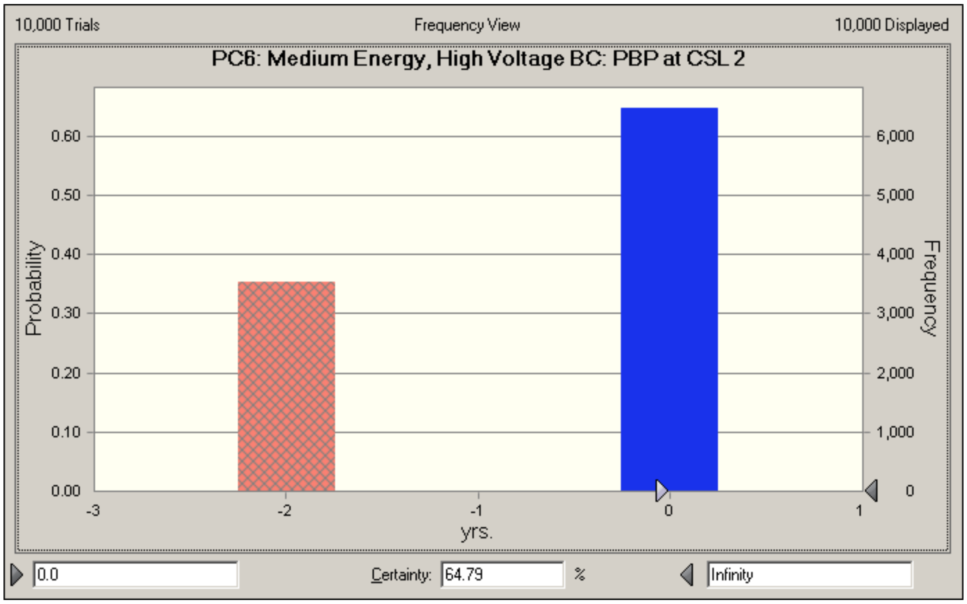
$0.00

Certainty: 100.00 %

Infinity

Figure 8.43 PC6 Medium Energy, High Voltage Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 2

The PBP distribution for PC6 Medium Energy, High Voltage BCs is split between two options (-2.0 and 0.0) because at this standards level all consumers are either not impacted (-2.0) or they have an immediate payback (0.0). At CSL 2, 35.2 percent of consumers are not impacted. The remaining 64.8 percent of consumers have an immediate payback at CSL 2 because the installed cost at CSL 2 is below the installed cost of both CSL 0 and CSL 1. Therefore, any consumer shifting from CSL 0 or CSL 1 to a CSL 2 BC will save money and have an immediate payback.



0.0 Certainty: 64.79 % Infinity

Figure 8.44 PC6 Medium Energy, High Voltage Battery Chargers: Distribution of PBPs at CSL 2

Table 8.4.12 summarizes the LCC and PBP results for medium energy, high voltage BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

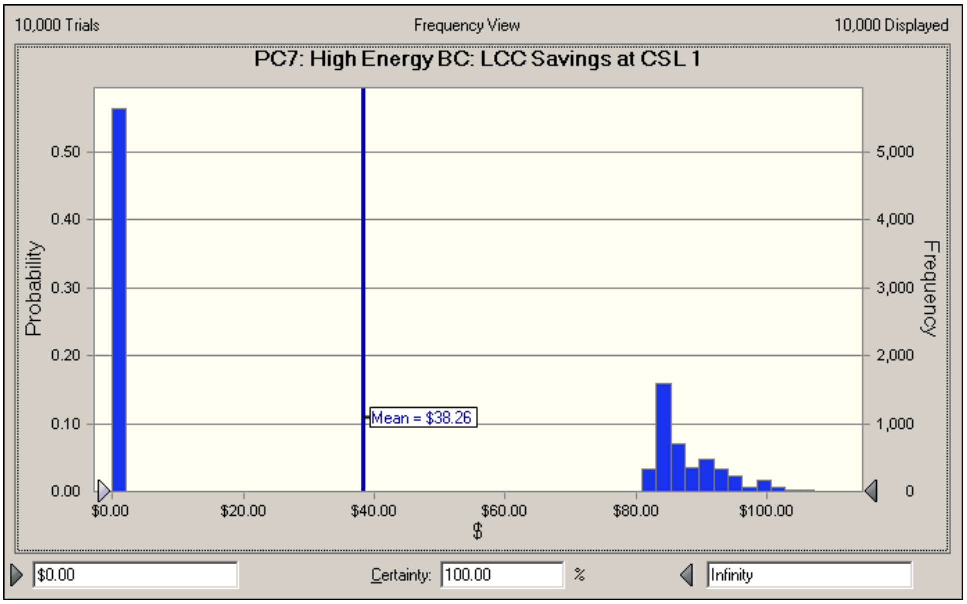
For medium energy, high voltage BCs, CSL 2 has the greatest LCC savings, and is the highest CSL with positive LCC savings. At this CSL, all consumers either experience no impact or a net benefit. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard. The installed price at CSL 2 is below that of CSL 0 and CSL 1, so any consumer shifting from these CSLs to CSL 2 will save money and experience an immediate payback.

Table 8.4.12 LCC and PBP Results for PC6 Medium Energy, High Voltage Battery Chargers

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	120.6	45.37	97.26	142.63	-	-	-	-	-
1	81.7	50.13	66.66	116.78	9.96	0.0	64.6	35.4	1.2
2	38.3	38.52	30.55	69.07	40.78	0.0	35.2	64.8	0.0
3	16.8	205.10	10.60	215.71	-86.76	85.4	13.0	1.6	20.8

8.4.3.8 PC7 High Energy Battery Chargers

Figure 8.45 and Figure 8.46 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 1. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



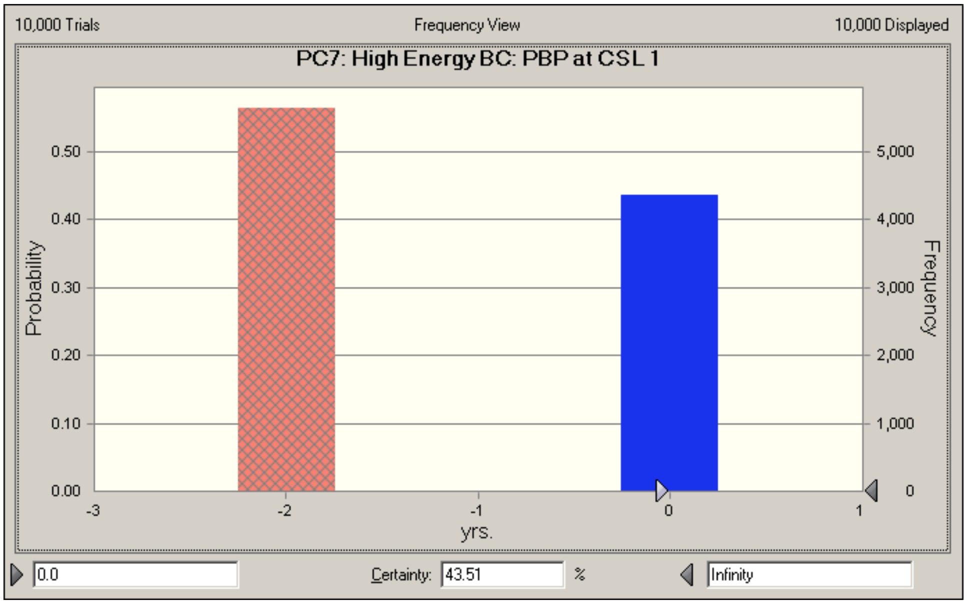
$0.00

Certainty: 100.00 %

Infinity

Figure 8.45 PC7 High Energy Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 1

The PBP distribution for PC7 High Energy BCs is split between two options (-2.0 and 0.0) because at this standards level all consumers are either not impacted (-2.0) or they have an immediate payback (0.0). At CSL 1, 56.5 percent of consumers are not impacted. The remaining 43.5 percent of consumers have an immediate payback at CSL 1 because the installed cost at CSL 1 is below the installed cost of CSL 0. Therefore, any consumer shifting from CSL 0 to a CSL 1 BC will save money and have an immediate payback.



0.0 Certainty: 43.51 % Infinity

Figure 8.46 PC7 High Energy Battery Chargers: Distribution of PBPs at CSL 1

Table 8.4.13 summarizes the LCC and PBP results for high energy BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

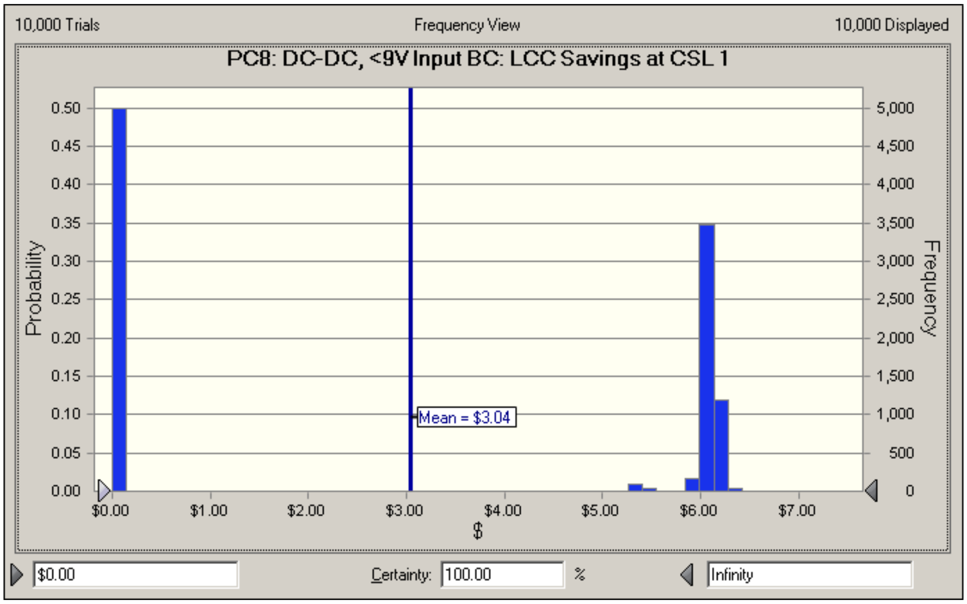
For high energy BCs, CSL 1 has the greatest LCC savings and an immediate (0.0 year) median PBP. At CSL 1, all consumers either experience no impact or a net benefit. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard. The installed price at CSL 1 is below that of CSL 0, so any consumer shifting from CSL 0 to CSL 1 will save money and experience an immediate payback.

Table 8.4.13 LCC and PBP Results for PC7 High Energy Battery Chargers

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	255.0	222.08	75.39	297.47	-	-	-	-	-
1	191.7	153.47	56.10	209.56	38.26	0.0	56.5	43.5	0.0
2	136.8	335.09	40.04	375.12	-127.30	100.0	0.0	0.0	27.2

8.4.3.9 PC8 DC-DC, <9V Input Battery Chargers

Figure 8.47 and Figure 8.48 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 1. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00

Certainty: 100.00 %

Infinity

Figure 8.47 PC8 DC-DC, <9V Input Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 1

The PBP distribution for PC8 DC-DC, <9V Input BCs is split between two options (-2.0 and 0.0) because at this standards level all consumers are either not impacted (-2.0) or they have an immediate payback (0.0). At CSL 1, 50.0 percent of consumers are not impacted. The remaining 50.0 percent of consumers have an immediate payback at CSL 1 because the installed cost at CSL 1 is below the installed cost of CSL 0. Therefore, any consumer shifting from CSL 0 to a CSL 1 BC will save money and have an immediate payback.

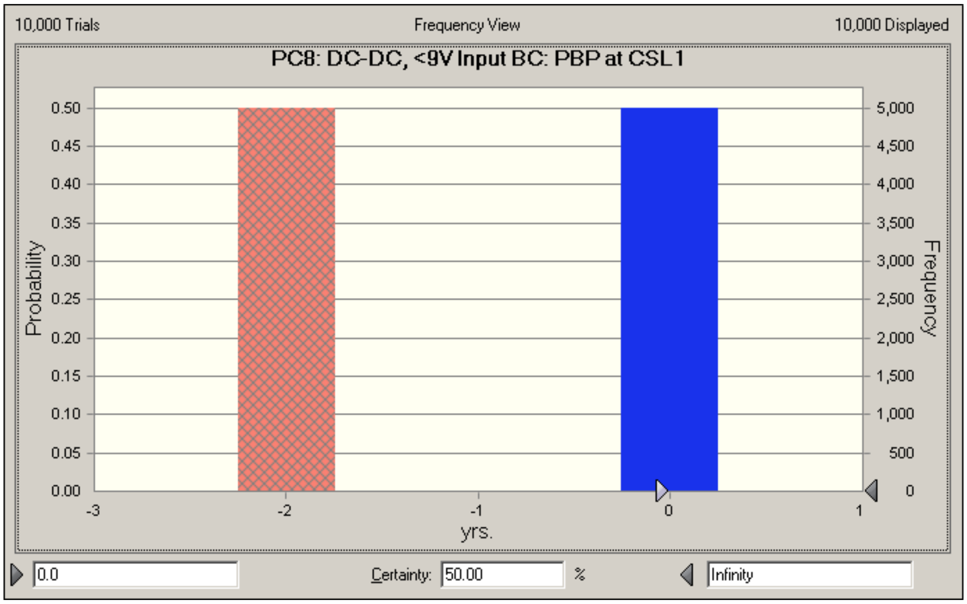


Figure 8.48 PC8 DC-DC, <9V Input Battery Chargers: Distribution of PBPs at CSL 1

Table 8.4.14 summarizes the LCC and PBP results for DC-DC, <9V input BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

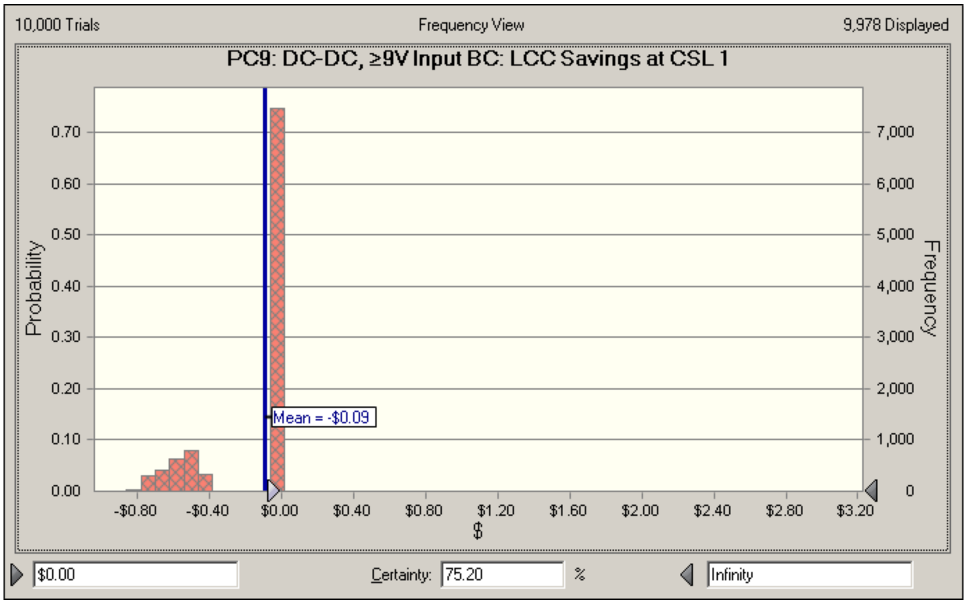
For DC-DC, <9V input BCs, CSL 1 has the greatest LCC savings, and an immediate (0.0 year) PBP. At this CSL, all consumers either experience no impact or a net benefit. Consumers are said to have “no impact” if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard. The installed price at CSL 1 is below that of CSL 0, so any consumer shifting from CSL 0 to CSL 1 will save money and experience an immediate payback. CSL 2 also has an immediate (0.0 year) median PBP because 50 percent of consumers are at the baseline (CSL 0), which has a greater installed price than CSL 2. When these consumers shift to purchasing BCs at CSL 2, they experience and immediate PBP.

Table 8.4.14 LCC and PBP Results for PC8 DC-DC, <9V Input Battery Chargers

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with Net Cost *%*	No Impact *%*	Net Benefit *%*	Payback Period Median *yrs.*
0	0.9	13.40	0.32	13.71	-	-	-	-	-
1	0.7	7.40	0.23	7.63	3.04	0.0	50.0	50.0	0.0
2	0.2	13.10	0.08	13.19	-1.96	40.0	10.0	50.0	0.0
3	0.2	13.48	0.06	13.54	-2.31	55.4	0.0	44.6	24.9

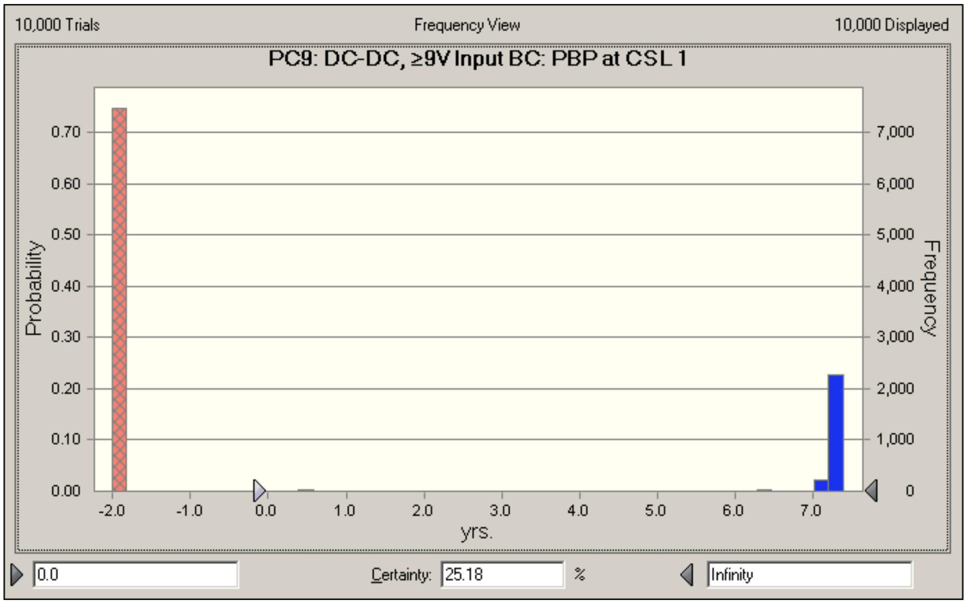
8.4.3.10 PC9 DC-DC, ≥9V Input Battery Chargers

For PC9, DOE is proposing a standard level equivalent to TSL 1 (CSL 1) of PC2, PC3, and PC4. The CSLs examined for PC9 were more efficient than this proposed standard level, so DOE presents the LCC and PBP results for CSL1 of PC9 in Figure 8.49 and Figure 8.50. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled “Certainty” at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.



$0.00 Certainty: 75.20 % Infinity

Figure 8.49 PC9 DC-DC, ≥9V Input Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 1



0.0 Certainty: 25.18 % Infinity

Figure 8.50 PC9 DC-DC, ≥9V Input Battery Chargers: Distribution of PBPs at CSL 1

Table 8.4.15 summarizes the LCC and PBP results for DC-DC, ≥9V input BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For DC-DC, ≥9V input BCs, no CSLs have positive LCC savings. CSL 1 has the greatest LCC savings, which is a negative savings (cost) of $0.09. At CSL 1, the majority of consumers (74.8 percent) experience no impact, but the vast majority of the remaining impacted consumers experience a net cost. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.15 LCC and PBP Results for PC9 DC-DC, ≥9V Input Battery Chargers

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	0.8	5.41	1.54	6.95	-	-	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	24.8	74.8	0.4	7.2
2	0.1	7.36	0.26	7.62	-0.25	74.3	24.9	0.8	8.8

8.4.3.11 PC10 Low Energy, AC Out Battery Chargers

Figure 8.51 and Figure 8.52 show the distribution of LCC savings and PBPs for DOE's proposed standard level of CSL 3. For the LCC savings, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC savings. In the case of the PBP distribution, a small change in operating cost can occasionally result in a very large PBP, skewing the average PBP. Therefore, DOE does not present the mean PBP, but the median PBP is presented in the table of results below. The number in the box labeled "Certainty" at the bottom of the chart indicates the percent of consumers who will either not be impacted or will have positive LCC savings at the given CSL. For the distribution of LCC savings, a spike at LCC savings of $0 indicates the proportion of consumers who are not impacted by a standard set at the given CSL. For the distribution of PBPs, a spike at the PBP value of -2.0 indicates the percentage of consumers who are not impacted by a standard set at the given CSL. These consumers are removed from the median PBP calculation. DOE can generate distribution charts like these for every CSL within each representative unit and product class.

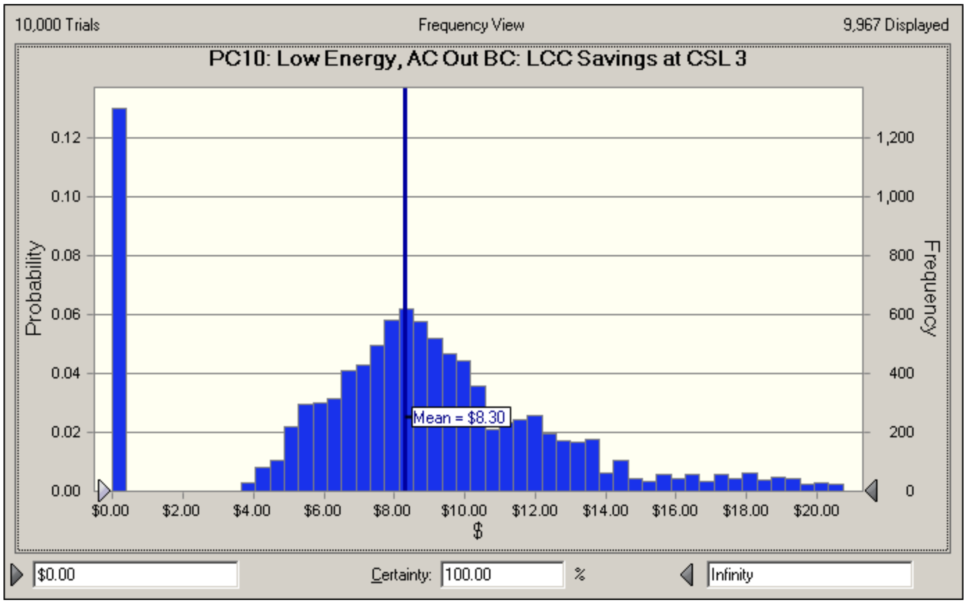


Figure 8.51 PC10 Low Energy, AC Out Battery Chargers: Distribution of Life-Cycle Cost Impacts at CSL 3

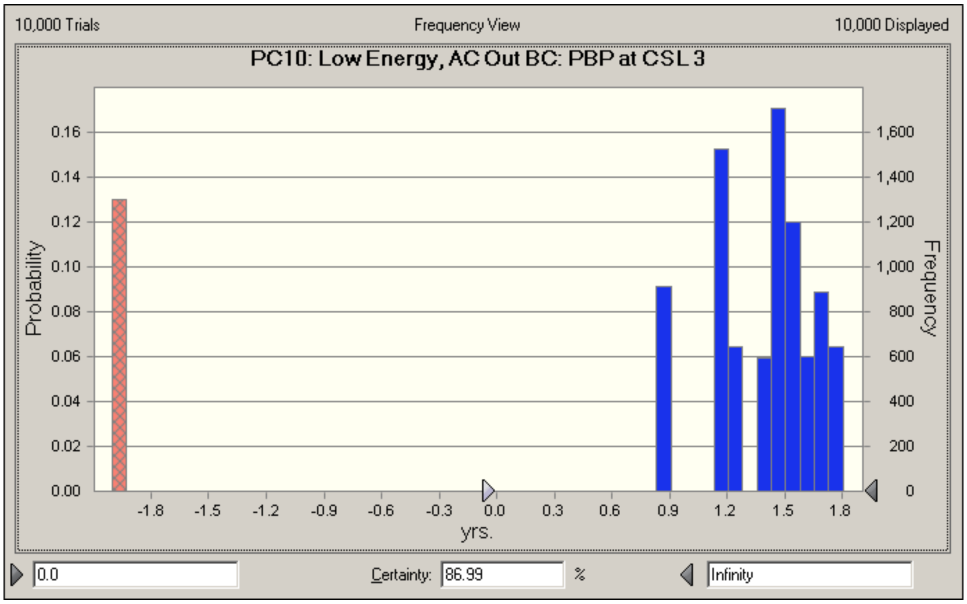


Figure 8.52 PC10 Low Energy, AC Out Battery Chargers: Distribution of PBPs at CSL 3

Table 8.4.16 summarizes the LCC and PBP results for low energy, AC out BCs. As mentioned earlier, for some consumers, DOE assigned products in the base case that are more energy efficient than some of the energy levels under consideration. For that reason, the average LCC impacts are not equal to the difference between the LCC of a specific energy efficiency level and the LCC of the baseline product. Similarly with regard to PBPs shown below, DOE determined the median values by excluding the percentage of consumers not impacted by a standard at a given efficiency level. The values for average operating cost in the table are discounted sums of the annual operating costs over the product lifetime.

For low energy, AC out BCs, all CSLs have positive LCC savings, and CSL 3 has the greatest LCC savings. At CSL 3, all consumers experience a net benefit, with a median PBP of 1.5 years and an average LCC savings of $8.30. The LCC results for this product class are so overwhelmingly positive because currently 100 percent of consumers purchase at the baseline (CSL 0) efficiency. The operating costs associated with CSL 0 ($13.29) are significant compared to the operating costs of any of the higher efficiency CSLs. All consumers experience LCC savings due to these gains in operating cost savings. Consumers are said to have "no impact" if the base case forecast product assigned to them has a greater efficiency than the level indicated by a standard.

Table 8.4.16 LCC and PBP Results for PC10 Low Energy, AC Out Battery Chargers

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	19.3	5.94	13.29	19.22	-	-	-	-	-
1	6.1	7.63	4.23	11.85	6.41	0.0	13.0	87.0	1.3
2	4.0	8.09	2.78	10.87	7.26	0.0	13.0	87.0	1.4
3	1.5	8.65	1.03	9.68	8.30	0.0	13.0	87.0	1.5

8.5 SENSITIVITY RUNS AND LCC SUBGROUP ANALYSIS

DOE presents additional sensitivity runs from the LCC analysis in Appendix 8B. These results include electricity price sensitivity scenarios, scenarios for high-usage and low-usage, and a scenario modeling an alternative spillover effect on shipments in the base case due to the California battery charger energy conservation standards. DOE also presents LCC and PBP results for several consumer subgroups in Chapter 11. These include results for low-income consumers, small businesses, top tier marginal electricity price consumers, and consumers of specific applications within the analyzed representative units and product classes.

REFERENCES

---

[i] U.S. Department of Energy. Energy Information Administration. Annual Energy Outlook 2010. November, 2010. Washington, D.C.
http://www.eia.doe.gov/oiaf/aeo/.

[ii] U.S. Department of Energy. Energy Information Administration. Energy Market and Economic Impacts of S.2191, The Lieberman-Warner Climate Security Act of 2007. April 2008. Washington, D.C.
http://www.eia.doe.gov/oiaf/servicerpt/s2191/excel/s2191.xls.

[iii] U.S. Department of Energy. Energy Information Administration. Form EIA-861 Final Data File for 2008. November, 2010. Washington, D.C.
http://www.eia.doe.gov/cneaf/electricity/page/eia861.html.

[iv] Title 10, Code of Federal Regulations, Part 474, Subpart C – Electric and Hybrid Vehicle Research, Development, and Demonstration Program. June 12, 2000.
http://www.gpo.gov/fdsys/pkg/FR-2000-06-12/html/00-14446.htm.

[v] Bradfield, M. Improving Alternator Efficiency Measurably Reduces Fuel Costs. 2008. Remy International, Inc: Pendleton, IN.

[vi] The Federal Reserve Board, Survey of Consumer Finances 1989, 1992, 1995, 1998, 2001, 2004, 2007.
http://www.federalreserve.gov/pubs/oss/oss2/scfindex.html.

[vii] The Federal Reserve Board, Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: CDs (secondary market), Maturity: 6-month, Frequency: Annual, Description: Average rate on 6-month negotiable certificates of deposit (secondary market), quoted on an investment basis, 2010.
http://www.federalreserve.gov/releases/H15/data.htm.

[viii] The Federal Reserve Board, Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: State and local bonds, Maturity: 20-year, Frequency: Monthly, Description: Bond buyer go 20-bond municipal bond index, 2010.
http://www.federalreserve.gov/releases/H15/data.htm.

[ix] The Federal Reserve Board, Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: Corporate bonds/Moody's Seasoned AAA, Frequency: Annual, Description: Moody's yield on seasoned corporate bonds - all industries, AAA, 2010.
http://www.federalreserve.gov/releases/H15/data.htm.

[x] Mortgage-X - Mortgage Information Service, Cost of Savings Index (COSI) Index History, 2010.
http://mortgage-x.com/general/indexes/default.asp.

[xi] Damodaran Online Data Page, Historical Returns on Stocks, Bonds and Bills-United States, 2010. Damodaran.
http://pages.stern.nyu.edu/~adamodar.

[xii] Modigliani, F. and M. Miller. The Cost of Capital, Corporation Finance and the Theory of Investment. *American Economic Review.* 1958. (June): pp. 261-297.

[xiii] The Federal Reserve Board, Federal Reserve Statistical Release, Selected Interest Rates, Historical Data, Instrument: Treasury Constant Maturities, Maturity: 10-year, Frequency: Annual, Description: Market yield on U.S. Treasury securities at 10-year constant maturity, quoted on investment basis. http://www.federalreserve.gov/releases/H15/data.htm.

[xiv] Damodaran, A. Damodaran Online. Current US data.
http://pages.stern.nyu.edu/~adamodar.

[xv] Executive Office of the President. *2010 Economic Report of the President*, U.S. Government Printing Office, Washington, D.C., p. 75.
http://www.whitehouse.gov/sites/default/files/microsites/economic-report-president.pdf.

[xvi] Value Line. Value Line Investment Survey. 2010.
http://www.valueline.com.

[xvii] U.S. Office of Management and Budget. Circular No. A-94. Appendix C. 2009.
http://www.whitehouse.gov/omb/circulars_a094_a94_appx-c/.

[xviii] U.S. Census Bureau. The 2010 Statistical Abstract. Table 607 – Employment by Industry.
http://www.census.gov/compendia/statab/2010/tables/10s0607.xls.

[xix] U.S. Census Bureau. The 2010 Statistical Abstract. Table 484 – Federal Civilian Employment and Annual Payroll by Branch.
http://www.census.gov/compendia/statab/2010/tables/10s0484.xls.

[xx] U.S. Census Bureau. Government Employment and Payroll. 2008 State and Local Government.
http://www2.census.gov/govs/apes/08stlall.xls.

CHAPTER 9. SHIPMENTS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 9. SHIPMENTS ANALYSIS

9.1 Introduction

This chapter describes the data and methods that DOE used to generate shipment forecasts and base case efficiency distributions for each of the product classes being considered in this preliminary analysis of standards for battery chargers and external power supplies. Outputs from the shipments analysis are inputs to the life-cycle cost analysis (chapter 8), national impact analysis (chapter 10), and manufacturer impact analysis (chapter 12).

The calculations for shipment forecasts were implemented as part of the National Impact Analysis (NIA). These calculations are contained in the NIA Microsoft® Excel workbook that can be downloaded from the EERE web site.[a] The workbook, entitled BCEPS_NIA.xlsx contains a tab for each of the product classes analyzed as part of the rulemaking.

This document is a guide to the inputs and methodology employed in the workbook. Section 9.2 presents the methodology for developing a base case shipments forecast. Section 9.3 discusses the potential impacts of standards on the shipments forecast. The outputs from the shipments analysis are shown in Section 9.4.

9.2 BC and EPS Shipments in the Base Case

The shipment analysis consists of two outputs:

- A shipments forecast, which calculates the total number of BCs and EPSs shipped each year over a 30 year period, beginning in 2013 and ending in 2042.
- An efficiency forecast, which shows the distribution of shipments of BCs and EPSs by candidate standard level (CSL), which determines the percentage of shipments affected by a standard.

9.2.1 Shipments Forecast

To develop its shipments forecast, DOE combined current year (2009) shipments, discussed in the market assessment (chapter 3) with a compound annual growth rate for BCs and EPSs, discussed in this section. Shipment values were calculated for 30 years, through 2042, the last year of the analysis period. Shipments for 2009, 2013 and 2042 are presented in Table 9.2 (EPSs) and Table 9.4 (BCs).

As discussed in the market assessment (chapter 3), the variety of product applications that employ BCs and EPSs is vast. DOE is aware that this mix of product applications will very likely change dramatically over the analysis period. Indeed, most of the end-use products that now employ BCs or EPSs were not on the market twenty years ago. Therefore, forecasting the size of the market more than twenty years into the future is extremely difficult.

---

[a] Available for download from the EERE website: http://www.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html

In its research regarding the market for BCs and EPSs, DOE noted that the market for these products has grown tremendously in the past 10 years. Additionally, DOE found that many market reports have predicted enormous future growth for the applications that employ BCs and EPSs. However, in forecasting the size of the BC and EPS markets over the next 32 years, DOE considered the possibility that much of the market growth associated with these products has already occurred. For many reports predicting growth of applications that employ BCs or EPSs, DOE noted that growth was predicted for new applications, but older applications were generally not included. That is, the demand for BCs and EPSs had not grown, but rather the products that use BCs and EPSs had transitioned to a new product mix.

With this in mind, in its forecast DOE took a conservative approach and assumed that while the specific applications that use BCs or EPSs will change, the overall number of individual units that use BCs or EPSs will grow slowly, with new applications replacing some current applications, but with little change in per-capita ownership of BCs or EPSs over time.

To estimate future market size while assuming no change in the per-capita BC and EPS purchase rate, DOE used population growth rate as the compound annual market growth rate. DOE feels this growth rate represents a conservative approximation of the expected market progression for these products. Population growth rate values were obtained from the U.S. Census Bureau 2009 National Projections, which forecast population through 2050. DOE took the average annual population growth rate, 0.75 percent, and applied this rate to all BC and EPS product classes.

9.2.2 Efficiency Forecast

To evaluate the potential impacts of standards, DOE developed a base case efficiency forecast, which represents DOE’s estimate of the future state of the market with respect to efficiency if energy conservation standards for the units covered under this rulemaking are not adopted. The impact of a standard is then the relative improvement in efficiency compared to this forecast.

DOE’s starting point in developing base case efficiency forecasts was current year efficiency distributions, as described in the market assessment (chapter 3). To extrapolate from the present day forward to 2013, the first year of the analysis period, DOE looked at recent trends in product efficiency and considered what factors might lead BCs and EPSs to become more efficient between now and 2013.

In the preliminary analysis, DOE found two programs that would influence EPS efficiency in the short term. The first is the ENERGY STAR program for EPSs (called “external power adapters”), which specified that EPSs be at or above CSL 1 in order to qualify. This voluntary program was very active, with more than 3,300 qualified products as of May 2010.[b] The second program influencing EPS efficiency is the European Union Ecodesign requirements on Energy Using Products, which includes legislation on EPSs that requires that EPSs sold in the

---

[b] EPA, "ENERGY STAR External Power Supplies AC-DC Product List," May 24, 2010 and EPA, "ENERGY STAR External Power Supplies AC-AC Product List," May 24, 2010. Both documents last retrieved on May 28, 2010 from http://www.energystar.gov/index.cfm?c=ext_power_supplies.power_supplies_consumers.

EU be at or above CSL 1, effective April 2011. Europe currently represents approximately one-third of the global EPS market. DOE did not identify any programs that required efficiency above CSL 1. These factors apply to Class A EPSs.

With these two programs in mind, DOE estimated that approximately half of the Class A EPS market at CSL 0 in 2009 would transition to CSL 1 by 2013. In updating its analysis for the NOPR, DOE reviewed these two programs for any changes. DOE found that no new European standards had been announced during the time between the preliminary analysis and the NOPR. However, in regard to the ENERGY STAR program, the U.S. Environmental Protection Agency announced that its program for EPSs would be cancelled effective December 31, 2010.[c] In summary, DOE found no new evidence to support the long-term improvement of EPSs beyond the initial improvement of units as estimated during the preliminary analysis. Thus, DOE has maintained its earlier assumption that EPSs will not improve in efficiency after 2013 in the base case.

In the preliminary analysis, DOE found no compelling evidence that battery chargers will improve in efficiency before 2013. There were no were standards slated to take effect and the ENERGY STAR voluntary program for battery charging systems had a limited impact. DOE found that as of January 22, 2010, less than 150 battery charging systems had been qualified, and as of July 1, 2011, only 241 battery charging systems had been qualified.[d] (Contrast this with the more than 3,300 EPSs that were ENERGY STAR-qualified as of May 2010.)

However, on January 12, 2012, the California Energy Commission (CEC) announced new standards for battery chargers that would come into effect beginning February 1, 2013. DOE expects that all products sold in California will improve in efficiency to comply with these standards, but less efficient products will remain on the market outside of California. To account for these standards in its base case efficiency forecast, DOE first determined how the CEC standard levels would equate to the CSLs that DOE analyzed. These equivalencies can be found in Table 9.1 below. Next, DOE calculated the proportion of the U.S. market for battery chargers represented by California. No shipments data could be found that was specific to California so DOE assumed that California's share of the battery charger market was equal to California's share of U.S. GDP, or 13%.[e] Assuming that prior to standards the efficiency distribution of products in California was equal to the rest of the U.S. market, DOE then "rolled-up" the efficiency of battery chargers in California's segment of the market and used a weighted average to calculate a new national base case efficiency forecast.

---

[c] EPA, "ENERGY STAR EPS EUP Sunset Decision Memo," July 19, 2010. Last retrieved on July 8, 2011 from http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_eup_sunset_decision_july2010.pdf.

[d] EPA, "Qualified Product (QP) List for ENERGY STAR Qualified Battery Charging Systems." Retrieved on July 8, 2011 from http://www.energystar.gov/ia/products/prod_lists/BCS_prod_list.xls.

[e] In 2010, California's gross state product was $1.9 trillion while the U.S. gross domestic product was $14.59 trillion (See http://www.usgovernmentrevenue.com/compare_state_revenue_2010bZ0a).

Table 9.1 CSLs Corresponding to CEC Standards

Product Class	**CSL Equivalent of CEC Standard**
1	CSL 0
2	CSL 2
3	CSL 2
4	CSL 2
5	CSL 3
6	CSL 3
7	CSL 1
8	CSL 0
10	CSL 1

In light of the above considerations, DOE developed base case efficiency forecasts in which there are modest improvements in EPS and battery charger efficiency between now and 2013. These efficiency forecasts are shown in Table 9.4 for EPSs and Table 9.6 for BCs. DOE believes that these forecasts provide a reasonable reference point for assessing the impact of potential standards.

DOE next evaluated the likelihood that BCs and EPSs would continue to improve in efficiency throughout the analysis period. However, DOE found that although efficiencies might improve between now and 2013, no data exist to suggest that BC or EPS efficiencies would improve further during the following 30 years in the absence of standards. While additional standards for large DC-input battery chargers and large battery chargers for industrial equipment are expected to come into effect in California in 2014 and 2017, respectively, these products are currently not in the scope of DOE’s rulemaking. Therefore, DOE forecasts static efficiency distributions for both BCs and EPSs throughout the analysis period.

9.3 Effect of Standards on BC and EPS Shipments

9.3.1 Efficiency of BCs and EPSs

In addition to quantifying the projected impact of standards on total shipments, DOE must also consider the change in the mix of product efficiencies due to standards. DOE assumed that manufacturers will respond to standards by improving those products that do not meet the standards to the standard level, but no higher, while the products that were already as or more efficient than the standard remain unaffected. This is referred to as a “roll-up” response to standards.

The mechanics of a roll-up response are detailed in Table 9.2. The “Base Case” gives the efficiency distribution with no standard. In the “Standard Set at CSL 1” scenario, all the shipments from CSL 0 are rolled up to CSL 1, the level of the standard. The same methodology is applied to the other standards cases.

Table 9.2 Roll-Up Market Response for a Hypothetical BC or EPS Product Class

Case	Percent of Market at Each Efficiency Level				
	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Base Case	25	50	25	0	0
Standard Set at CSL 1	0	75	25	0	0
Standard Set at CSL 2	0	0	100	0	0
Standard Set at CSL 3	0	0	0	100	0
Standard Set at CSL 4	0	0	0	0	100

9.3.2 Price Elasticity of Demand for BCs and EPSs

In other rulemakings, forecasted shipments in the standards case typically deviate from the base case. The magnitude of the difference between the standards case and base case shipments forecasts depends on the calculated purchase price increase and the operating cost savings from the standard. Standards case forecasts typically show elasticity of demand, usually manifested as a decrease in shipments relative to the base case.

However, in the case of BCs and EPSs, the incremental cost of more efficient BCs and EPSs is very small relative to the total cost of the end-use product, in most cases. For example, the incremental final product prices of BCs at the proposed standard levels range from $0.11 to $4.40, while the average product prices of BC applications range from $22.14 to $6,135.17. Thus, for the reference case of the analysis, DOE makes the simplifying assumption that the demand for BCs and EPSs is perfectly inelastic; that is, a price increase in the standards case will not lead to a decrease in demand for the product.

In response to comments from stakeholders on the preliminary analysis, DOE took into account the price elasticity of demand for BCs in the shipments sensitivity analysis. To DOE’s knowledge, elasticity estimates are not readily available in existing literature for BCs or their end-use consumer products. Home appliances have an estimated price elasticity of -0.34 (See – http://ees.ead.lbl.gov/bibliography/an_analysis_of_the_price_elasticity_of_demand_for_household_appliances); however, some applications using BCs and EPSs, such as smartphones and videogame consoles, could be considered more discretionary than home appliances, and thus demand would be more elastic with respect to price. Because the market for BC applications is so diverse, , DOE made the simplifying assumption that BC applications are unit elastic (E_d = -1). Unit elasticity means that a given percentage increase in the final product price would be accompanied by that same percentage decrease in shipments (e.g., a 10% increase in price would lead to a 10% decrease in demand).

To calculate the effect of standards on shipments, DOE first multiplies the cost of standards by the incremental markup calculated in the Markups Analysis for each end-use application (see chapter 6) then adds it to the average retail price for that application. Using the base case efficiency forecast, DOE assumes that shipments of products affected by the standard (those below the efficiency level of the proposed standard level) would be reduced by the same percentage as the price increases (in percentage terms). In those cases where the standard is assumed to result in a price decrease (rather than the usual price increase), DOE assumes there would be no change in demand. In all cases, DOE found the decrease in shipments as a result of standards to be negligible, with a total decrease in BC shipments of 612,000 units.[f] See Appendix 9A for the results of the sensitivity analysis for all BC product classes.

9.3.3 Substitution Away from BCs and EPSs

Another potential market response to the presence of a standard for BCs or EPSs would be to substitute a different power source for the BC or EPS. This could reduce BC or EPS shipments in the standards case relative to the base case. However, for both BCs and EPSs, the extent to which manufacturers choose substitute power sources will be limited by design constraints.

Possible substitutions for BCs include mains power and primary batteries. DOE considers the possibility of substitution to mains power to be minimal, since such a substitution would remove the primary functionality that battery chargers offer, portability. Similarly, primary batteries offer significantly less utility to the consumer; therefore, DOE believes any substitution would be negligible.

Possible substitutions for EPSs include internal power supplies, batteries, or USB power. As with BCs, DOE considers the potential for substitution to be minimal. In most cases, the choice of an external power supply over an internal power supply is to minimize the size of the application. Use of batteries would not eliminate the usage of an EPS. The last substitute, USB power, may have some impact; however, DOE estimates this impact to be limited because USB ports are much less common than traditional wall outlets.

Thus, DOE assumes that the impact of substitution for BCs and EPSs is negligible and, thus, does not attempt to quantify it in the reference case.

---

[f] DOE did not receive similar comments from stakeholders on EPS applications and therefore did not conduct a shipments sensitivity analysis for them. However, because the costs of standards for EPSs were lower than for BCs, DOE concluded that the effect of standards would likewise be negligible.

9.4 Results

9.4.1 External Power Supply Shipments Forecast

In DOE's forecast, EPS shipments grow from 345 million in 2009 to 430 million in 2042. Table 9.3 shows DOE's shipments forecast for each EPS product class.

Table 9.3 External Power Supply Shipments by Product Class

ID	Product Class Description		Shipments in 2009 (Thousand Units)	Shipments in 2013 (Thousand Units)	Shipments in 2042 (Thousand Units)
B	DC Output, Basic Voltage	0-10.25 W	68,473	70,551	87,621
		10.25-39 W	70,257	72,389	89,904
		39-90 W	47,559	49,002	60,858
		91-250 W	7,021	7,233	8,984
C	DC Output, Low Voltage		58,845	60,631	75,301
D	AC Output, Basic Voltage		7,994	8,237	10,230
E	AC Output, Low Voltage		2,250	2,318	2,879
X	Multiple Voltage		7,677	7,909	9,823
H	High Power		3	3	4
N	Indirect Operation		74,782	77,025	93,291

Table 9.4 shows DOE's assumptions about the efficiency of EPSs in 2013 in the base case. The percentages show, for each product class, what fraction of new products sold each year are at each efficiency level (CSL). These market shares are assumed to remain constant throughout the analysis period, which begins in 2013.

Table 9.4 Base Case External Power Supply Efficiency in 2013

ID	Product Class Description		Percent of Market at Each CSL				
			CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
B	DC Output, Basic Voltage	0-10.25 W	42	49	6	2	0
		10.25-39 W	19	52	18	10	0
		39-90 W	19	63	17	1	0
		91-250 W	26	53	18	3	0
C	DC Output, Low Voltage		42	53	2	3	0
D	AC Output, Basic Voltage		24	55	17	4	0
E	AC Output, Low Voltage		30	53	13	4	0
X	Multiple Voltage		5	95	0	0	-
H	High Power		50	50	0	0	-
N	Indirect Operation		-	-	-	-	-

9.4.2 Battery Charger Shipments Forecast

In DOE’s forecast, BC shipments grow from 437 million in 2009 to 545 million in 2042. Table 9.5 shows DOE’s shipments forecast for each of the 10 BC product classes.

Table 9.5 Battery Charger Shipments by Product Class

Class ID		Battery Energy	Battery Voltage	Shipments in 2009 (Thousand Units)	Shipments in 2013 (Thousand Units)	Shipments in 2042 (Thousand Units)
1	AC-DC	<100 Wh	Inductive Connection	15,100	15,558	19,323
2			<4 V	249,018	256,573	318,652
3			4<10 V	23,060	23,760	29,509
4			≥10 V	60,926	62,774	77,963
5		100–3000 Wh	<20 V	4,866	5,014	6,227
6			≥20 V	624	643	798
7		>3000 Wh		211	217	270
8	DC-DC		<9 V Input	65,210	67,188	83,445
9			≥9 V Input	9,583	9,874	12,263
10	AC-AC		AC Output from Battery	8,000	8,243	10,237

Table 9.6 shows DOE's assumptions about the efficiency of BCs in 2013 in the base case. The percentages show, for each product class, what fraction of new products sold each year are at each efficiency level (CSL). These market shares are assumed to remain constant throughout the analysis period, which begins in 2013.

Table 9.6 Base Case Battery Charger Efficiency in 2013

	Battery Energy	Battery Voltage	Class ID	Percent of Market at Each CSL				
				CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
AC-DC	<100 Wh	Inductive Connection	1	78	11	11	0	-
		<4 V	2	18	22	57	3	0
		4<10 V	3	17	62	21	0	-
		≥10 V	4	9	39	52	0	-
	100–3000 Wh	<20 V	5	28	52	7	13	-
		≥20 V	6	36	29	22	13	-
	>3000 Wh		7	44	56	0	0	-
DC-DC		<9 V Input	8	50	40	10	0	-
		≥9 V Input	9	25	50	25	0	-
AC-AC		AC Output from Battery	10	87	0	0	13	-

CHAPTER 10 NATIONAL IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 10 NATIONAL IMPACT ANALYSIS

10.1 Introduction

This chapter describes the methods the U.S. Department of Energy (DOE) used to conduct a national impacts analysis (NIA) of potential standard levels for BCs and EPSs. DOE evaluated the following impacts: (1) national energy savings (NES) attributable to each possible standard, (2) monetary value of those energy savings to consumers of the considered products, (3) increased cost of the products because of standards, and (4) net present value (NPV) of total consumer costs and savings (the difference between the value of energy savings and increased product costs).

For reference, if current EPS and BC efficiencies were applied to shipments from 2009, those units would consume approximately 2.0 billion kWh and 2.8 billion kWh of site electricity, respectively, or 22 trillion Btu and 31 trillion Btu of primary energy, respectively. Values reflect the inputs used in the reference savings case, as described in appendix 8B.

To make the analysis more accessible and transparent to all interested parties, DOE used an MS Excel spreadsheet model to calculate the energy savings and the national consumer costs and savings from each CSL and TSL. MS Excel is the most widely used spreadsheet calculation tool in the United States and there is general familiarity with its basic features. Thus, DOE's use of MS Excel as the basis for the spreadsheet models provides interested parties with access to the models within a familiar context. The TSD and other documentation that DOE provides during the rulemaking help explain the models and how to use them, and interested parties can review DOE's analyses by changing various input quantities within the spreadsheet. The NIA spreadsheet model uses average values as inputs (as opposed to probability distributions). As discussed in chapter 16, the NIA model also performs the calculations for the Regulatory Impact Analysis. Details and instructions for using the NIA model are contained in the spreadsheet.

The calculations contained in the NIA model are described in detail as follows:

- *National Inventory*, discussed in section 10.1.1, details the methodology for calculating the number of units in use in a given year that are subject to a standard.

- *NES*, discussed in section 10.2, combines the average change in unit energy consumption (UEC) due to a standard (unit energy savings) with the national inventory to obtain the aggregate energy savings generated by a standard.

- *NPV*, discussed in Section 10.3, compares the present value (in 2009$) of the NES with the present value (in 2009$) of the national improvement costs associated with a standard. National improvement cost combines the average change in unit cost (unit improvement cost) with the number of units shipped in a given year to obtain the aggregate incremental costs paid by consumers due to a standard.

The methodology for calculating the NIA is depicted graphically in Figure 10.1. Results for BCs and EPSs are presented in section 10.4.

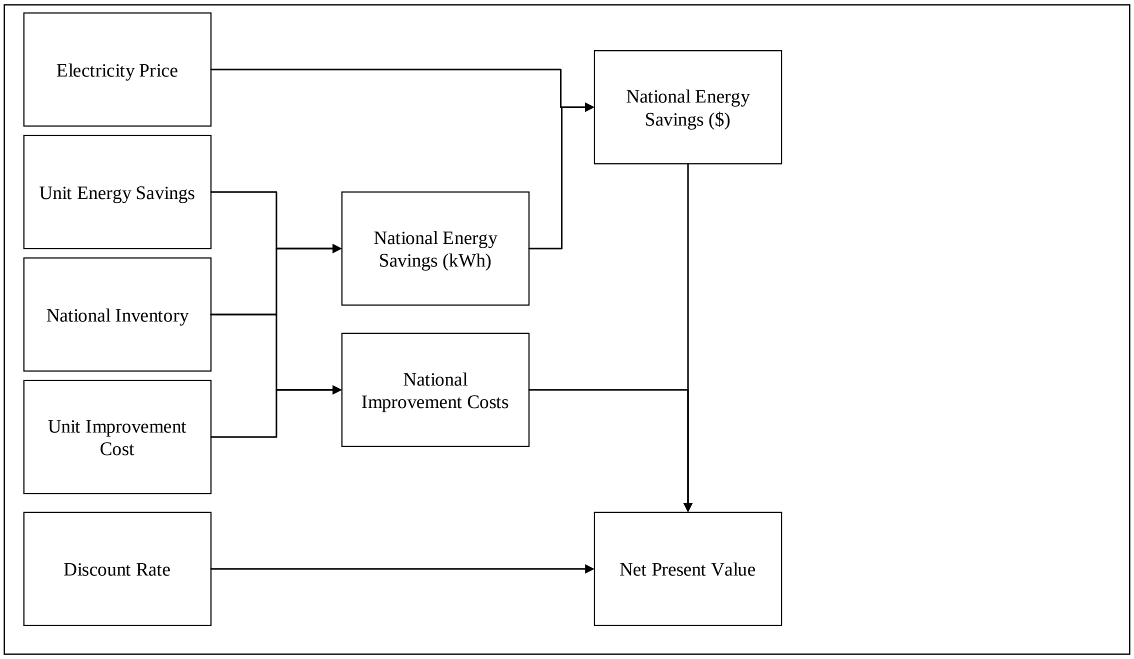


Figure 10.1 Flow Chart Showing the Calculation of National Energy Savings and Net Present Value

10.1.1 Scaled Costs

While the life-cycle cost analysis weighs the costs and savings associated with standards for a set of representative units, the NIA considers the costs and savings associated with standards for all products, including those in the "scaled" product classes. For these scaled product classes, most inputs to the NIA could be obtained in the same manner as for the representative product classes. However, cost data were not available for the scaled product classes, as they were not directly analyzed in the engineering analysis. Therefore, as is done in other rulemakings, and as described in the engineering analysis, DOE extrapolated from its knowledge of costs for the representative product classes to the scaled product classes.

In the NOPR, DOE applied costs from the EPS representative units in product class B to product classes C, D and E. All BC product classes were representative product classes. This methodology is described in more detail in chapter 5 of the TSD.

10.1.2 Alternative Electricity Price Scenarios

The results in this chapter were calculated using electricity pricing inputs from the Reference case in EIA's *Annual Energy Outlook 2010 (AEO 2010)*[1]. DOE also calculated NIA results from the Low Economic Growth case and High Economic Growth case. Appendix 10-A presents the NIA results in the alternative economic growth cases.

10.2 National Inventory Accounting Model

DOE used a national inventory model to represent the number of BC and EPS units in use during a given year that would be subject to a standard.

Unlike many other rulemakings, where an installed base of products governs shipments (via retirement/replacement of the existing stock and installation of new stock in new homes), for BCs and EPSs shipments govern the national inventory. DOE chose this method for calculating national inventory based on two factors that distinguish BCs and EPSs. First, the size of the existing inventory of products in use is not fully known. Second, DOE cannot assume that all retired products are immediately replaced, so the number of shipments in a given year cannot be based on the number of existing products retired in that year.

Initially there are no units in the national inventory. Each year after a standard takes effect, new units are added to the inventory and those units that have reached the end of their lives are removed from the inventory. DOE used two inputs to calculate the national inventory: shipments forecasts (see chapter 9) and product class lifetime profiles, which are derived by combining base-year shipments by application with application lifetimes (see chapter 3).

10.2.1 Calculation of Product Class Lifetime Profiles

DOE calculated product class lifetime profiles using the percentage of shipments of applications within a given product class, and the lifetimes of those applications. These values were combined to estimate the percentage of units remaining in use for each year following the initial year in which those units were shipped.

As an example, consider a product class X with four associated applications: A, B, C, and D. Base year shipments and lifetimes for these applications are shown in Table 10.1.

Table 10.1 Example Product Class Characteristics for Calculation of Lifetime Profile

Application	Base Year Shipments (Units)	Percentage of Base Year Shipments (%)	Lifetime (Years)
A	100,000	53%	4
B	25,000	13%	3
C	15,000	8%	2
D	50,000	26%	5

Based on these application-specific values, product class X's lifetime profile would be as shown in Table 10.2.

Table 10.2 Example Lifetime Profile

Percentage of Units Remaining in Use					
2013 (Shipment Year)	2014	2015	2016	2017	2018
100%	100%	92%	79%	26%	0%

- In 2013, 100% of units are shipped and put into use.

- At the end of 2013, after 1 year of use, none of the products have reached their lifetime, so 0% of the units are retired, leaving 100% of the initial shipment remaining in use in 2014.
- At the end of 2014, after 2 years of use, units for product C, representing 8% of the total initial shipment, reach their lifetime and are retired, leaving 92% of the initial shipment remaining in use in 2015.
- At the end of 2015, after 3 years of use, units for product B, representing 13% of the total initial shipment, reach their lifetime and are retired, leaving 79% of the initial shipment remaining in use in 2016.
- At the end of 2016, after 4 years of use, units for product A, representing 53% of the total initial shipment, reach their lifetime and are retired, leaving 26% of the initial shipment remaining in use in 2017.
- At the end of 2017, after 5 years of use, units for product D, representing 26% of the total initial shipment, reach their lifetime and are retired, leaving 0% of the initial shipment remaining in use in 2018.
- Since no units remain in use in 2018, the lifetime profile calculation is complete.

10.2.2 National Inventory Example

Table 10.3 gives an example showing how the national inventory is tracked over the first seven years of the analysis period. This example uses as inputs:

- Shipments of 100 units in 2013
- Market growth of 5 percent per year
- The lifetime profile shown in Table 10.2.

Table 10.3 Example National Inventory Table

Vintage	Year of Analysis						
	2013	2014	2015	2016	2017	2018	2019
2013	100	100	92	79	26	-	-
2014	-	105	105	97	83	27	
2015	-	-	110	110	101	87	29
2016	-	-	-	116	116	107	92
2017	-	-	-	-	122	122	112
2018	-	-	-	-	-	128	128
2019	-	-	-	-	-	-	134
National Inventory	100	205	307	402	446	468	492

In 2013:

- 100 units are shipped (vintage 2013) and are added to the national inventory.
- The total national inventory is 100 units.

In 2014:

- 0 units from vintage 2013 are retired, leaving 100 units.
- 105 new units are shipped (vintage 2014), reflecting a 5% increase over the previous year.
- The total national inventory is 205 units.

In 2015:

- 8 units (8%) from vintage 2013 are retired, leaving 92 units.
- 0 units from vintage 2014 are retired, leaving 105 units.
- 110 units are shipped (vintage 2015).
- The total national inventory is 307 units.

In 2016:

- 13 units (13%) from vintage 2013 are retired, leaving 79 units.
- 8 units (8%) from vintage 2014 are retired, leaving 97 units.
- 0 units from vintage 2015 are retired, leaving 110 units.
- 116 units are shipped (vintage 2016).
- The total national inventory is 402 units.

In 2017:

- 53 units (53%) from vintage 2013 are retired, leaving 26 units.
- 14 units (13%) from vintage 2014 are retired, leaving 83 units.
- 9 units (8%) from vintage 2015 are retired, leaving 101 units.
- 0 units from vintage 2016 are retired, leaving 116 units.
- 122 units are shipped (vintage 2017).
- The total national inventory is 446 units.

In 2018:

- 26 units (26%) from vintage 2013 are retired, leaving 0 units.
- 56 units (53%) from vintage 2014 are retired, leaving 27 units.
- 14 units (13%) from vintage 2015 are retired, leaving 87 units.
- 9 units (8%) from vintage 2016 are retired, leaving 107 units.
- 0 units from vintage 2017 are retired, leaving 122 units.
- 128 units are shipped (vintage 2018).
- The total national inventory is 468 units.

In 2019:

- 27 units (26%) from vintage 2014 are retired, leaving 0 units.
- 58 units (53%) from vintage 2015 are retired, leaving 29 units.
- 15 units (13%) from vintage 2016 are retired, leaving 92 units.
- 10 units (8%) from vintage 2017 are retired, leaving 112 units.
- 0 units from vintage 2018 are retired, leaving 128 units.
- 134 units are shipped (vintage 2019).

- The total national inventory is 492 units.

10.3 National Energy Savings

DOE calculated the national energy savings (NES) associated with the difference between the base case and the case associated with each CSL for BCs and EPSs. The calculation of NES, which represents the total energy savings for a product class over the entire analysis period, encompasses three steps:

1) The annual unit energy savings (UES) associated with a CSL is calculated as the difference in energy consumption between an average unit in the absence of standards (base case) and an average unit with a standard set at that CSL.
2) The UES is then multiplied by the national inventory for a given year for that product class to obtain annual NES for that year.
3) Annual NES is then calculated for each year of the analysis period and summed.

10.3.1 Calculating National Energy Savings

For a given product class and CSL, DOE first calculated annual UES (in kWh/year) as the difference in annual energy consumption between an average unit in the base case (UEC_{Base}) and an average unit in the standards case (UEC_{CSL}).

Equation 10-1 $$\mathbf{UES_{CSL} = UEC_{Base} - UEC_{CSL}}$$

DOE then calculated the NES in a given year ($NES_{Year\text{-}kWh}$) by multiplying the national inventory in that year ($NationalInventory_{Year}$) by the UES_{CSL}. The calculation of $NES_{Year\text{-}kWh}$ is represented by the following equation:

Equation 10-2 $$\mathbf{NES_{Year\text{-}kWh} = NationalInventory_{Year} \times UES_{CSL}}$$

DOE then calculated NES_{kWh} for the entire analysis period by repeating the above NES_{Year} for each year, and then summing the results. The calculation is represented by the following equation:

Equation 10-3 $$\mathbf{NES_{kWh} = \sum NES_{Year\text{-}kWh}}$$

10.3.2 Inputs to National Energy Savings Calculation

The inputs to the calculation of national energy savings are:

- National inventory (explained in section 10.2)
- Unit energy savings (explained in section 10.3.2.1)
- Site-to-source conversion factor (explained in section 10.3.2.2)

10.3.2.1 Unit Energy Savings

DOE used the efficiency distributions for the base case presented in the shipments analysis along with the annual UEC values presented in the energy use analysis to estimate shipment-weighted average UEC under the base and standards cases, which were then compared against one another to give UES values for each CSL.

In order to better evaluate actual energy savings, when calculating unit energy consumption for a product class at a given CSL, DOE considered only those units that would actually be at that CSL, and did not consider any units already at higher CSLs. That is, the shipment-weighted average unit energy consumption for a CSL ignored any shipments from higher CSLs.

In addition, when calculating unit energy consumption for a product class, DOE used marginal energy consumption, which was taken to be the consumption of a unit above the minimum energy consumption possible for that unit. Marginal unit energy consumption values were calculated by subtracting the unit energy consumption values for the highest considered CSL from the unit energy consumption values at each CSL.As explained in the shipments analysis, DOE assumed that energy efficiency for BCs and EPSs would not improve after 2013 in the base case. Therefore, UEC values do not vary over time, and thus UES values do not vary over time. In addition, DOE assumed that manufacturers would respond to a standard by improving the efficiency of underperforming products but not those that already meet or exceed the standard, as discussed in shipments analysis.

The average annual UES for each product class and CSL is shown in Table 10.4 for EPSs and in Table 10.5 for BCs. EPS product class B is broken out into four segments by nameplate output power, corresponding to the four representative units examined in the engineering analysis.

Table 10.4 Shipment-Weighted Average Unit Energy Savings for External Power Supplies (kWh/yr)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	1.27	1.74	1.97	2.14
B – 18W Representative Unit	3.26	5.09	6.51	9.37
B – 60W Representative Unit	1.09	2.81	4.24	7.20
B – 120W Representative Unit	2.69	5.43	6.08	12.87
C	0.68	1.05	1.39	1.60
D	3.28	5.74	7.09	10.21
E	1.68	2.60	3.27	3.72
X	90.25	90.92	96.35	N/A
H	144.10	189.74	198.59	212.69

Table 10.5. Shipment-Weighted Average Unit Energy Savings for Battery Chargers, (kWh/yr)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	2.63	5.69	7.44	N/A
2	2.37	5.88	8.28	8.54
3	8.71	12.91	12.95	N/A
4	16.86	21.57	23.06	N/A
5	98.52	137.92	158.10	N/A
6	41.11	87.32	107.50	N/A
7	60.96	117.29	N/A	N/A
8	0.23	0.63	0.69	N/A
10	13.14	15.24	17.78	N/A

10.3.2.2 Site-to-Source Conversion Factors

In determining national annual energy consumption, DOE initially calculated the annual energy consumption and savings at the site in kWh. DOE then converted site energy savings to primary (source) energy savings by applying a site-to-source conversion factor to account for losses associated with the generation, transmission, and distribution of electricity.

DOE used annual site-to-source conversion factors based on EIA's *Annual Energy Outlook 2010 (AEO 2010), Table 4. Residential Sector Key Indicators and Consumption*.[2] Figure 10.2 shows the site-to-source conversion factors for each year from 2010 through 2060. Factors for each year from 2010 to 2035 were calculated by dividing the sum of *Delivered Energy [Electricity]* and *Electricity Related Losses* by *Delivered Energy [Electricity]*. The site-to-source conversion factor given by *AEO 2010* for 2013 is 3.169. The factor declines gradually from 2013 to 2035 as the power system is expected to become more energy efficient during that period. The site-to-source conversion factor is held constant at the 2035 value in later years, which are beyond the time horizon of the *AEO 2010* forecast.

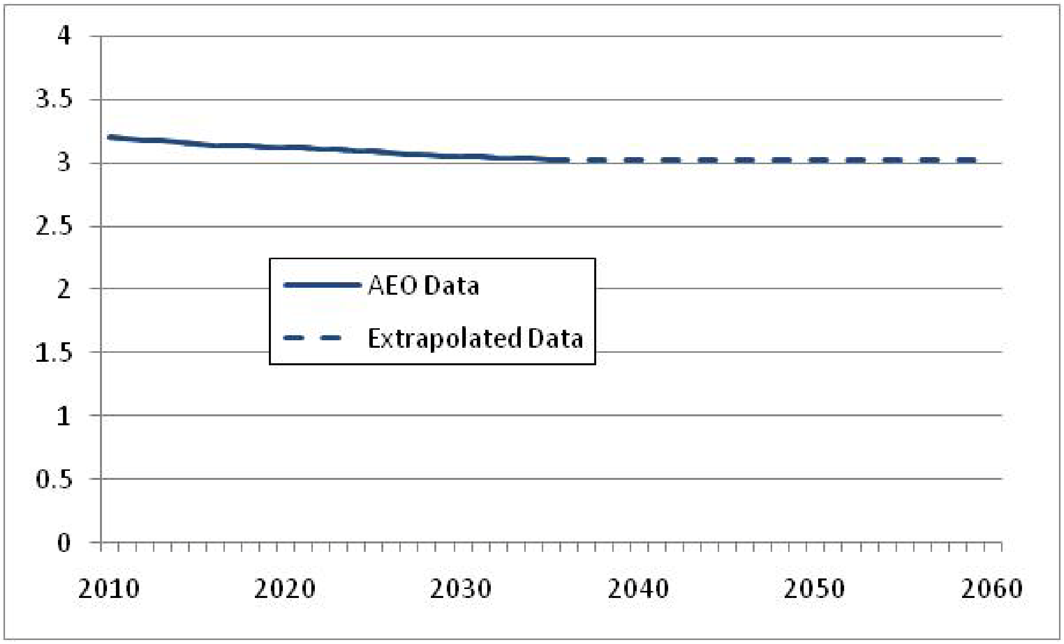


Figure 10.2 Site-to-Source Conversion Factors, 2010 to 2060

10.4 Net Present Value

DOE calculated the NPV of the increased product costs and reduced operating costs associated with the difference between the base case and each potential standard case for BCs and EPSs. The calculation of NPV, which represents the present year (2011) value of the difference between consumer savings and costs over the entire analysis period, encompasses six steps:

1. The $NES_{Year\text{-}kWh}$ site electricity savings values are converted to energy cost savings by multiplying by forecast electricity rates, with each year discounted to present value.
2. The unit improvement costs (UIC) associated with a CSL is calculated as the difference in cost between an average unit in the base case and an average unit in the standards case.
3. The UIC is then multiplied by the shipments for a given shipment year for that product class to obtain an annual National Improvement Cost (NIC_{Year}).
4. The calculation of the annual NIC_{Year} is then repeated for each year of the shipment forecast period, with each year discounted to the present year.
5. Present value NIC_{Year} is then subtracted from present value $NES_{Year\text{-}\$}$ for each year of the analysis period, yielding net present value for each year (NPV_{Year}).
6. NPV_{Year} values are then summed to yield total NPV.

10.4.1 Calculating Net Present Value

10.4.1.1 Present Value of Savings

DOE first converted site national energy savings for a given year ($NES_{Year\text{-}kWh}$) to present value energy cost savings (in 2010$) by first multiplying by the projected fuel price for that year ($FuelPrice_{Year}$), and multiplying the product by a discount factor for that year (DF_{Year}).

Equation 10-4 $$\mathbf{NES_{Year\text{-}\$} = NES_{Year\text{-}kWh} \times FuelPrice_{Year} \times DF_{Year}}$$

Equation 10-5 $$\mathbf{DF_{Year} = 1/[(1+r)\wedge(y-y_p)]}$$

Where:

r = discount rate

y = year of analysis

y_p = year in which the present value is being determined (2011)

10.4.1.2 Present Value of Costs

Next for a given product class and CSL, DOE first calculated UIC as the difference in unit cost between an average unit in the base case ($AvgUnitCost_{Base}$) and an average unit in the standards case ($AvgUnitCost_{CSL}$).

Equation 10-6 $$\mathbf{UIC_{CSL} = AvgUnitCost}_{Base} - \mathbf{AvgUnitCost}_{CSL}$$

DOE then calculated the present value of NIC (in 2010$) for a given year ($NIC_{Year}$) by multiplying the shipments for a given year for the product class ($Shipments_{Year}$) by the UIC_{CSL} of that product class, and multiplying the product by a discount factor for that year (DF_{Year}). The calculation of NIC_{Year} is represented by the following equation. This process was repeated for each year.

Equation 10-7 $$\mathbf{NIC_{Year} = Shipments_{Year} \times UIC_{CSL} \times DF_{Year}}$$

10.4.1.3 Net Present Value

DOE calculated net present value for each year as the difference between $NES_{\$\text{-}Year}$ and NIC_{Year}, with positive values indicating cost effectiveness.

Equation 10-8 $$\mathbf{NPV_{Year} = NES_{\$\text{-}Year} - NIC_{Year}}$$

Finally, DOE summed NPV_{Year} values over all years to obtain NPV.

Equation 10-9 $$\mathbf{NPV = \sum NPV_{Year}}$$

10.4.2 Inputs to Net Present Value Calculation

The inputs to the calculation of the net present value are:

- Shipments (explained in chapter 9)
- National energy savings (explained in section 10.3)

- Electricity prices (explained in section 10.4.2.1)
- Gasoline prices (explained in section 10.4.2.2)
- Unit improvement costs (explained in section 10.4.2.3)
- Discount rates (explained in section 10.4.2.4)

10.4.2.1 Electricity Prices

DOE used the methodology described in chapter 8 for forecasting electricity prices for residential and commercial consumers. In the preliminary analysis, DOE assumed all energy consumption and savings would take place in the residential sector and used a trend function to extend the electricity price forecast used in the LCC analysis from 2030 until the end of the analysis period.

To reflect the fact that some BCs and EPSs are used in the commercial sector, in the NOPR, DOE calculated the estimated energy use split between the commercial and residential sectors, and applied this split to energy pricing between the two sectors. The resulting energy price reflects the consideration by DOE that energy savings in the commercial sector have lower value, due to lower energy prices in the commercial sector, and that the assumption during the preliminary analysis of using only the residential energy price would lead to an overestimate of cost savings.

In order to calculate the energy use split for each product class. DOE first separated individual products into residential-use and commercial-use categories. DOE then calculated the installed inventory consumption for these products, by multiplying the shipments by the average lifetime and the average UEC in the base case. Results for a product class were then summed, yielding both residential and commercial energy use estimates. These results were then compared against each other, and the ratio between the two was applied to the residential and commercial energy prices.

10.4.2.2 Unit Improvement Costs

DOE used the efficiency distributions for the base case presented in chapter 9, the manufacturer selling prices presented in chapter 5, and markups and sales tax from chapter 6 to calculate the UIC in each standards case. Manufacturers are assumed to respond to a standard by improving the efficiency of underperforming products but not those that already meet or exceed the standard, as discussed in chapter 9. Average unit improvement costs in each scenario are shown in Table 10.6 for EPSs and Table 10.7 for BCs.

As previously discussed, in the NOPR DOE applied costs from the EPS representative units in product class B to product classes C, D and E. All BC product classes were representative product classes. This methodology is described in more detail in chapter 5 of the TSD.

Table 10.6 Shipment-Weighted Average Unit Improvement Costs for External Power Supplies (2010$)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	$0.09	$0.33	$0.50	$0.60
B – 18W Representative Unit	$0.00	$0.17	$0.76	$3.93
B – 60W Representative Unit	$0.00	$0.97	$1.64	$3.71
B – 120W Representative Unit	$0.00	$0.34	$0.53	$8.88
C	$0.10	$0.36	$0.54	$0.64
D	$0.00	$0.19	$0.84	$4.06
E	$0.07	$0.28	$0.44	$0.53
X	$0.19	$0.51	$8.35	N/A
H	-$18.72	-$18.72	-$15.03	$33.67

Table 10.7 Shipment-Weighted Average Unit Improvement Costs for Battery Chargers (2010$)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	$0.26	$0.84	$6.10	N/A
2	$0.02	$0.88	$3.37	$6.19
3	$0.29	$4.23	$4.28	N/A
4	$0.39	$4.47	$12.42	N/A
5	$1.35	-$5.80	$138.13	N/A
6	$1.69	-$4.04	$138.58	N/A
7	-$17.59	$135.91	N/A	N/A
8	-$1.93	$1.38	$1.64	N/A
10	$1.47	$1.87	$2.36	N/A

Note: In the NIA workbook, the input manufacturer selling prices (MSPs) are presented for both EPSs and BCs. While input prices may be absolute or marginal (adjusted so that the price of a unit at CSL 0 is zero), the type of input does not affect the calculation of incremental improvement costs.

10.4.2.3 Projection of Future Product Prices

For reasons discussed in chapter 8 (section 8.2.2), DOE used a constant price assumption for the default forecast in the NIA. In order to investigate the impact of different product price forecasts on the consumer NPV for the considered TSLs for battery chargers and EPSs, DOE also considered three alternative price trends. All are based on specific “chained price indexes” forecasted for *AEO 2010*. Details on how these alternative price trends were developed are in Appendix 10-B, which also presents the results of the sensitivity analysis.

10.4.2.4 Discount Rates

To calculate NPV, DOE discounted future consumer costs and savings to the present day (2011) using discount rates of 3 percent and 7 percent. These discount rates are specified by the U.S. Office of Management and Budget (OMB) (OMB, Circular A-4: Regulatory Analysis, 2003).

10.5 NES and NPV Results

DOE estimated NES and NPV for BC standards separately from EPS standards. Results for the two products should not be added to one another because many BCs incorporate an EPS. One way to improve the efficiency of these BCs is to improve the efficiency of the EPS part. The resulting savings are counted in both the BC analysis and in the separate EPS analysis. Thus, due to this overlap, combining BC and EPS NES (or NPV) estimates would overstate savings resulting from improving BCs and EPSs.

10.5.1 National Energy Savings

The tables in this section provide results of calculating NES for standards at each of the CSLs analyzed for the considered products. NES results are expressed in primary energy savings of quadrillion Btu (quads). DOE based the inputs on weighted-average values for each product class, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis of chapter 8. This section also presents NES results if the savings were discounted at rates of 3 percent and 7 percent.

Results for each candidate standard level are shown in Table 10.8, Table 10.9 and Table 10.10 for EPSs, and Table 10.11, Table 10.12 and Table 10.13 for BCs.

Table 10.8 National Energy Savings Potential from Standards for External Power Supplies, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	0.0605	0.1086	0.1337	0.1525
B – 18W Representative Unit	0.0733	0.2246	0.3712	0.7026
B – 60W Representative Unit	0.0130	0.1029	0.1931	0.3828
B – 120W Representative Unit	0.0053	0.0218	0.0266	0.0785
C	0.0255	0.0562	0.0852	0.1039
D	0.0191	0.0665	0.0985	0.1750
E	0.0020	0.0049	0.0074	0.0092
X	0.0625	0.0718	0.1470	N/A
H	0.0008	0.0013	0.0014	0.0015

Table 10.9 National Energy Savings Potential from Standards for External Power Supplies at a 3 Percent Discount Rate, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	0.0358	0.0644	0.0793	0.0904
B – 18W Representative Unit	0.0435	0.1331	0.2200	0.4165
B – 60W Representative Unit	0.0078	0.0617	0.1158	0.2295
B – 120W Representative Unit	0.0032	0.0132	0.0162	0.0477
C	0.0153	0.0335	0.0509	0.0621
D	0.0106	0.0370	0.0548	0.0974
E	0.0012	0.0029	0.0044	0.0054
X	0.0369	0.0424	0.0869	N/A
H	0.0004	0.0007	0.0008	0.0008

Table 10.10 National Energy Savings Potential from Standards for External Power Supplies at a 7 Percent Discount Rate, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	0.0201	0.0361	0.0445	0.0507
B – 18W Representative Unit	0.0244	0.0747	0.1235	0.2337
B – 60W Representative Unit	0.0044	0.0351	0.06595	0.1306
B – 120W Representative Unit	0.0019	0.0077	0.0094	0.0276
C	0.0086	0.0190	0.0288	0.0352
D	0.0055	0.0193	0.0286	0.0508
E	0.0007	0.0016	0.0025	0.0030
X	0.0206	0.0237	0.0485	N/A
H	0.0002	0.0004	0.0004	0.0004

Table 10.11 National Energy Savings Potential from Standards for Battery Chargers, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	0.0557	0.1298	0.1775	N/A
2	0.1351	0.5848	1.3267	1.4080
3	0.0521	0.1687	0.1703	N/A
4	0.1219	0.3013	0.4189	N/A
5	0.2412	0.5150	0.6676	N/A
6	0.0267	0.0812	0.1132	N/A
7	0.0067	0.0209	N/A	N/A
8	0.096	0.0408	0.0453	N/A
10	0.2308	0.2678	0.3124	N/A

Table 10.12 National Energy Savings Potential from Standards for Battery Chargers at a 3 Percent Discount Rate, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	0.0329	0.0767	0.1049	N/A
2	0.0806	0.3489	0.7916	0.8401
3	0.0310	0.1005	0.1014	N/A
4	0.0731	0.1807	0.2512	N/A
5	0.1409	0.3009	0.3900	N/A
6	0.0150	0.0457	0.0638	N/A
7	0.0040	0.0126	N/A	N/A
8	0.0057	0.0245	0.0271	N/A
10	0.1325	0.1537	0.1793	N/A

Table 10.13 National Energy Savings Potential from Standards for Battery Chargers at a 7 Percent Discount Rate, by Candidate Standard Level (Quadrillion Btu)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	0.0184	0.0428	0.0586	N/A

2	0.0456	0.1975	0.4480	0.4755
3	0.0175	0.0567	0.0572	N/A
4	0.0416	0.1028	0.1430	N/A
5	0.0778	0.1662	0.2154	N/A
6	0.0079	0.0241	0.0337	N/A
7	0.0023	0.0072	N/A	N/A
8	0.0033	0.0139	0.0154	N/A
10	0.0715	0.0829	0.0968	N/A

10.5.2 Annual Costs and Savings

Figure 10.3 illustrates the basic inputs of the calculation of NPV by showing the 3-percent discounted annual increases in product cost and annual savings in operating cost at the national level for BC Product Class 1 at CSL 1. The figure also shows the net savings, which is the difference between the savings and costs for each year. The annual increase in product cost is the total cost increase for products shipped each year of the shipment period. The annual savings cost applies to all products operating in each year of the analysis period. DOE can create figures like this one for each product class at each CSL.

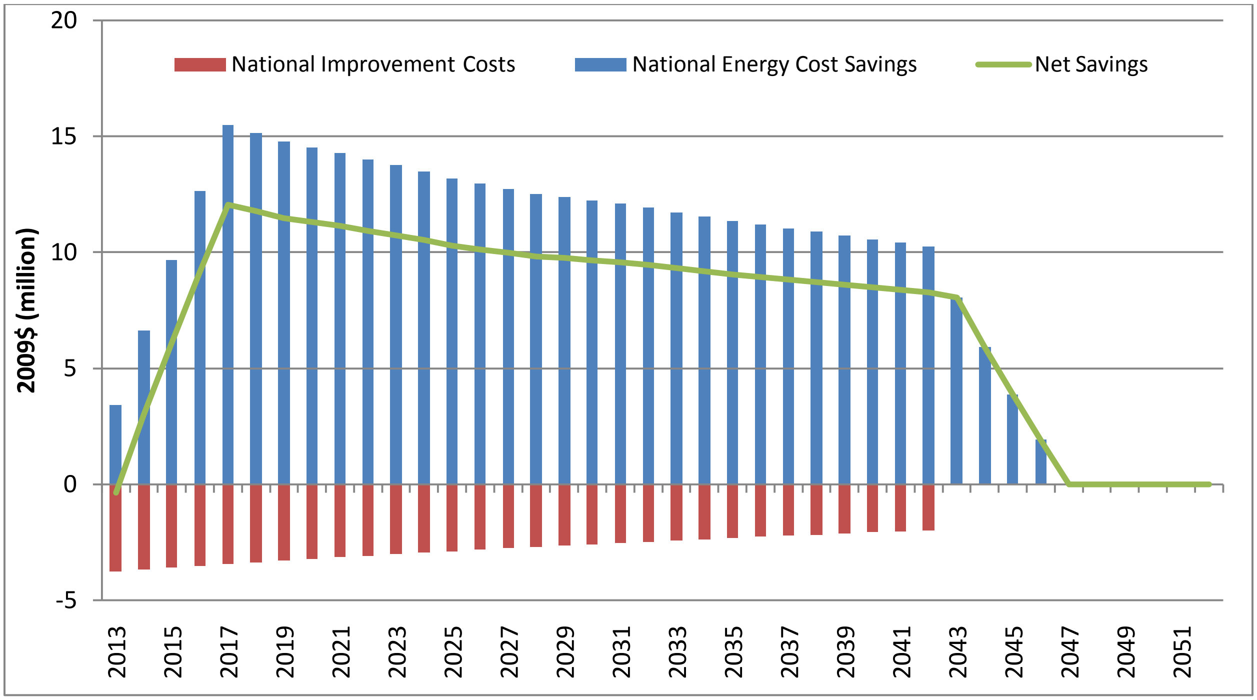


Figure 10.3 Annual Consumer Costs and Savings from a Standard at CSL 1 for BC Product Class 1 at a 3 Percent Discount Rate

10.5.3 Net Present Value

The tables in this section present results of calculating NPV of consumer benefit for standards at each CFL for for BCs and EPSs. Results are shown as value of the net savings in

2010 dollars, discounted to 2011. Similar to the NES, DOE based inputs to the NIA on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis of chapter 8. This section presents NPV results discounted at rates of 3 percent and 7 percent.

Results for EPSs are shown first, using discount rates of 3 percent (Table 10.14) and 7 percent (Table 10.15). The corresponding values for BCs are shown in Table 10.16 and Table 10.17. Results in this section reflect NPV calculated with reference case energy prices. Results for high economic growth and low economic growth cases are presented in Appendix 10-A.

Table 10.14 Net Present Value from Amended Standards for External Power Supplies at a 3 Percent Discount Rate, by Candidate Standard Level (2010$ millions)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	$262.45	$229.43	$156.94	$135.22
B – 18W Representative Unit	$487.79	$1,237.07	$1,315.35	($1,268.98)
B – 60W Representative Unit	$84.66	($324.70)	($421.36)	($1,311.82)
B – 120W Representative Unit	$33.52	$85.89	$87.45	($846.71)
C	$41.18	($90.73)	($116.80)	($127.13)
D	$119.91	$385.74	$475.18	$400.85
E	$10.01	$19.48	$28.65	$35.66
X	$329.15	$330.28	($533.17)	N/A
H	$6.19	$9.35	$9.73	$7.55

Table 10.15 Net Present Value from Amended Standards for External Power Supplies at a 7 Percent Discount Rate, by Candidate Standard Level (2010$ millions)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
B – 2.5W Representative Unit	$137.60	$102.52	$51.18	$32.20
B – 18W Representative Unit	$268.20	$667.87	$667.97	($982.21)
B – 60W Representative Unit	$47.17	($221.21)	($302.78)	($885.03)
B – 120W Representative Unit	$18.97	$46.98	$46.95	($521.77)
C	$17.37	($70.17)	($93.98)	($105.48)
D	$60.10	$193.66	$229.41	$142.56
E	$5.34	$10.04	$14.71	$18.33
X	$177.66	$175.52	($363.51)	N/A
H	$3.23	$4.81	$4.98	$3.59

Table 10.16 Net Present Value from New Standards for Battery Chargers at a 3 Percent Discount Rate, by Candidate Standard Level (2010$ millions)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	$293.99	$605.61	($781.20)	N/A
2	$767.33	($854.66)	($9,284.15)	($23,872.17)
3	$205.00	($965.67)	($982.11)	N/A
4	$282.80	($3,909.15)	($13,588.44)	N/A
5	$1,476.63	$4,063.85	($9,999.68)	N/A
6	$151.31	$583.82	($1,123.02)	N/A
7	$119.36	($493.18)	N/A	N/A
8	$2,780.48	($1,654.45)	($2001.13)	N/A
10	$1,192.42	$1,354.45	$1,549.50	N/A

Table 10.17 Net Present Value from New Standards for Battery Chargers at a 7 Percent Discount Rate, by Candidate Standard Level (2010$ millions)

Product Class	Candidate Standard Level			
	CSL 1	CSL 2	CSL 3	CSL 4
1	$156.78	$317.85	($527.25)	N/A
2	$419.83	($678.73)	($5,930.02)	($14,672.55)
3	$106.86	($627.93)	($638.22)	N/A
4	$137.14	($2,415.29)	($8,231.32)	N/A
5	$790.95	$2,233.33	($6,230.33)	N/A
6	$76.33	$306.03	($731.08)	N/A
7	$69.84	($299.46)	N/A	N/A
8	$1,659.29	($999.88)	($1,208.30)	N/A
10	$611.29	$691.91	$788.88	N/A

10.6 NES and NPV Results by Trial Standard Level

10.6.1 Trial Standard Levels

In considering standards for EPSs and BCs, DOE created trial standard levels (TSLs) that combine specific efficiency levels across product classes. DOE then analyzed the NIA for these TSLs. Table 10.18 and Table 10.19 list the Candidate Standard Levels associated with each TSL for EPSs and BCs, respectively.

Table 10.18 Trial Standard Levels for External Power Supplies

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	CSL2	CSL3	CSL4
C	CSL2	CSL3	CSL4
D	CSL2	CSL3	CSL4
E	CSL2	CSL3	CSL4
X	CSL1	CSL2	CSL3
H	CSL2	CSL3	CSL4

Table 10.19 Trial Standard Levels for Battery Chargers

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	CSL1	CSL2	CSL3	N/A
2	CSL1	CSL2	CSL3	CSL4
3	CSL1	CSL1	CSL2	CSL3
4	CSL1	CSL1	CSL2	CSL3
5	CSL1	CSL2	CSL3	N/A
6	CSL1	CSL2	CSL3	N/A
7	CSL1	CSL2	N/A	N/A
8	CSL1	CSL2	CSL3	N/A
10	CSL1	CSL2	CSL3	N/A

10.6.2 National Energy Savings by Trial Standard Level

Table 10.20, Table 10.21, Table 10.22, Table 10.23, Table 10.24 and Table 10.25 show the national energy savings associated with standards at the considered TSLs for BCs and EPSs in the reference case. Results are displayed by product class groups, rather than by individual product classes.

Table 10.20 National Energy Savings Potential from Standards for External Power Supplies, by Trial Standard Level (Quadrillion Btu)

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	0.458	0.725	1.316
B, C, D, E	0.585	0.916	1.604
X	0.063	0.072	0.147
H	0.001	0.001	0.002

Table 10.21 National Energy Savings Potential from Standards for Battery Chargers, by Trial Standard Level (Quadrillion Btu)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	0.056	0.130	0.178	
2, 3, 4	0.309	0.759	1.797	1.997
5, 6	0.268	0.596	0.781	
7	0.007	0.021		
8	0.010	0.041	0.045	
10	0.231	0.268	0.312	

10.6.3 Net Present Value by Trial Standard Level

Table 10.26, Table 10.27, Table 10.28 and Table 10.29 show the net present value associated with standards at the considered TSLs for BCs and EPSs in the reference case.

Table 10.22 Net Present Value from Standards for External Power Supplies at a 3 Percent Discount, by Trial Standard Level (2009$ millions)

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	1,228	1,138	-3,292
B, C, D, E	1,542	1,525	-2,983
X	329	330	-533
H	9	10	8

Table 10.23 Net Present Value from Standards for External Power Supplies at a 7 Percent Discount, by Trial Standard Level (2009$ millions)

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	596	463	-2,357
B, C, D, E	730	613	-2,301
X	178	176	-364
H	5	5	4

Table 10.24 Net Present Value from Standards for Battery Chargers at a 3 Percent Discount Rate, by Trial Standard Level (2009$ millions)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	294	606	-781	
2, 3, 4	1,255	-367	-14,159	-38,443
5, 6	1,628	4,648	-11,123	
7	119	-493		
8	2,780	-1,654	-2,001	
10	1,192	1,354	1,550	

Table 10.25 Net Present Value from Standards for Battery Chargers at a 7 Percent Discount Rate, by Trial Standard Level (2009$ millions)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	157	318	-527	
2, 3, 4	664	-435	-8,973	-23,542
5, 6	867	2,539	-6,961	
7	70	-299		
8	1,659	-1,000	-1,208	
10	611	692	789	

REFERENCES

---

[1] U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2010 with Projections to 2035*. April 2010. U.S. DOE–EIA: Washington, D.C. DOE/EIA-0383(2010).

[2] U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2010 with Projections to 2035*. April 2010. U.S. DOE–EIA: Washington, D.C. DOE/EIA-0383(2010). http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html

CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

11.1 INTRODUCTION

Chapter 8 describes the life-cycle cost (LCC) and payback period (PBP) analysis that examines impacts of energy conservation standards on the U.S. population. In analyzing the potential impact of new or amended standards on consumers, DOE further evaluates the impact on identifiable groups of consumers (i.e., consumer subgroups) that may be disproportionately affected by a national standard level. The LCC subgroup analysis evaluates impacts by analyzing the LCC and PBPs for subgroups of households or commercial and industrial consumers.

In the case of battery chargers (BCs) and external power supplies (EPSs), DOE identified the following consumer subgroups: (1) low-income consumers, (2) small businesses (i.e., those with low annual revenues), (3) top tier marginal electricity price consumers, and (4) consumers of specific applications within a representative unit. These subgroups may experience different economic conditions than the average owner of a BC or EPS. The analysis determines whether these groups of consumers would be adversely affected by any of the trial standard levels.

DOE determined the impact on consumer subgroups for BCs and EPSs using the LCC spreadsheet model, which allows for the examination of particular consumer subgroups. The LCC analysis for the general population (described in Chapter 8) focuses on consumers that use BCs and EPSs. DOE has the ability to use the LCC spreadsheet model to analyze the LCC for any subgroup by sampling only the data that apply to that subgroup. (Chapter 8 explains in detail the inputs to the model used in determining LCC and PBPs).

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for BCs and EPSs. Section 11.2 discusses the definitions and inputs used for each of the four subgroups, while section 11.3 gives the LCC and PBP results for the four subgroups.

11.2 SUBGROUP DEFINITIONS AND INPUTS TO THE SUBGROUP ANALYSIS

DOE researched the subgroups by utilizing a number of data sources. To calculate the inputs for low income consumers, DOE used the 2005 RECS[i] database. DOE used the Ibbotson Associates' *Stocks, Bonds, Bills, and Inflation 2007 Yearbook*[ii] to develop inputs for the small businesses subgroup. DOE relied on marginal electricity rates provided by Southern California Edison[iii] and Pacific Gas & Electric[iv] to calculate inputs for top tier marginal electricity rates. Finally, DOE relied on various sources for the application-specific subgroup inputs, which are outlined further in chapter 3.

11.2.1 Low-Income Consumers

In several past rulemakings, DOE has defined low-income consumers as residential consumers with incomes at or below the poverty line as defined by the U.S. Census Bureau.[v] DOE defines low-income consumers in the same way for this rule. The poverty line varies with household size, head of household age, and family income. Table 11.2.1 summarizes the criteria given for selecting low-income households from the 2005 RECS database; households with incomes below the weighted-average thresholds were considered to be low-income households.

Table 11.2.1 U.S. Census Bureau 2005 Definition of Low-Income Households

Household Size	Owner Age	Weighted-Average Threshold
1	65 and over	$9,367
1	64 and under	$10,160
2	65 and over	$11,815
2	64 and under	$13,145
3	Any	$15,577
4	Any	$19,971
5	Any	$23,613
6	Any	$26,683
7	Any	$30,249
8	Any	$33,610
9 or more	Any	$40,288

DOE discovered that residential low-income consumers faced electricity prices that were lower by 0.2 cents per kWh (in 2005 dollars) than the prices faced by consumers above the poverty line in 2005, as shown in Table 11.2.2. The weights in the table represent approximately the number of households represented by the statistic. Using this information, DOE multiplied the U.S. average residential electricity price of $0.112 (2010$) by 0.096/0.098 (approximately 0.9814) to arrive at the low-income residential electricity price of approximately $0.109. DOE then used this price as a modification to the residential-sector primary LCC analysis. Because of the large diversity of low-income families in the residential sector, DOE does not expect to see differences in other inputs like unit energy consumption or product lifetime that vary significantly on average from the residential sector as a whole. Therefore, with the exception of electricity prices, DOE used the same inputs in the low-income consumer subgroup analysis as it used for the general residential sector population.

Table 11.2.2 Electricity Price Statistics From 2005 Residential Energy Consumption Survey

Category	Sum of Weights [*Millions*]	Dollars per kWh for Electricity [*2005$*]
All Electrically-Connected Households	111	$0.098
Above Poverty Line	94	$0.098
Below Poverty Line	17	$0.096

11.2.2 Small Businesses

The Small Business Administration (SBA) defines a small business by its annual receipts or its number of employees. To calculate discount rates for small companies that purchase BCs or EPSs, DOE used the same methodology as for the general population as presented in chapter 8.[a] Although the methodology is appropriate, the capital asset pricing model (CAPM) described in chapter 8 for the general population underestimates the cost of capital for small companies. In CAPM, the risk premium β is used to account for the higher returns associated with greater risk. However, for small companies, particularly very small companies, historic returns have been significantly higher than the CAPM equation predicts. This additional return can be accounted for by adding a size premium to the cost of equity for small firms:

$$k_e = R_f + (\beta \times ERP) + S$$

where

k_e = the cost of equity for a company, expressed in dollars,
R_f = the expected return of the risk-free asset, expressed in dollars,
β = the risk coefficient,
ERP = the expected equity risk premium, expressed in dollars.
S = the size premium.

DOE obtained size premium data from Ibbotson Associates' *Stocks, Bonds, Bills, and Inflation 2007 Yearbook*.[ii] For the period of 1926-2006, the average size premium for the smallest companies in all industries is 6.27 percent, implying that on average, historic performance of small companies has been 6.27 percent higher than the CAPM estimate of the small company cost of equity.[b]

DOE calculated the real weighted average cost of capital (as described in chapter 8) using the cost of equity including a size premium for small companies instead of the CAPM cost of equity. DOE estimates that in industries that purchase BCs and EPSs, small companies have an average discount rate 4.48 percent higher than the industry average. This conclusion is supported by the similar difference (3.8 percent) between small and average company discount rates for the entire market based on data from Damodaran[c, vi] (see Table 11.2.3).

Table 11.2.3 Discount Rate Difference Between Small Company and Market Average

Sector	**Discount Rate**		**Difference**
	Average	**Std. Dev.**	
Entire Market	6.3%	2.3%	--
Small Company	10.2%	3.3%	3.8%

In chapter 8, DOE estimated the average discount rate for commercial customers to be 7.1 percent. Applying the additional small capitalization (small cap) discount rate premium of

---

[a] DOE assumed that small businesses as a whole are a reasonable approximation for small businesses that use BCs or EPSs.

[b] In this calculation, small companies are defined as companies with market capitalization of less than or equal to $84.5 million, the Ibbotson Associates' definition of Decile 10 companies.

[c] The Damodaran database for the entire market used for this comparison includes 6559 companies, 2605 of which are small companies.

4.48 percent presented above to these discount rates for businesses that purchase BCs and EPSs, the average discount rate for small commercial companies is approximately 11.6 percent. Because of the large diversity of small businesses in the commercial sector, DOE does not expect to see differences in other inputs like unit energy consumption or product lifetime that vary significantly on average from the commercial sector as a whole. Therefore, with the exception of the discount rate, DOE used the same inputs in the small business consumer subgroup analysis as it used for the general commercial sector population.

11.2.3 Top Tier Marginal Electricity Price Consumers

DOE analyzed consumers in the top tier of marginal electricity prices to determine if these consumers would experience different economic impacts from potential efficiency standards. During the Framework Document stage of the rulemaking, DOE received comment requesting that it consider this electricity price scenario. Because of the large diversity of consumers in the residential and commercial sectors, respectively, DOE does not expect to see differences in other inputs like unit energy consumption or product lifetime that vary significantly on average from the population average as a whole. Therefore, with the exception of the electricity price, DOE used the same inputs in the top tier marginal electricity price consumer subgroup analysis as it used for the general population.

DOE examined a top tier marginal electricity price for both the residential and commercial sectors. To determine the price for each sector, DOE reviewed publicly available information on increasing block rate electricity price tiers. DOE selected the highest electricity price it could find that applied to general service customers. For the residential sector, DOE selected a marginal electricity price of $0.31 per kWh, representing the fifth tier in an inclined marginal block rate structure.[iii] For the commercial sector, DOE selected a marginal electricity price based on a peak rate time-of-usage rate structure for typical customers using electricity between 9:00 a.m. and 5:00 p.m. The rate chosen was $0.225 per kWh.[iv] Each of these rates were in 2010$, and correspond with the LCC and PBP analysis. Table 11.2.4 shows the top tier marginal electricity price chosen for each sector, along with the corresponding average electricity price that DOE used in its analysis described in chapter 8.

Table 11.2.4 Top Tier Marginal Electricity Prices and Average Electricity Prices

Electricity Price Scenario	**Residential [2010*$/kWh*]**	**Commercial [2010*$/kWh*]**
Top Tier Marginal Price	$0.310	$0.225
Average Price	$0.112	$0.097

11.2.4 Application-Specific Consumer Subgroups

DOE analyzed the LCC savings and PBP for each application within the representative units and product classes (PC). Within each representative unit, DOE identified 1–40 applications and their relevant shipments, lifetimes, markups, base case market efficiency distributions, and unit energy consumption. In the analysis described in chapter 8, DOE evaluated each representative unit by sampling these inputs from the applications based on the applications' shipment-weighting. In the subgroup analysis, DOE examines the LCC and PBP results for each of these applications individually.

When analyzing these applications, DOE considered all inputs that are unique to the application. These inputs include lifetime, markups, base case market efficiency distribution, and unit energy consumption. Further detail on these application-specific inputs can be found in chapter 3 and appendix 8C. No other inputs were changed between the analyses for different applications within a given representative unit. Because of the large diversity of consumers for each application, DOE does not expect to see differences in other inputs like electricity prices or discount rates.

Additionally, DOE used the same manufacturer selling price (MSP) for each application within a given representative unit when considering the LCC and PBP results. The representative unit's MSP is based on the price of the BC or EPS itself, not the end use application, so the MSP will not change from one application to another. Even though the MSP as a percentage of the application's final purchase price may be relatively larger or smaller across different applications, DOE's analysis considers marginal impacts from a baseline product. For example, a marginal purchase price increase of $5 between the baseline and TSL 1 will not change whether the application originally costs $10 or $100. Further explanation on how DOE derived the MSPs for each representative unit can be found in chapter 5.

11.3 RESULTS FOR BATTERY CHARGER AND EXTERNAL POWER SUPPLY SUBGROUPS

The following tables present the results of the LCC subgroup analyses for low-income consumers, small businesses, top tier marginal electricity price consumers, and consumers of specific applications within a representative unit. The subgroup analysis is based on the primary LCC analysis described in chapter 8, with modifications described in section 11.2.

11.3.1 Low-Income Consumers

The results for the LCC and PBP subgroup analyses for low-income consumers are shown in Table 11.3.1 and Table 11.3.2 for Non-Class A EPSs, Table 11.3.3 through Table 11.3.6 for Direct Operation EPSs, and Table 11.3.7 through Table 11.3.16 for BCs.

The LCC savings and PBPs of low-income consumers are similar to that of the total population of consumers. In general, low-income consumers experience slightly reduced LCC savings, particularly in product classes dominated by residential applications. However, product classes with a large proportion of commercial applications experience less of an effect under the low-income consumer scenario, which is specific to the residential sector, and sometimes have greater LCC savings than the reference case results. None of the changes in LCC savings between the reference scenario and the low-income consumer subgroup scenario move a CSL from positive to negative LCC savings, or vice versa.

11.3.1.1 Non-Class A External Power Supplies

Table 11.3.1 Low-Income Consumers – LCC and PBP Results for 203W Multiple-Voltage Non-Class A External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* *%*	No Load Power *W*	Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	82.4	12.330	0.00	59.83	59.83	-	-	-	-	-
1	86.4	0.400	3.81	16.06	19.87	2.00	0.0	95.0	5.0	0.4
2	86.4	0.300	4.12	15.74	19.86	2.01	55.1	0.0	44.9	4.8
3	88.5	0.300	11.97	13.11	25.07	-3.20	95.0	0.0	5.0	13.5

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

Table 11.3.2 Low-Income Consumers – LCC and PBP Results for 345W High-Power Non-Class A External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* *%*	No Load Power *W*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	62.4	15.430	176.82	206.21	383.03	-	-	-	-	-
1	81.3	6.010	139.31	79.22	218.53	82.29	0.0	50.1	49.9	0.0
2	84.6	0.500	139.31	39.01	178.31	122.51	0.0	0.0	100.0	0.0
3	87.5	0.500	143.00	31.21	174.22	126.61	0.0	0.0	100.0	0.4
4	92.0	0.266	191.81	18.78	210.59	90.23	18.2	0.0	81.8	4.3

* “Eff.” stands for “efficiency level.”

11.3.1.2 Direct Operation External Power Supplies

Table 11.3.3 Low-Income Consumers - LCC and PBP Results for 2.5W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* *%*	No Load Power *W*	Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	58.3	0.500	0.00	1.53	1.53	-	-	-	-	-
1	67.9	0.300	0.22	0.99	1.21	0.14	5.5	58.1	36.5	1.6
2	71.0	0.130	0.48	0.78	1.26	0.10	46.3	8.5	45.2	3.5
3	73.5	0.100	0.65	0.68	1.33	0.04	59.7	2.5	37.8	4.4
4	74.8	0.039	0.75	0.60	1.35	0.01	62.1	0.0	37.9	4.4

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

Table 11.3.4 Low-Income Consumers – LCC and PBP Results for 18W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	76.0	0.500	0.00	5.78	5.78	-	-	-	-	-
1	80.3	0.300	0.00	4.41	4.41	0.29	0.0	80.0	20.0	0.0
2	83.0	0.200	0.24	3.63	3.87	0.69	17.2	28.4	54.4	1.2
3	85.4	0.100	0.90	2.96	3.86	0.70	39.2	9.9	50.9	3.4
4	91.1	0.039	4.06	1.68	5.74	-1.19	73.2	0.0	26.8	9.8

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

Table 11.3.5 Low-Income Consumers – LCC and PBP Results for 60W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	85.0	0.500	0.00	5.38	5.38	-	-	-	-	-
1	87.0	0.500	0.00	4.75	4.75	0.08	0.0	84.9	15.1	0.0
2	87.0	0.200	1.21	4.00	5.20	-0.29	75.1	14.7	10.2	6.4
3	88.0	0.073	1.89	3.37	5.27	-0.35	81.3	1.0	17.7	5.3
4	92.2	0.050	4.00	2.11	6.10	-1.19	91.0	0.0	9.0	6.3

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

Table 11.3.6 Low-Income Consumers – LCC and PBP Results for 120W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	85.0	0.500	0.00	7.01	7.01	-	-	-	-	-
1	87.0	0.500	0.00	6.08	6.08	0.24	0.0	74.3	25.7	0.0
2	88.0	0.230	0.44	5.12	5.56	0.65	0.2	21.2	78.6	1.3
3	88.4	0.210	0.63	4.90	5.53	0.68	6.4	3.1	90.5	1.8
4	93.5	0.089	8.98	2.55	11.53	-5.32	100.0	0.0	0.0	8.8

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

11.3.1.3 Battery Chargers

Table 11.3.7 Low-Income Consumers – LCC and PBP Results for Low Energy, Inductive Battery Chargers (PC1)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	8.7	4.39	4.23	8.62	-	-	-	-	-
1	6.1	4.72	2.96	7.68	0.74	0.0	22.2	77.8	1.3
2	3.0	5.38	1.47	6.85	1.47	0.0	11.1	88.9	1.7
3	1.3	10.63	0.62	11.26	-2.94	98.8	0.0	1.3	8.6

Table 11.3.8 Low-Income Consumers – LCC and PBP Results for Low Energy, Low Voltage Battery Chargers (PC2)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	8.9	1.42	3.00	4.41	-	-	-	-	-
1	6.7	1.55	2.26	3.81	0.15	1.3	82.6	16.1	0.5
2	2.9	3.68	1.12	4.80	-0.16	27.9	60.0	12.1	5.5
3	1.0	6.24	0.32	6.56	-1.87	87.2	3.0	9.8	8.7
4	0.8	9.06	0.23	9.29	-4.60	97.0	0.0	3.0	17.2

Table 11.3.9 Low-Income Consumers – LCC and PBP Results for Low Energy, Medium Voltage Battery Chargers (PC3)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	12.1	1.79	5.68	7.47	-	-	-	-	-
1	4.7	3.52	2.26	5.77	0.31	9.0	83.3	7.8	4.4
2	0.8	8.51	0.37	8.88	-2.21	66.2	21.1	12.7	22.4
3	0.8	8.57	0.35	8.92	-2.25	86.7	0.0	13.3	22.4

Table 11.3.10 Low-Income Consumers – LCC and PBP Results for Low Energy, High Voltage Battery Chargers (PC4)

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
		Avg. Installed Price	**Avg. Operating Cost**	**Avg. LCC**	**Wtd. Avg. Savings**	**Consumers with**			
CSL	**UEC**					**Net Cost**	**No Impact**	**Net Benefit**	**Median**
	kWh	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	37.8	8.16	15.02	23.19	-	-	-	-	-
1	9.9	12.38	3.86	16.24	0.61	5.8	87.4	6.7	3.2
2	4.6	20.82	1.62	22.44	-2.79	50.6	46.1	3.3	12.3
3	3.0	28.79	1.14	29.93	-10.28	97.2	0.0	2.8	43.1

Table 11.3.11 Low-Income Consumers – LCC and PBP Results for Medium Energy, Low Voltage Battery Chargers (PC5)

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
		Avg. Installed Price	**Avg. Operating Cost**	**Avg. LCC**	**Wtd. Avg. Savings**	**Consumers with**			
CSL	**UEC**					**Net Cost**	**No Impact**	**Net Benefit**	**Median**
	kWh	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	84.6	46.61	54.30	100.90	-	-	-	-	-
1	56.1	51.40	35.80	87.21	9.47	1.7	72.0	26.4	1.8
2	29.3	39.57	18.56	58.12	33.26	0.0	20.1	79.9	0.0
3	15.4	207.82	9.45	217.27	-105.27	78.9	13.0	8.1	54.5

Table 11.3.12 Low-Income Consumers – LCC and PBP Results for Medium Energy, High Voltage Battery Chargers (PC6)

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
		Avg. Installed Price	**Avg. Operating Cost**	**Avg. LCC**	**Wtd. Avg. Savings**	**Consumers with**			
CSL	**UEC**					**Net Cost**	**No Impact**	**Net Benefit**	**Median**
	kWh	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	120.6	45.37	95.27	140.64	-	-	-	-	-
1	81.7	50.13	65.30	115.42	9.72	0.0	64.6	35.4	1.3
2	38.3	38.52	29.93	68.44	40.06	0.0	35.2	64.8	0.0
3	16.8	205.10	10.39	215.49	-87.83	85.6	13.0	1.5	21.2

Table 11.3.13 Low-Income Consumers – LCC and PBP Results for High Energy Battery Chargers (PC7)

		Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
		Avg. Installed Price	**Avg. Operating Cost**	**Avg. LCC**	**Wtd. Avg. Savings**	**Consumers with**			
CSL	**UEC**					**Net Cost**	**No Impact**	**Net Benefit**	**Median**
	kWh	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	255.0	222.08	46.81	268.89	-	-	-	-	-
1	191.7	153.47	25.34	178.81	39.20	0.0	56.5	43.5	0.0
2	136.8	335.09	18.45	353.54	-135.53	100.0	0.0	0.0	126.6

Table 11.3.14 Low-Income Consumers – LCC and PBP Results for DC-DC, <9V Input Battery Chargers (PC8)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	1.0	13.40	0.36	13.76	-	-	-	-	-
1	0.7	7.40	0.27	7.67	3.05	0.0	50.0	50.0	0.0
2	0.3	13.11	0.10	13.20	-1.93	40.0	10.0	50.0	0.0
3	0.2	13.48	0.07	13.55	-2.29	55.5	0.0	44.5	26.6

Table 11.3.15 Low-Income Consumers – LCC and PBP Results for DC-DC, ≥9V Input Battery Chargers (PC9)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	0.8	5.41	1.54	6.95	-	-	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	24.8	74.8	0.4	7.2
2	0.1	7.36	0.26	7.62	-0.25	74.3	24.9	0.8	8.8

Table 11.3.16 Low-Income Consumers – LCC and PBP Results for Low Energy, AC Out Battery Chargers (PC10)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	19.3	5.94	13.02	18.95	-	-	-	-	-
1	6.1	7.63	4.14	11.77	6.24	0.0	13.0	87.0	1.3
2	4.0	8.09	2.72	10.81	7.08	0.0	13.0	87.0	1.4
3	1.5	8.65	1.01	9.66	8.08	0.0	13.0	87.0	1.5

11.3.2 Small Business Consumers

The results for the LCC and PBP subgroup analyses for small business consumers are shown in Table 11.3.17 through Table 11.3.20 for Direct Operation EPSs and Table 11.3.21 through Table 11.3.26 for BCs. DOE did not identify any commercial applications for Non-Class A EPSs or BC product classes PC1, PC5, PC6, or PC9, so it did not perform a small business consumer subgroup analysis for these product classes.

The small business consumer subgroup LCC results are not directly comparable to the reference case LCC results because this subgroup only considers commercial applications. In the reference case scenario, the LCC results are strongly influenced by the presence of residential applications, which typically compose the majority of application shipments. For Direct Operation EPSs, the LCC savings for the 2.5W representative unit go negative at CSL 3 and 4 under the small business scenario (reflecting a change in LCC savings of $0.08 and $0.10, respectively), but none of the other representative units change from positive to negative, or vice versa. Similarly, none of the BC product classes that were positive in the reference case went negative in the small business subgroup analysis, or vice versa. This indicates that small business consumers would experience similar LCC impacts as the general population.

11.3.2.1 Non-Class A External Power Supplies

DOE did not identify any commercial applications for the Non-Class A EPS product classes. Since the small business consumer subgroup exclusively considers commercial customers, DOE does not present any LCC results for Non-Class A EPSs in this consumer subgroup.

11.3.2.2 Direct Operation External Power Supplies

Table 11.3.17 Small Business Consumers – LCC and PBP Results for 2.5W Regular AC/DC External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	58.3	0.500	0.00	1.40	1.40	-	-	-	-	-
1	67.9	0.300	0.22	0.91	1.13	0.12	7.4	54.9	37.7	1.7
2	71.0	0.130	0.49	0.74	1.23	0.03	51.6	6.8	41.6	4.4
3	73.5	0.100	0.65	0.65	1.30	-0.04	60.9	1.4	37.7	5.0
4	74.8	0.039	0.76	0.59	1.34	-0.08	65.1	0.0	34.9	5.0

* “Eff.” stands for “efficiency level.”

† Based on an incremental MSP over the baseline.

Table 11.3.18 Small Business Consumers – LCC and PBP Results for 18W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
		No Load	Avg. Installed	Avg. Operating		Wtd. Avg.	Consumers with			
CSL	Eff.*	Power	Price†	Cost	Avg. LCC†	Savings	Net Cost	No Impact	Net Benefit	Median
	%	*W*	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	76.0	0.500	0.00	4.60	4.60	-	-	-	-	-
1	80.3	0.300	0.00	3.52	3.52	0.19	0.0	81.8	18.3	0.0
2	83.0	0.200	0.24	2.90	3.13	0.44	12.0	30.2	57.8	1.1
3	85.4	0.100	0.90	2.36	3.26	0.32	33.4	11.6	55.0	2.8
4	91.1	0.039	4.05	1.34	5.39	-1.81	91.9	0.0	8.1	6.9

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.19 Small Business Consumers – LCC and PBP Results for 60W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
		No Load	Avg. Installed	Avg. Operating		Wtd. Avg.	Consumers with			
CSL	Eff.*	Power	Price†	Cost	Avg. LCC†	Savings	Net Cost	No Impact	Net Benefit	Median
	%	*W*	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	85.0	0.500	0.00	3.39	3.39	-	-	-	-	-
1	87.0	0.500	0.00	2.98	2.98	0.10	0.0	75.8	24.2	0.0
2	87.0	0.200	1.15	2.56	3.71	-0.46	73.2	23.4	3.5	7.1
3	88.0	0.073	1.81	2.18	3.99	-0.73	94.8	1.8	3.4	6.0
4	92.2	0.050	3.83	1.36	5.19	-1.93	97.8	0.0	2.2	7.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.20 Small Business Consumers – LCC and PBP Results for 120W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
		No Load	Avg. Installed	Avg. Operating		Wtd. Avg.	Consumers with			
CSL	Eff.*	Power	Price†	Cost	Avg. LCC†	Savings	Net Cost	No Impact	Net Benefit	Median
	%	*W*	*2010$*	*2010$*	*2010$*	*2010$*	*%*	*%*	*%*	*yrs.*
0	85.0	0.500	0.00	5.72	5.72	-	-	-	-	-
1	87.0	0.500	0.00	4.96	4.96	0.20	0.0	74.2	25.8	0.0
2	88.0	0.230	0.44	4.19	4.63	0.46	0.0	21.2	78.8	1.4
3	88.4	0.210	0.63	4.01	4.64	0.45	12.6	3.0	84.3	2.0
4	93.5	0.089	8.98	2.09	11.06	-5.98	100.0	0.0	0.0	9.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

11.3.2.3 Battery Chargers

DOE did not identify any commercial applications for certain BC product classes. For these product classes, DOE does not present LCC results for the small business consumer subgroup. The BC product classes without commercial applications are PC1, PC5, PC6, and

PC9. The remaining product classes have LCC results for the small business consumer subgroup.

Table 11.3.21 Small Business Consumers – LCC and PBP Results for Low Energy, Low Voltage Battery Chargers (PC2)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	8.9	1.41	3.02	4.43	-	-	-	-	-
1	6.7	1.54	2.31	3.86	0.18	0.0	79.1	20.9	0.5
2	2.9	3.71	1.23	4.94	-0.18	27.6	57.1	15.4	4.4
3	1.0	6.31	0.37	6.68	-1.88	92.5	2.7	4.8	8.4
4	0.8	9.17	0.30	9.46	-4.66	99.6	0.0	0.4	15.4

Table 11.3.22 Small Business Consumers – LCC and PBP Results for Low Energy, Medium Voltage Battery Chargers (PC3)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	12.1	1.68	8.94	10.62	-	-	-	-	-
1	4.7	3.40	3.36	6.76	1.08	3.3	74.1	22.6	1.2
2	0.8	8.36	0.83	9.19	-0.85	55.3	20.7	24.1	4.7
3	0.8	8.41	0.68	9.09	-0.75	65.4	0.0	34.6	4.6

Table 11.3.23 Small Business Consumers – LCC and PBP Results for Low Energy, High Voltage Battery Chargers (PC4)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	37.8	7.87	10.90	18.77	-	-	-	-	-
1	9.9	12.05	2.91	14.96	0.06	1.1	95.7	3.2	2.3
2	4.6	20.43	1.47	21.90	-2.82	40.8	59.1	0.1	17.0
3	3.0	28.35	0.91	29.26	-10.18	100.0	0.0	0.0	34.8

Table 11.3.24 Small Business Consumers – LCC and PBP Results for High Energy Battery Chargers (PC7)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	255.0	222.08	71.80	293.89	-	-	-	-	-
1	191.7	153.47	54.48	207.94	37.40	0.0	56.5	43.5	0.0
2	136.8	335.09	38.84	373.93	-128.58	100.0	0.0	0.0	27.2

Table 11.3.25 Small Business Consumers – LCC and PBP Results for DC-DC, <9V Input Battery Chargers (PC8)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	1.0	13.28	0.20	13.49	-	-	-	-	-
1	0.7	7.34	0.15	7.49	3.00	0.0	50.0	50.0	0.0
2	0.3	12.99	0.05	13.05	-2.00	40.0	10.0	50.0	0.0
3	0.2	13.36	0.04	13.41	-2.36	52.1	0.0	47.9	10.9

Table 11.3.26 Small Business Consumers – LCC and PBP Results for Low Energy, AC Out Battery Chargers (PC10)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	19.3	5.94	8.74	14.67	-	-	-	-	-
1	6.1	7.63	2.78	10.41	3.71	0.0	13.0	87.0	1.5
2	4.0	8.09	1.83	9.91	4.14	0.0	13.0	87.0	1.7
3	1.5	8.65	0.68	9.33	4.65	0.0	13.0	87.0	1.8

11.3.3 Top Tier Marginal Electricity Price Consumers

The results for the LCC and PBP subgroup analyses for top tier marginal electricity price consumers are shown in Table 11.3.27 and Table 11.3.28 for Non-Class A EPSs, Table 11.3.29 through Table 11.3.32 for Direct Operation EPSs, and Table 11.3.33 through Table 11.3.42 for BCs.

Consumers in the top tier marginal electricity price bracket experience greater LCC savings than those in the reference case scenario. This is because these consumers pay more for their electricity than other consumers, and therefore experience greater savings when using products that are more energy efficient. This subgroup analysis changed many of the negative LCC savings results to positive LCC savings. Some product classes and representative units still have negative LCC savings, which indicates that these product classes have increasing installed costs (purchase price plus installation costs, which are assumed to be zero) at higher CSLs that cannot be overcome through operating cost savings using top tier marginal electricity prices.

11.3.3.1 Non-Class A External Power Supplies

Table 11.3.27 Top Tier Electricity Price – LCC and PBP Results for 203W Multiple-Voltage Non-Class A External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* %	No Load Power W	Avg. Installed Price† 2010$	Avg. Operating Cost 2010$	Avg. LCC† 2010$	Wtd. Avg. Savings 2010$	Net Cost %	No Impact %	Net Benefit %	Median yrs.
0	82.4	12.330	0.00	169.82	169.82	-	-	-	-	-
1	86.4	0.400	3.81	45.60	49.40	6.02	0.0	95.0	5.0	0.1
2	86.4	0.300	4.12	44.68	48.80	6.62	0.0	0.0	100.0	1.5
3	88.5	0.300	11.97	37.20	49.17	6.25	33.8	0.0	66.2	4.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.28 Top Tier Electricity Price – LCC and PBP Results for 345W High-Power Non-Class A External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* %	No Load Power W	Avg. Installed Price 2010$	Avg. Operating Cost 2010$	Avg. LCC 2010$	Wtd. Avg. Savings 2010$	Net Cost %	No Impact %	Net Benefit %	Median yrs.
0	62.4	15.430	176.82	585.21	762.04	-	-	-	-	-
1	81.3	6.010	139.30	224.84	364.14	199.20	0.0	50.0	50.0	0.0
2	84.6	0.500	139.30	110.69	250.00	313.34	0.0	0.0	100.0	0.0
3	87.5	0.500	143.00	88.58	231.58	331.76	0.0	0.0	100.0	0.0
4	92.0	0.266	191.81	53.31	245.11	318.23	0.0	0.0	100.0	0.2

* "Eff." stands for "efficiency level."

11.3.3.2 Direct Operation External Power Supplies

Table 11.3.29 Top Tier Electricity Price – LCC and PBP Results for 2.5W Regular AC/DC External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	58.3	0.500	0.00	4.25	4.25	-	-	-	-	-
1	67.9	0.300	0.22	2.75	2.97	0.56	3.9	57.6	38.5	0.6
2	71.0	0.130	0.48	2.18	2.66	0.86	12.7	8.3	79.0	1.4
3	73.5	0.100	0.65	1.89	2.54	0.97	14.9	2.4	82.8	1.7
4	74.8	0.039	0.75	1.69	2.44	1.08	15.3	0.0	84.8	1.7

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.30 Top Tier Electricity Price – LCC and PBP Results for 18W Regular AC/DC External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	76.0	0.500	0.00	15.86	15.86	-	-	-	-	-
1	80.3	0.300	0.00	12.10	12.10	0.77	0.0	80.5	19.6	0.0
2	83.0	0.200	0.24	9.96	10.20	2.14	12.8	28.5	58.7	0.4
3	85.4	0.100	0.90	8.12	9.02	3.19	21.3	10.2	68.4	1.2
4	91.1	0.039	4.06	4.61	8.67	3.54	41.5	0.0	58.5	3.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.31 Top Tier Electricity Price – LCC and PBP Results for 60W Regular AC/DC External Power Supplies

			Life-Cycle Cost			**Life-Cycle Cost Savings**				**Payback Period**
							Consumers with			
CSL	**Eff.*** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	85.0	0.500	0.00	12.70	12.70	-	-	-	-	-
1	87.0	0.500	0.00	11.19	11.19	0.24	0.0	81.4	18.7	0.0
2	87.0	0.200	1.19	9.47	10.65	0.73	18.1	18.0	63.9	2.1
3	88.0	0.073	1.86	8.01	9.87	1.51	4.3	1.3	94.4	1.9
4	92.2	0.050	3.93	5.00	8.93	2.45	10.5	0.0	89.5	2.2

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

Table 11.3.32 Top Tier Electricity Price – LCC and PBP Results for 120W Regular AC/DC External Power Supplies

			Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
							Consumers with			
CSL	Eff.* *%*	No Load Power *W*	Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	85.0	0.500	0.00	16.94	16.94	-	-	-	-	-
1	87.0	0.500	0.00	14.69	14.69	0.58	0.0	74.2	25.8	0.0
2	88.0	0.230	0.44	12.39	12.82	2.05	0.0	21.2	78.8	0.5
3	88.4	0.210	0.63	11.85	12.48	2.38	0.1	3.0	96.9	0.6
4	93.5	0.089	8.98	6.16	15.14	-0.28	57.6	0.0	42.4	3.8

* "Eff." stands for "efficiency level."

† Based on an incremental MSP over the baseline.

11.3.3.3 Battery Chargers

Table 11.3.33 Top Tier Electricity Price – LCC and PBP Results for Low Energy, Inductive Battery Chargers (PC1)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	8.7	4.39	12.00	16.39	-	-	-	-	-
1	6.1	4.72	8.39	13.11	2.55	0.0	22.2	77.8	0.4
2	3.0	5.38	4.18	9.56	5.71	0.0	11.1	88.9	0.5
3	1.3	10.63	1.77	12.40	2.86	13.1	0.0	86.9	2.7

Table 11.3.34 Top Tier Electricity Price – LCC and PBP Results for Low Energy, Low Voltage Battery Chargers (PC2)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	UEC *kWh*	Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Net Cost *%*	No Impact *%*	Net Benefit *%*	Median *yrs.*
0	8.9	1.42	8.43	9.84	-	-	-	-	-
1	6.7	1.55	6.37	7.92	0.46	0.0	82.0	18.0	0.2
2	2.9	3.68	3.17	6.86	1.13	12.9	60.1	26.9	1.8
3	1.0	6.25	0.91	7.17	0.83	69.3	2.9	27.8	3.0
4	0.8	9.07	0.67	9.74	-1.75	81.3	0.0	18.7	6.0

Table 11.3.35 Top Tier Electricity Price – LCC and PBP Results for Low Energy, Medium Voltage Battery Chargers (PC3)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	12.1	1.79	16.31	18.09	-	-	-	-	-
1	4.7	3.51	6.46	9.98	1.47	6.5	82.8	10.6	1.4
2	0.8	8.51	1.07	9.58	1.60	54.9	20.9	24.3	7.1
3	0.8	8.56	1.02	9.58	1.60	71.6	0.0	28.4	7.2

Table 11.3.36 Top Tier Electricity Price – LCC and PBP Results for Low Energy, High Voltage Battery Chargers (PC4)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	37.8	8.04	36.36	44.40	-	-	-	-	-
1	9.9	12.24	9.46	21.70	1.83	0.2	90.7	9.1	1.0
2	4.6	20.65	4.23	24.89	0.22	35.4	51.5	13.2	6.4
3	3.0	28.61	2.84	31.45	-6.34	96.1	0.0	3.9	14.7

Table 11.3.37 Top Tier Electricity Price – LCC and PBP Results for Medium Energy, Low Voltage Battery Chargers (PC5)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	84.6	46.61	153.47	200.08	-	-	-	-	-
1	56.1	51.40	101.12	152.52	29.35	0.0	72.0	28.1	0.9
2	29.3	39.57	52.49	92.06	79.29	0.0	20.1	79.9	0.0
3	15.4	207.82	26.57	234.39	-44.77	72.8	13.0	14.2	21.3

Table 11.3.38 Top Tier Electricity Price – LCC and PBP Results for Medium Energy, High Voltage Battery Chargers (PC6)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	120.6	45.37	270.24	315.61	-	-	-	-	-
1	81.7	50.13	185.20	235.33	30.62	0.0	64.6	35.4	0.4
2	38.3	38.52	84.89	123.41	102.95	0.0	35.2	64.8	0.0
3	16.8	205.10	29.46	234.57	6.30	43.9	13.0	43.2	6.7

Table 11.3.39 Top Tier Electricity Price – LCC and PBP Results for High Energy Battery Chargers (PC7)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	255.0	222.08	176.44	398.53	-	-	-	-	-
1	191.7	153.47	130.78	284.25	49.74	0.0	56.5	43.5	0.0
2	136.8	335.09	93.36	428.44	-94.46	100.0	0.0	0.0	13.6

Table 11.3.40 Top Tier Electricity Price – LCC and PBP Results for DC-DC, <9V Input Battery Chargers (PC8)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	1.0	13.40	1.01	14.41	-	-	-	-	-
1	0.7	7.40	0.74	8.15	3.13	0.0	50.0	50.0	0.0
2	0.3	13.10	0.27	13.37	-1.57	40.0	10.0	50.0	0.0
3	0.2	13.48	0.21	13.68	-1.89	51.4	0.0	48.6	8.1

Table 11.3.41 Top Tier Electricity Price – LCC and PBP Results for DC-DC, ≥9V Input Battery Chargers (PC9)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	0.8	5.41	1.54	6.95	-	-	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	24.8	74.8	0.4	7.2
2	0.1	7.36	0.26	7.62	-0.25	74.3	24.9	0.8	8.8

Table 11.3.42 Top Tier Electricity Price – LCC and PBP Results for Low Energy, AC Out Battery Chargers (PC10)

		Life-Cycle Cost			Life-Cycle Cost Savings				Payback Period
						Consumers with			
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Net Cost** *%*	**No Impact** *%*	**Net Benefit** *%*	**Median** *yrs.*
0	19.3	5.94	36.93	42.86	-	-	-	-	-
1	6.1	7.63	11.75	19.38	20.43	0.0	13.0	87.0	0.4
2	4.0	8.09	7.72	15.81	23.53	0.0	13.0	87.0	0.4
3	1.5	8.65	2.85	11.51	27.27	0.0	13.0	87.0	0.5

11.3.4 Consumers of Specific Applications

The results for the LCC and PBP subgroup analyses for individual applications within a representative unit or product class are shown in Table 11.3.43 and Table 11.3.44 for Non-Class A EPSs, Table 11.3.45 through Table 11.3.48 for Direct Operation EPSs, and Table 11.3.49 through Table 11.3.58 for BCs. The LCC savings at each considered standard level for each application are presented in Figure 11.3.1 and Figure 11.3.2 for Non-Class A EPSs, Figure 11.3.3 through Figure 11.3.6 for Direct Operation EPSs, and Figure 11.3.7 through Figure 11.3.16 for BCs. DOE presents results for each application within a given representative unit and product class. For representative units and product classes where only one application exists, the application-specific results equal the shipment-weighted results.

11.3.4.1 Non-Class A External Power Supplies

The application-specific results for Non-Class A EPSs equal the shipment-weighted average results for the product classes because DOE only considered one application in each product class.

Table 11.3.43 Specific Applications – LCC and PBP Results for 203W Multiple-Voltage Non-Class A External Power Supplies

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Video Game Consoles	7,676,532	100.0	2.03	2.04	(3.14)	N/A
Shipment-Weighted Avg.	**7,676,532**	**100.0**	**2.03**	**2.04**	**(3.14)**	**N/A**

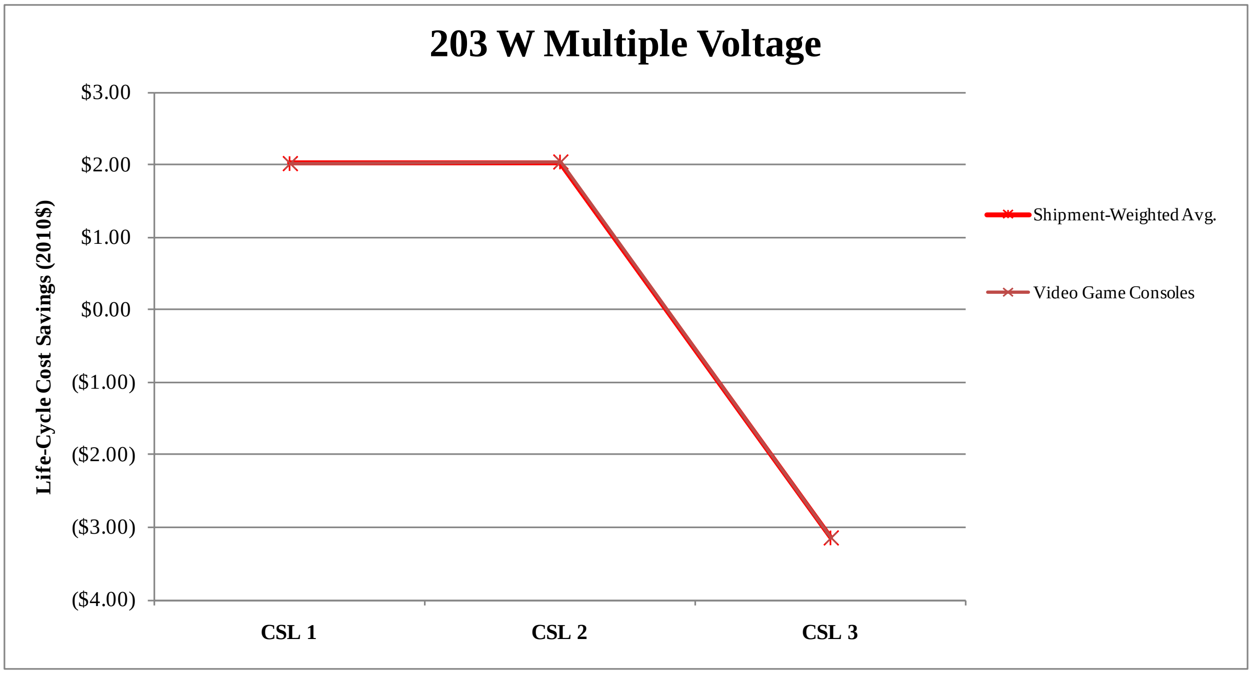


Figure 11.3.1 Specific Applications – LCC Savings for 203W Multiple-Voltage Non-Class A External Power Supplies

Table 11.3.44 Specific Applications – LCC and PBP Results for 345W High-Power Non-Class A External Power Supplies

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Amateur Radios	3,000	100.0	82.01	122.06	126.12	89.67
Shipment-Weighted Avg.	**3,000**	**100.0**	**82.01**	**122.06**	**126.12**	**89.67**

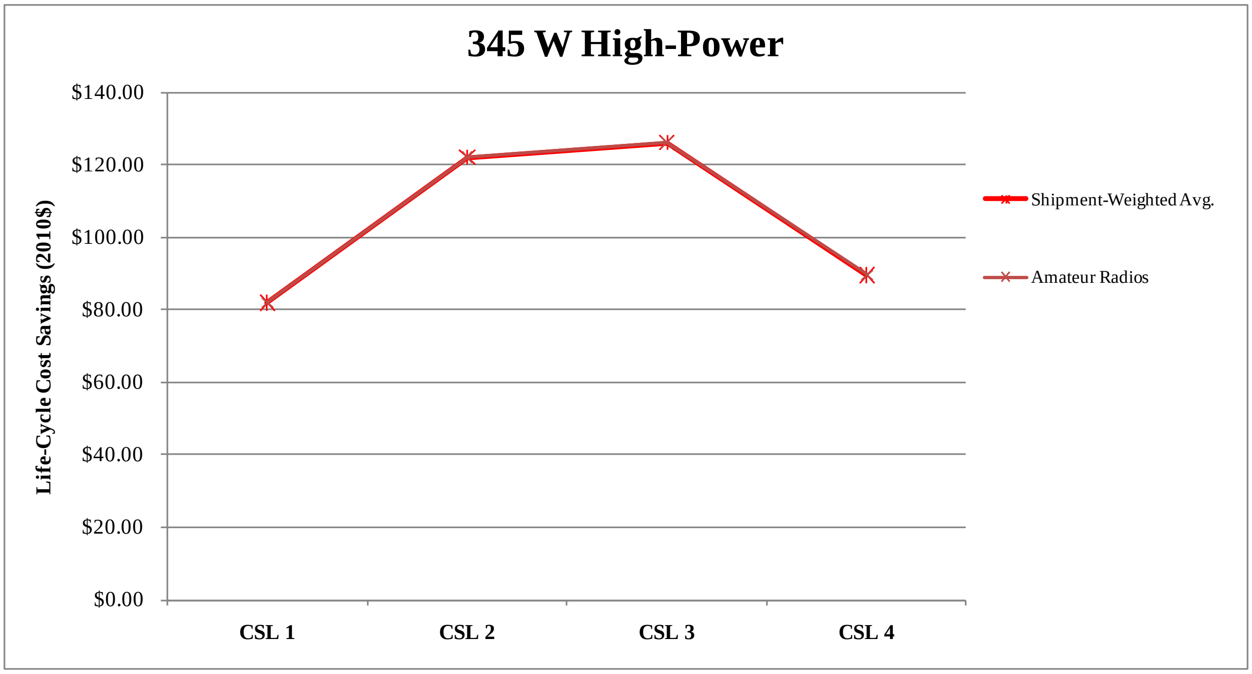


Figure 11.3.2 Specific Applications – LCC Savings for 345W Multiple-Voltage Non-Class A External Power Supplies

11.3.4.2 Direct Operation External Power Supplies

The application-specific results for Direct Operation EPSs identify several differences between applications within the four representative units. The 2.5W representative unit has positive LCC savings for each CSL, but some applications such as beard and moustache trimmers, guitar effects pedals, hair clippers, and other infrequently charged applications experience negative LCC savings. Similarly, the 18W representative unit has positive LCC savings through CSL 3, but applications like MP3 speaker docks, portable DVD players, and camcorders have negative savings. For the 60W representative unit, all applications follow the shipment-weighted average trends, except sleep apnea machines, which have positive LCC savings at each CSL. The same is true for the 120W representative unit, except for the portable O2 concentrator application, which has negative LCC results for CSLs 2 through 4.

Table 11.3.45 Specific Applications – LCC and PBP Results for 2.5W Regular AC/DC External Power Supplies

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings *[2010$]***			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Answering Machines	16,919,000	25.2	0.26	0.23	0.23	0.21
Cordless Phones	13,229,000	19.7	0.27	0.24	0.23	0.21
Mobile Phones	9,423,900	14.0	0.06	(0.01)	(0.12)	(0.15)
Portable Video Game Systems	6,481,903	9.7	0.05	0.06	(0.06)	(0.06)
Beard and Moustache Trimmers	5,287,500	7.9	(0.05)	(0.24)	(0.38)	(0.46)
Smartphone	4,116,300	6.1	0.05	(0.02)	(0.13)	(0.16)
Baby Monitors	3,400,000	5.1	0.15	0.18	0.13	0.13
Shavers	2,164,000	3.2	0.07	0.06	(0.01)	(0.03)
Guitar Effects Pedals	1,533,680	2.3	(0.04)	(0.24)	(0.37)	(0.45)
Hair Clippers	1,137,726	1.7	(0.05)	(0.24)	(0.37)	(0.46)
Clock Radios	748,818	1.1	0.42	0.53	0.65	0.70
Consumer Two-Way Radios	1,104,000	1.6	0.08	0.08	(0.02)	(0.02)
Breast Pumps	550,000	0.8	(0.06)	(0.25)	(0.38)	(0.46)
Pre-Amps	519,635	0.8	0.26	0.65	0.63	0.78
Wireless Headphones	500,000	0.7	(0.08)	(0.30)	(0.45)	(0.54)
Shipment-Weighted Avg.	**67,115,462**	**100.0**	**0.15**	**0.10**	**0.04**	**0.01**

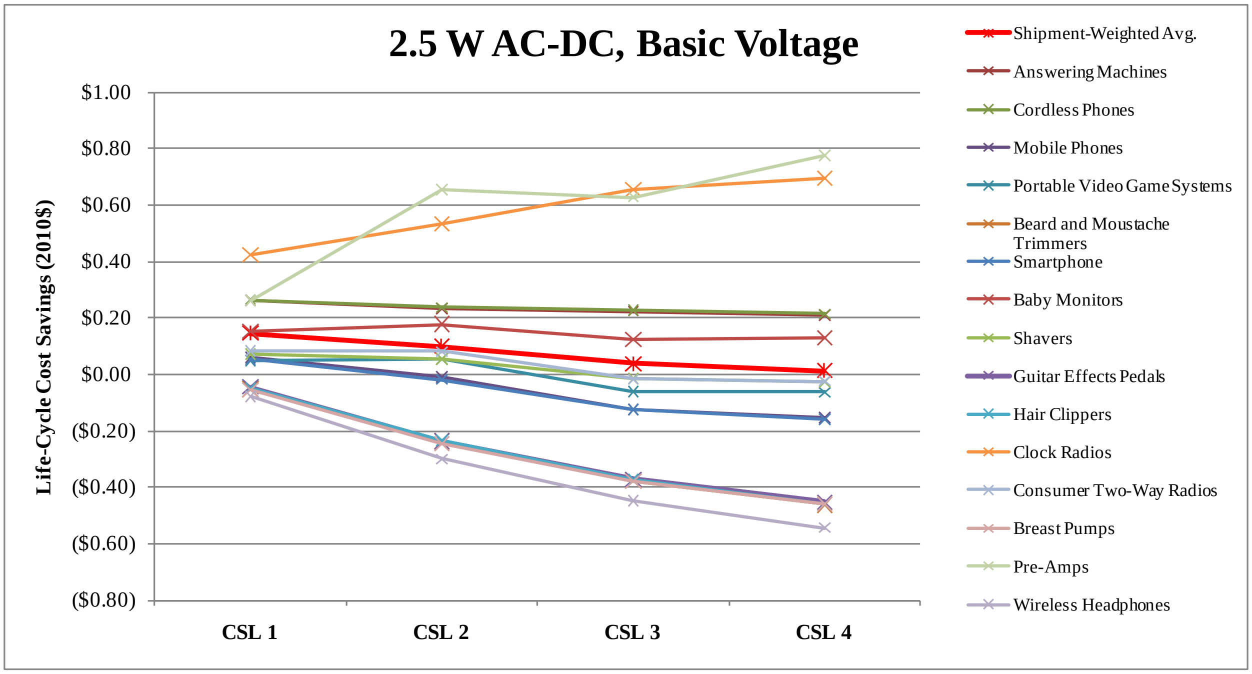


Figure 11.3.3 Specific Applications – LCC Savings for 2.5W Regular AC/DC Direct Operation External Power Supplies

Table 11.3.46 Specific Applications – LCC and PBP Results for 18W Regular AC/DC External Power Supplies

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings *[2010$]*			
			CSL1	**CSL2**	**CSL3**	**CSL4**
LAN Equipment	18,631,680	26.8	0.24	0.77	0.99	(0.14)
Digital Picture Frames	9,132,620	13.1	0.93	2.35	3.32	3.65
MP3 Speaker Docks	7,853,150	11.3	0.01	(0.15)	(0.78)	(3.95)
Media Tablets	7,002,693	10.1	0.12	0.17	(0.20)	(2.99)
VoIP Adapters	5,919,000	8.5	0.14	0.34	0.20	(2.51)
Portable DVD Players	3,702,700	5.3	0.04	(0.04)	(0.53)	(3.61)
Wireless Charging Stations	3,496,248	5.0	0.20	0.41	0.22	(2.37)
Computer Speakers	3,915,102	5.6	0.32	0.79	0.89	(1.01)
Image Scanners	3,138,394	4.5	0.17	0.31	0.05	(2.65)
Camcorders	1,566,750	2.3	0.01	(0.16)	(0.76)	(3.77)
Wireless Speakers	1,520,733	2.2	0.01	(0.14)	(0.74)	(3.84)
Medical Nebulizers	900,000	1.3	0.44	1.09	1.36	(0.82)
Clock Radios	748,818	1.1	1.03	2.34	3.12	3.06
Portable Printers	1,278,029	1.8	0.01	(0.16)	(0.77)	(3.89)
Sleep Apnea Machines	700,000	1.0	0.53	1.38	1.86	0.32
Shipment-Weighted Avg.	**69,505,916**	**100.0**	**0.27**	**0.66**	**0.67**	**(1.22)**

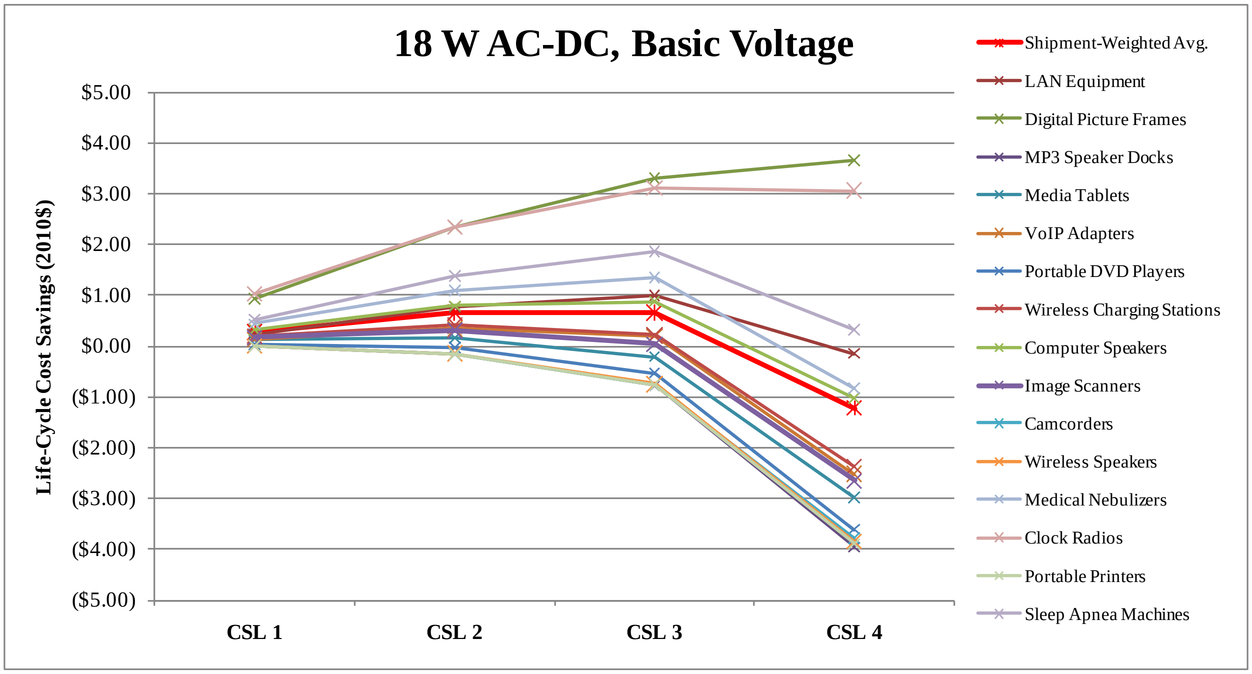


Figure 11.3.4 Specific Applications – LCC Savings for 18W Regular AC/DC Direct Operation External Power Supplies

Table 11.3.47 Specific Applications – LCC and PBP Results for 60W Regular AC/DC External Power Supplies

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings [2010$]			
			CSL1	CSL2	CSL3	CSL4
Notebooks	21,034,500	44.2	0.11	(0.38)	(0.59)	(1.72)
Video Game Consoles	11,514,798	24.2	0.04	(0.26)	(0.21)	(0.92)
Netbooks	8,675,700	18.2	0.08	(0.42)	(0.71)	(2.06)
Ink Jet Imaging Equipment	4,084,575	8.6	0.07	(0.26)	(0.23)	(0.59)
LED Monitors	1,949,400	4.1	0.21	(0.23)	(0.17)	(0.21)
Sleep Apnea Machines	300,000	0.6	0.47	0.37	1.19	3.24
Shipment-Weighted Avg.	**47,558,973**	**100.0**	**0.09**	**(0.34)**	**(0.46)**	**(1.40)**

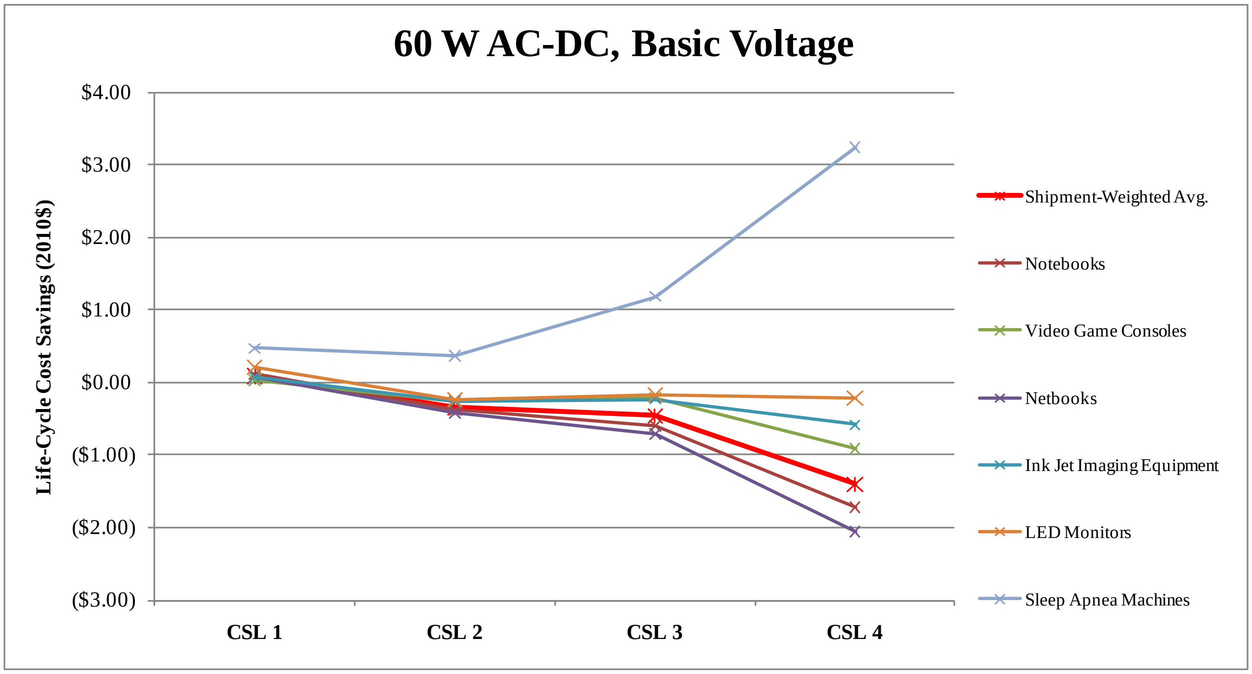


Figure 11.3.5 Specific Applications – LCC Savings for 60W Regular AC/DC Direct Operation External Power Supplies

Table 11.3.48 Specific Applications – LCC and PBP Results for 120W Regular AC/DC External Power Supplies

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings [2010$]			
			CSL1	CSL2	CSL3	CSL4
Notebooks	7,011,500	99.9	0.23	0.60	0.61	(5.50)
Portable O2 Concentrators	9,000	0.1	0.08	(0.21)	(0.37)	(9.19)
Shipment-Weighted Avg.	**7,020,500**	**100.0**	**0.23**	**0.60**	**0.61**	**(5.51)**

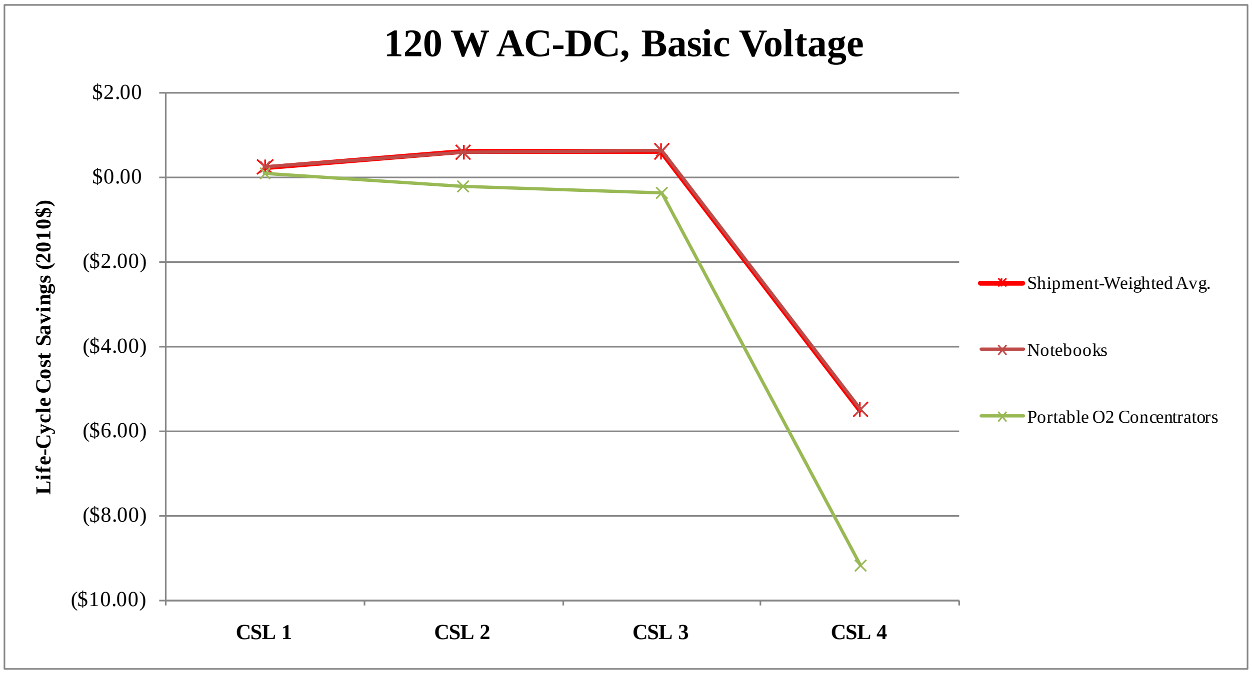


Figure 11.3.6 Specific Applications – LCC Savings for 120W Regular AC/DC Direct Operation External Power Supplies

11.3.4.3 Battery Chargers

The application-specific results for BCs identify several differences between applications within the 10 product classes. In general, DOE noted trends where less frequently used applications experienced lower LCC savings. For PC2, LCC savings is negative beyond CSL 1, but frequently used applications like answering machines, cordless phones, and home security systems experience positive LCC savings. In PC3, the top three applications (accounting for over 50 percent of total PC shipments) have negative LCC savings at all CSLs, contributing to the negative LCC savings of the product class average. However, some applications have starkly positive LCC savings, such as handheld vacuums, LAN equipment, stick vacuums, and universal battery chargers, which combine for 15 percent of the total shipments in PC3.

In PC4, notebooks and netbooks have no impacts at CSL 1 or CSL 2 because these products already use BC technology above the baseline efficiency level. LCC savings results vary within this product class, such as the LCC results at CSL 2, which vary from a cost of $7.21 (portable printers) to a savings of $2.67 (sleep apnea machines). Similarly, in PC5, mobility scooters and wheelchairs tend to benefit from higher standards much more than toy ride-on vehicles and marine/automotive/RV chargers.

PC9 shows a large divergence in LCC savings between applications, where in-vehicle GPSs lose $0.31 at CSL2, while flashlights/lanterns save $11.31 at the same CSL. In PC9, though, in-vehicle GPSs account for 99 percent of the shipment weighting, and thus their LCC results dominate the product class average. In the other BC product classes, the disparate applications tend to experience similar LCC savings with one another.

Table 11.3.49 Specific Applications – LCC and PBP Results for Low Energy, Inductive Battery Chargers (PC1)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Rechargeable Toothbrushes	15,000,000	99.3	0.75	1.50	(2.90)	N/A
Rechargeable Water Jets	100,000	0.7	0.75	1.50	(2.90)	N/A
Shipment-Weighted Avg.	**15,100,000**	**100.0**	**0.75**	**1.50**	**(2.90)**	**N/A**

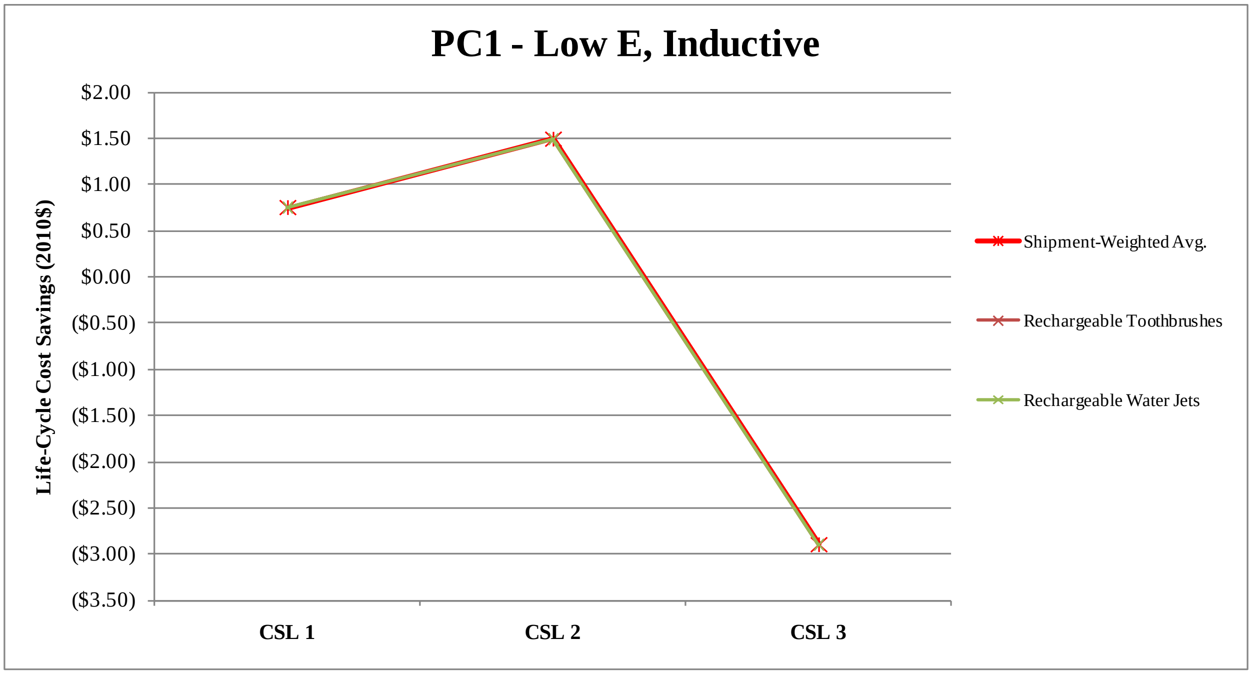


Figure 11.3.7 Specific Applications – LCC Savings for Low Energy, Inductive Battery Chargers (PC1)

Table 11.3.50 Specific Applications – LCC and PBP Results for Low Energy, Low Voltage Battery Chargers (PC2)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings *[2010$]***			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Mobile Phones	75,391,200	32.3	-	(0.34)	(2.44)	(5.35)
Smartphone	41,163,000	17.6	-	(0.33)	(2.36)	(5.27)
Digital Cameras	20,022,656	8.6	0.01	(0.86)	(2.84)	(5.37)
Answering Machines	16,919,000	7.2	0.80	1.17	0.75	(1.63)
Cordless Phones	10,980,070	4.7	0.84	1.30	0.96	(1.41)
Bluetooth Headsets	10,633,500	4.6	0.19	(0.24)	(1.62)	(4.40)
Portable Video Game Systems	10,386,000	4.4	0.16	(0.61)	(2.69)	(5.53)
Shavers	8,656,000	3.7	-	-	(0.97)	(3.27)
Consumer Two-Way Radios	11,040,000	4.7	0.20	(0.30)	(1.89)	(4.74)
Media Tablets	6,634,131	2.8	-	(0.35)	(2.22)	(4.74)
Video Game Consoles	4,501,670	1.9	0.02	(0.95)	(3.14)	(6.05)
Home Security Systems	4,219,178	1.8	0.83	3.30	3.96	1.92
MP3 Players	4,010,100	1.7	0.43	(0.14)	(1.80)	(4.40)
Baby Monitors	3,400,000	1.5	0.35	0.81	(0.09)	(2.49)
In-Vehicle GPS	3,161,250	1.4	0.01	(1.47)	(4.29)	(7.68)
Beard and Moustache Trimmers	2,350,000	1.0	0.02	(0.79)	(2.63)	(5.09)
Shipment-Weighted Avg.	**233,467,755**	**100.0**	**0.15**	**(0.13)**	**(1.83)**	**(4.58)**

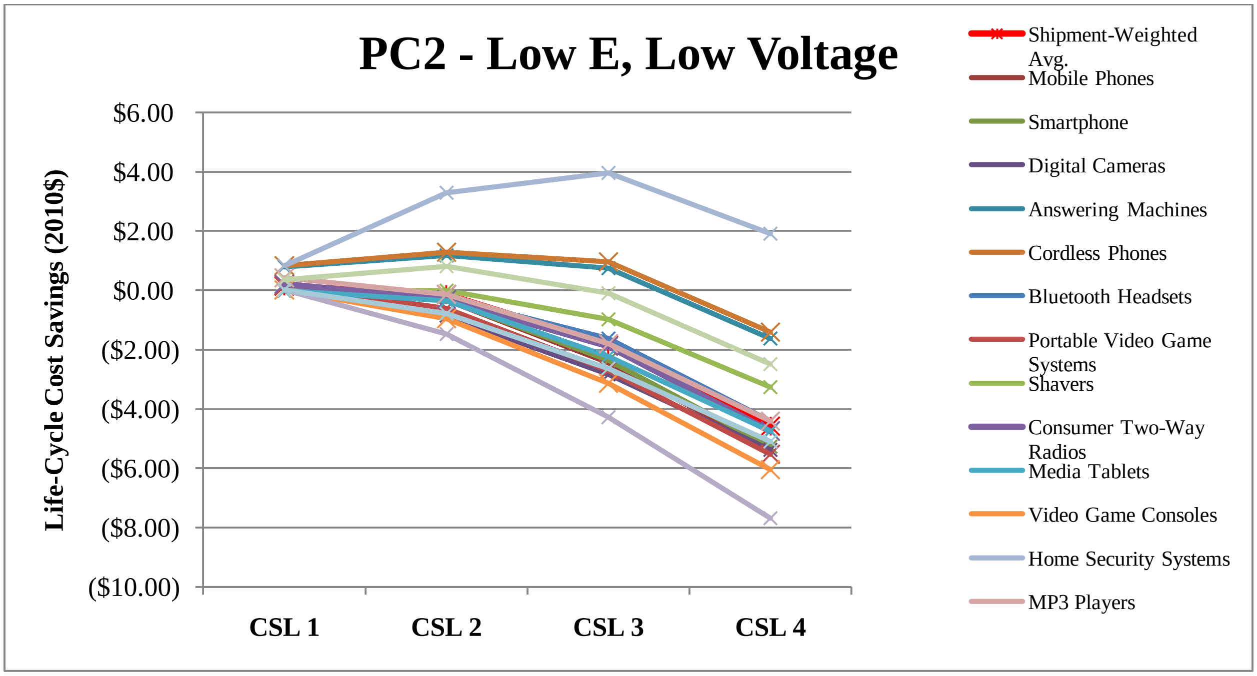


Figure 11.3.8 Specific Applications – LCC Savings for Low Energy, Low Voltage Battery Chargers (PC2)

Table 11.3.51 Specific Applications – LCC and PBP Results for Low Energy, Medium Voltage Battery Chargers (PC3)

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings *[2010$]*			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Camcorders	4,700,250	20.4	(0.25)	(3.89)	(3.93)	N/A
Toy Ride-On Vehicles	4,044,950	17.5	(0.03)	(3.44)	(3.49)	N/A
Portable DVD Players	3,702,700	16.1	-	(3.56)	(3.61)	N/A
DIY Power Tools (Integral)	2,337,500	10.1	0.98	0.31	0.27	N/A
RC Toys	2,100,000	9.1	(0.30)	(4.50)	(4.55)	N/A
DIY Power Tools (External)	1,753,125	7.6	0.83	(1.98)	(1.94)	N/A
Handheld Vacuums	1,320,000	5.7	1.76	3.86	3.85	N/A
LAN Equipment	1,282,450	5.6	1.37	1.72	1.67	N/A
Stick Vacuums	862,785	3.7	2.59	4.54	4.53	N/A
Air Mattress Pumps	250,000	1.1	(0.27)	(4.11)	(4.15)	N/A
Wireless Speakers	228,110	1.0	(0.21)	(3.87)	(3.90)	N/A
Portable Printers	239,630	1.0	(0.25)	(3.99)	(4.02)	N/A
Universal Battery Chargers	120,000	0.5	2.30	2.87	2.83	N/A
Blenders	61,250	0.3	(0.27)	(4.11)	(4.15)	N/A
Mixers	57,730	0.3	(0.45)	(2.94)	(2.97)	N/A
Shipment-Weighted Avg.	**23,060,480**	**100.0**	**0.35**	**(2.14)**	**(2.17)**	**N/A**

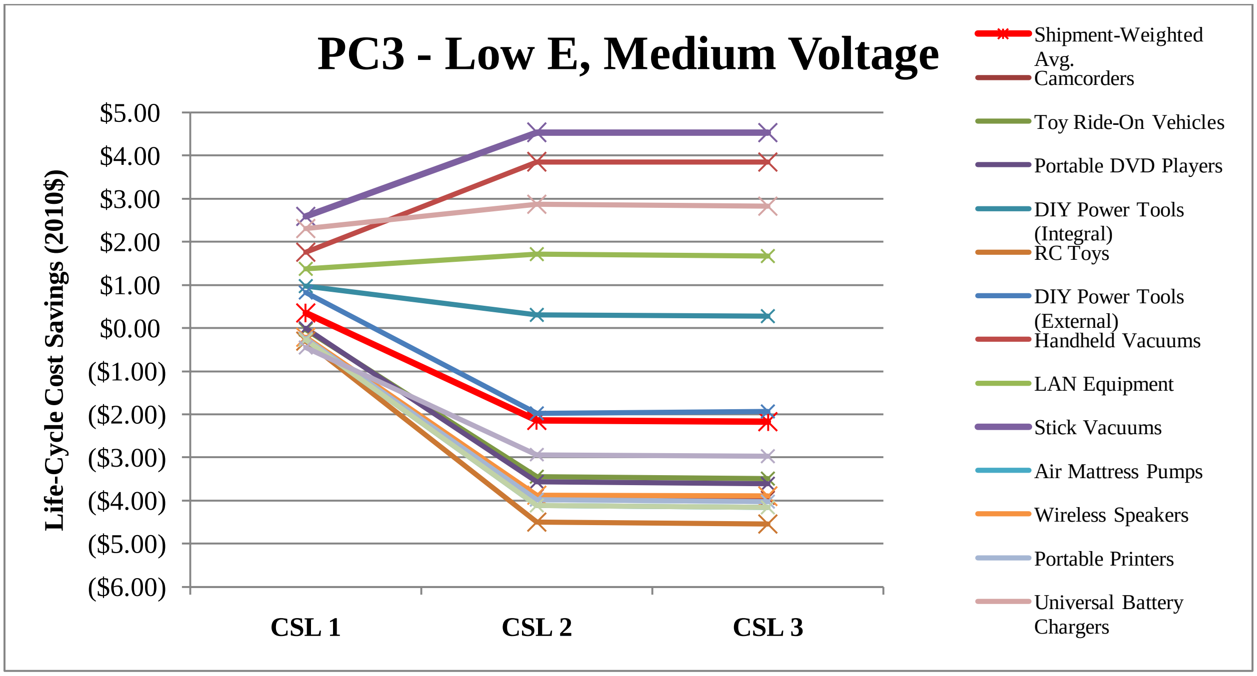


Figure 11.3.9 Specific Applications – LCC Savings for Low Energy, Medium Voltage Battery Chargers (PC3)

Table 11.3.52 Specific Applications – LCC and PBP Results for Low Energy, High Voltage Battery Chargers (PC4)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Notebooks	28,046,000	46.0	-	(2.02)	(9.37)	N/A
Professional Power Tools	11,687,500	19.2	0.06	(5.17)	(12.88)	N/A
Netbooks	8,675,700	14.2	-	(2.13)	(9.34)	N/A
DIY Power Tools (External)	5,259,375	8.6	0.38	(5.89)	(13.55)	N/A
Handheld Vacuums	2,680,000	4.4	2.70	(0.10)	(7.14)	N/A
Stick Vacuums	1,751,715	2.9	3.96	1.36	(5.68)	N/A
Robotic Vacuums	1,000,000	1.6	3.95	1.26	(5.51)	N/A
Sleep Apnea Machines	500,000	0.8	5.15	2.67	(5.44)	N/A
Medical Nebulizers	405,000	0.7	(0.63)	(6.89)	(15.57)	N/A
Portable Printers	718,891	1.2	(0.66)	(7.21)	(15.02)	N/A
Rechargeable Garden Care Products	91,500	0.2	0.15	(4.97)	(12.88)	N/A
Universal Battery Chargers	60,000	0.1	2.79	(0.07)	(7.70)	N/A
Flashlights/Lanterns	50,000	0.1	5.38	1.21	(6.31)	N/A
Shipment-Weighted Avg.	**60,925,681**	**100.0**	**0.38**	**(2.79)**	**(10.21)**	**N/A**

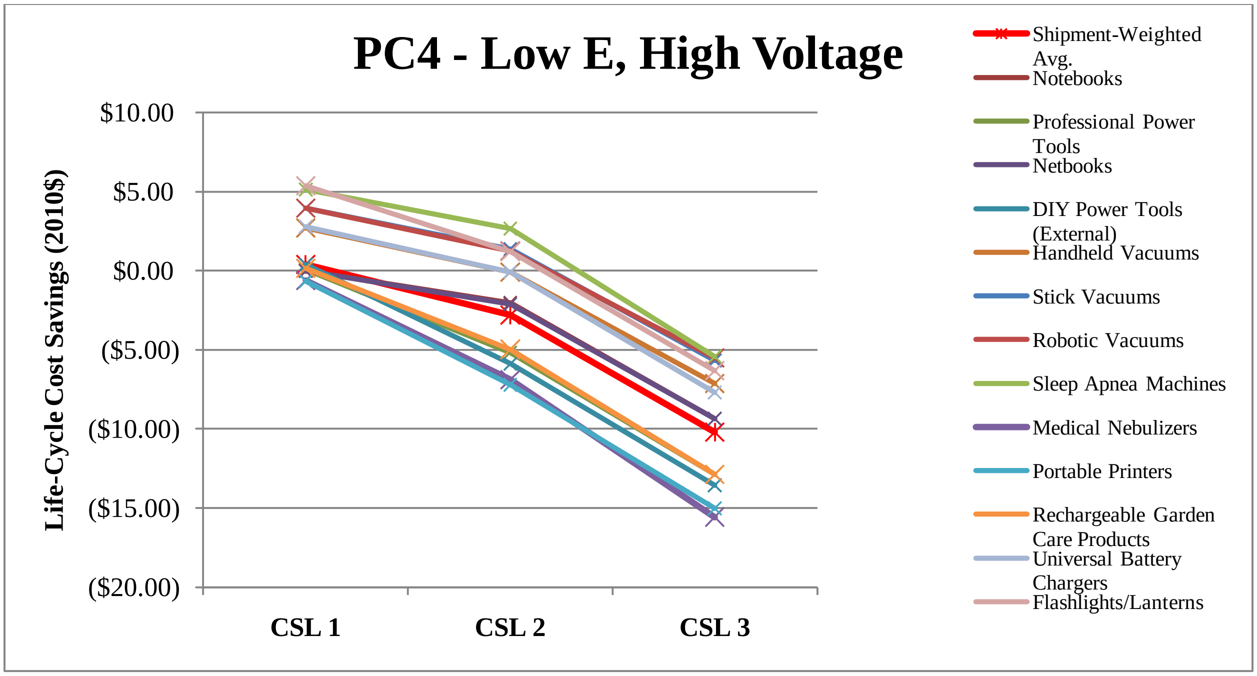


Figure 11.3.10 Specific Applications – LCC Savings for Low Energy, High Voltage Battery Chargers (PC4)

Table 11.3.53 Specific Applications – LCC and PBP Results for Medium Energy, Low Voltage Battery Chargers (PC5)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Toy Ride-On Vehicles	4,044,950	83.1	0.30	14.59	(129.19)	N/A
Marine/Automotive/RV Chargers	500,000	10.3	52.84	94.64	(2.54)	N/A
Mobility Scooters	192,274	4.0	60.46	178.25	42.69	N/A
Wheelchairs	124,543	2.6	60.46	178.25	42.69	N/A
Portable O2 Concentrators	4,500	0.1	2.94	34.40	(126.50)	N/A
Shipment-Weighted Avg.	**4,866,267**	**100.0**	**9.62**	**33.49**	**(104.98)**	**N/A**

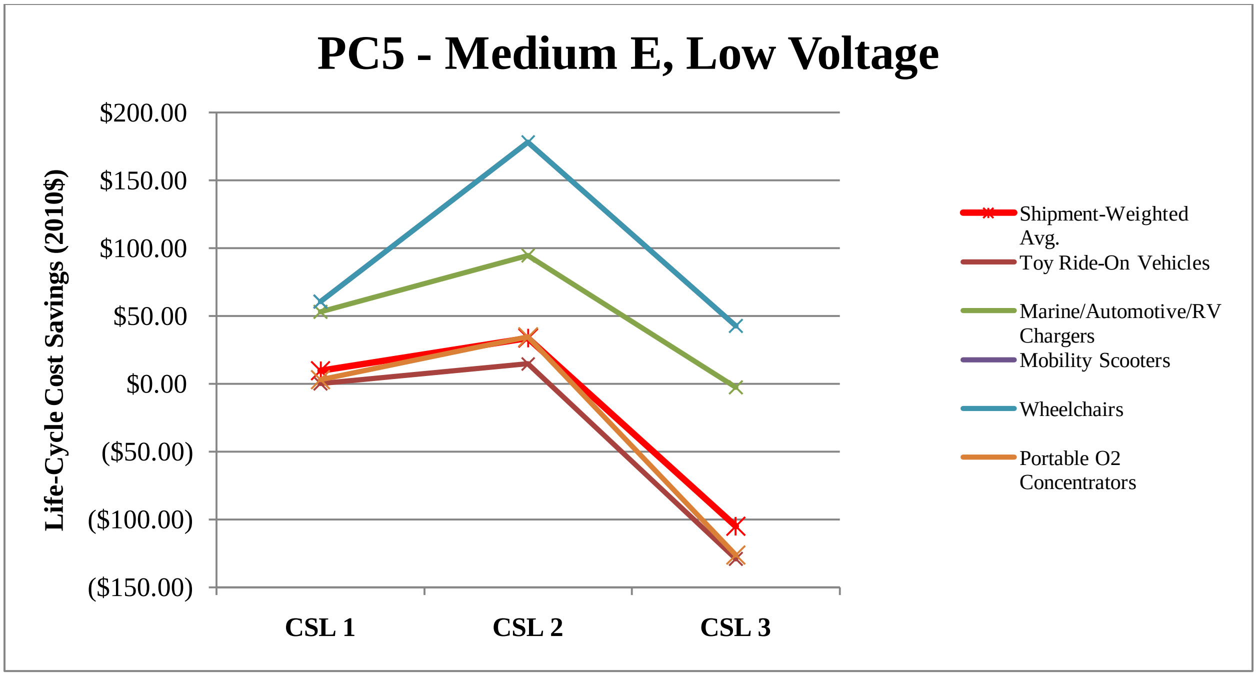


Figure 11.3.11 Specific Applications – LCC Savings for Medium Energy, Low Voltage Battery Chargers (PC5)

Table 11.3.54 Specific Applications – LCC and PBP Results for Medium Energy, High Voltage Battery Chargers (PC6)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
Electric Scooters	250,000	40.1	12.25	45.74	(83.07)	N/A
Lawn Mowers	182,143	29.2	1.78	17.81	(107.14)	N/A
Motorized Bicycles	150,000	24.1	12.25	45.74	(83.07)	N/A
Wheelchairs	41,514	6.7	19.78	82.45	(50.81)	N/A
Shipment-Weighted Avg.	**623,657**	**100.0**	**9.69**	**40.03**	**(87.95)**	**N/A**

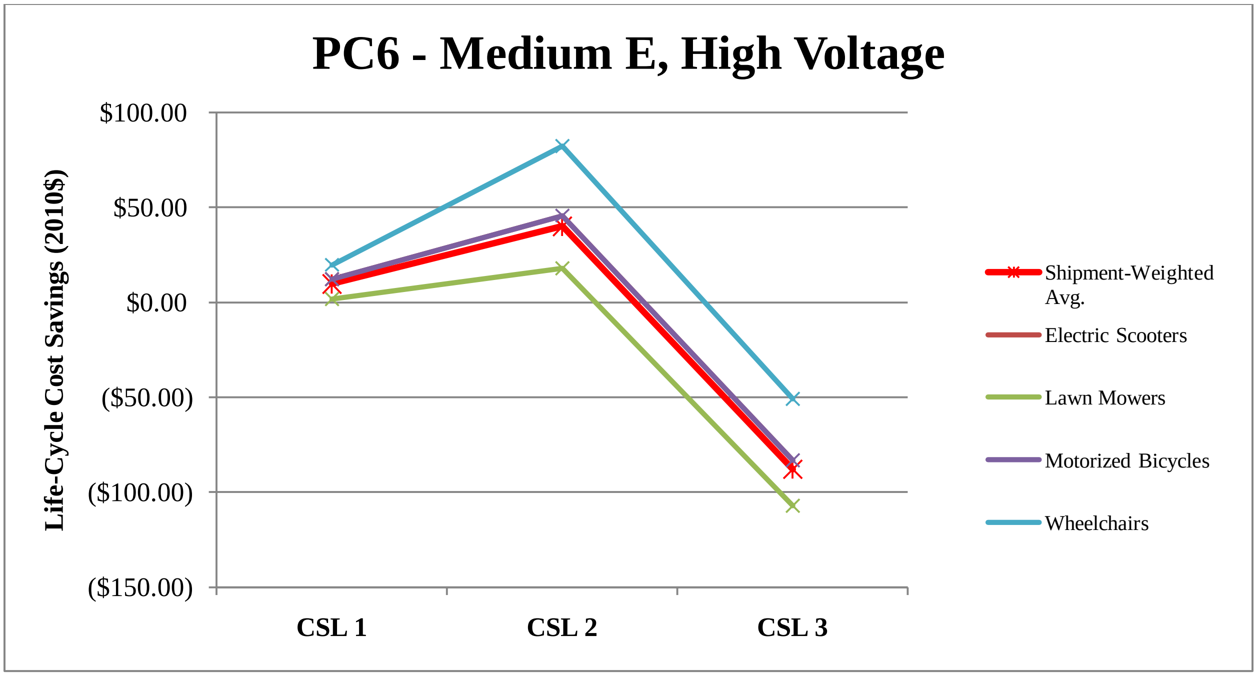


Figure 11.3.12 Specific Applications – LCC Savings for Medium Energy, High Voltage Battery Chargers (PC6)

Table 11.3.55 Specific Applications – LCC and PBP Results for High Energy Battery Chargers (PC7)

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings [*2010$*]			
			CSL1	CSL2	CSL3	CSL4
Golf Carts	210,620	100.0	38.22	(127.48)	N/A	N/A
Shipment-Weighted Avg.	**210,620**	**100.0**	**38.22**	**(127.48)**	**N/A**	**N/A**

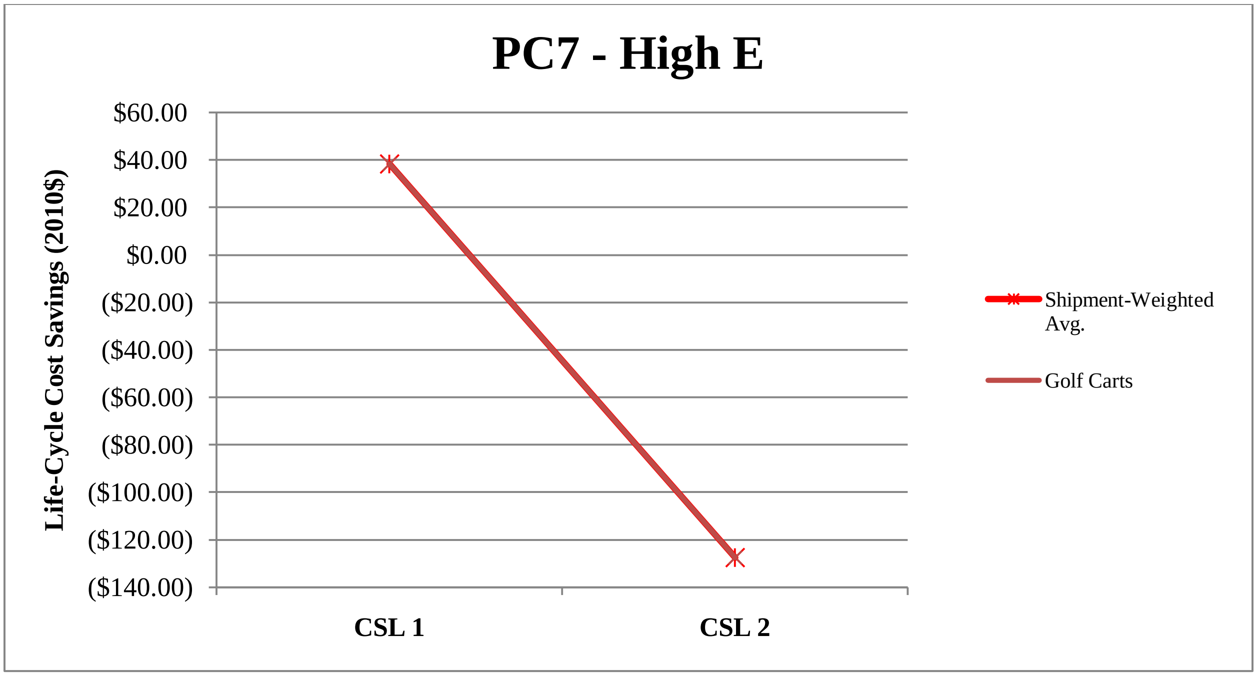


Figure 11.3.13 Specific Applications – LCC Savings for High Energy Battery Chargers (PC7)

Table 11.3.56 Specific Applications – LCC and PBP Results for DC-DC, <9V Input Battery Chargers (PC8)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings *[2010$]***			
			CSL1	**CSL2**	**CSL3**	**CSL4**
MP3 Players	36,090,900	55.3	3.04	(1.89)	(2.24)	N/A
Mobile Phones	18,847,800	28.9	3.06	(2.06)	(2.43)	N/A
Digital Cameras	5,269,120	8.1	3.04	(2.12)	(2.49)	N/A
Camcorders	1,566,750	2.4	3.03	(2.14)	(2.51)	N/A
Bluetooth Headsets	1,390,000	2.1	3.14	(1.71)	(2.03)	N/A
Personal Digital Assistants	1,575,000	2.4	2.70	(1.79)	(2.11)	N/A
E-Books	440,000	0.7	3.11	(2.06)	(2.42)	N/A
Handheld GPS	30,270	0.0	3.69	(2.60)	(3.06)	N/A
Shipment-Weighted Avg.	**65,209,840**	**100.0**	**3.04**	**(1.96)**	**(2.31)**	**N/A**

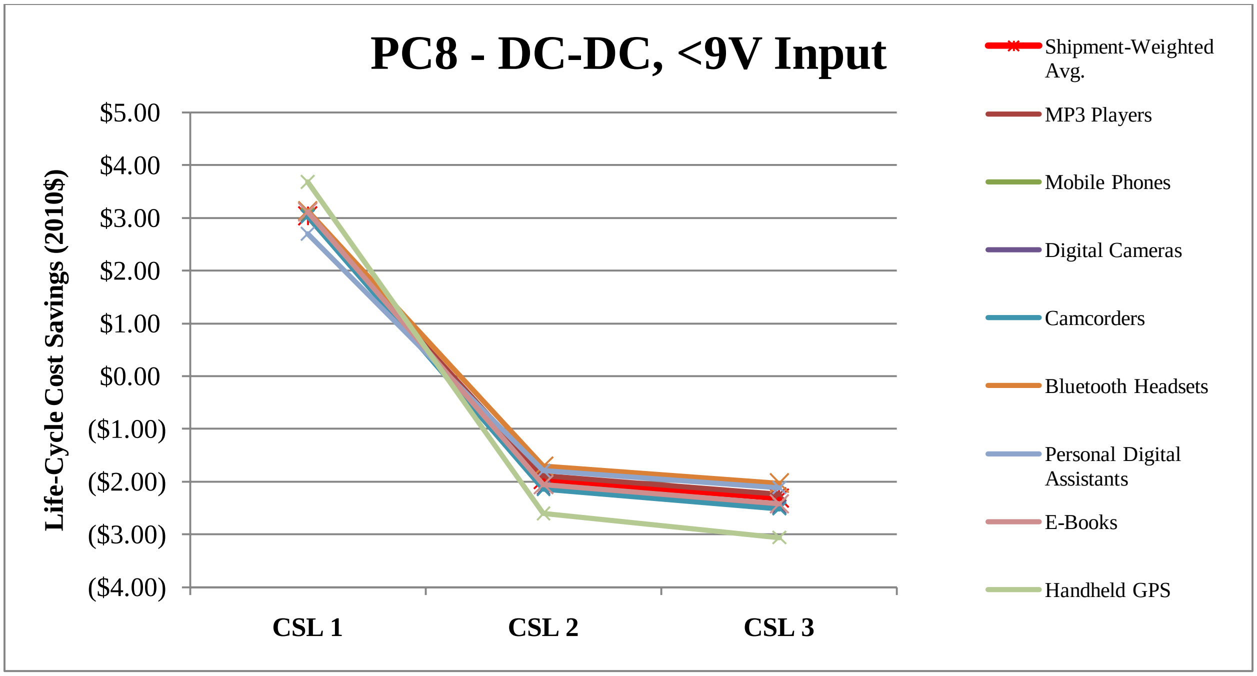


Figure 11.3.14 Specific Applications – LCC Savings for DC-DC, <9V Input Battery Chargers (PC8)

Table 11.3.57 Specific Applications – LCC and PBP Results for DC-DC, ≥9V Input Battery Chargers (PC9)

Application	**Shipments**	**Ship. Wgt. [%]**	**Weighted Average LCC Savings [*2010$*]**			
			CSL1	**CSL2**	**CSL3**	**CSL4**
In-Vehicle GPS	9,483,750	99.0	(0.14)	(0.31)	N/A	N/A
Flashlights/Lanterns	50,000	0.5	10.45	11.31	N/A	N/A
Medical Nebulizers	45,000	0.5	0.14	0.19	N/A	N/A
Portable O2 Concentrators	4,500	0.0	0.50	0.57	N/A	N/A
Shipment-Weighted Avg.	**9,583,250**	**100.0**	**(0.08)**	**(0.25)**	**N/A**	**N/A**

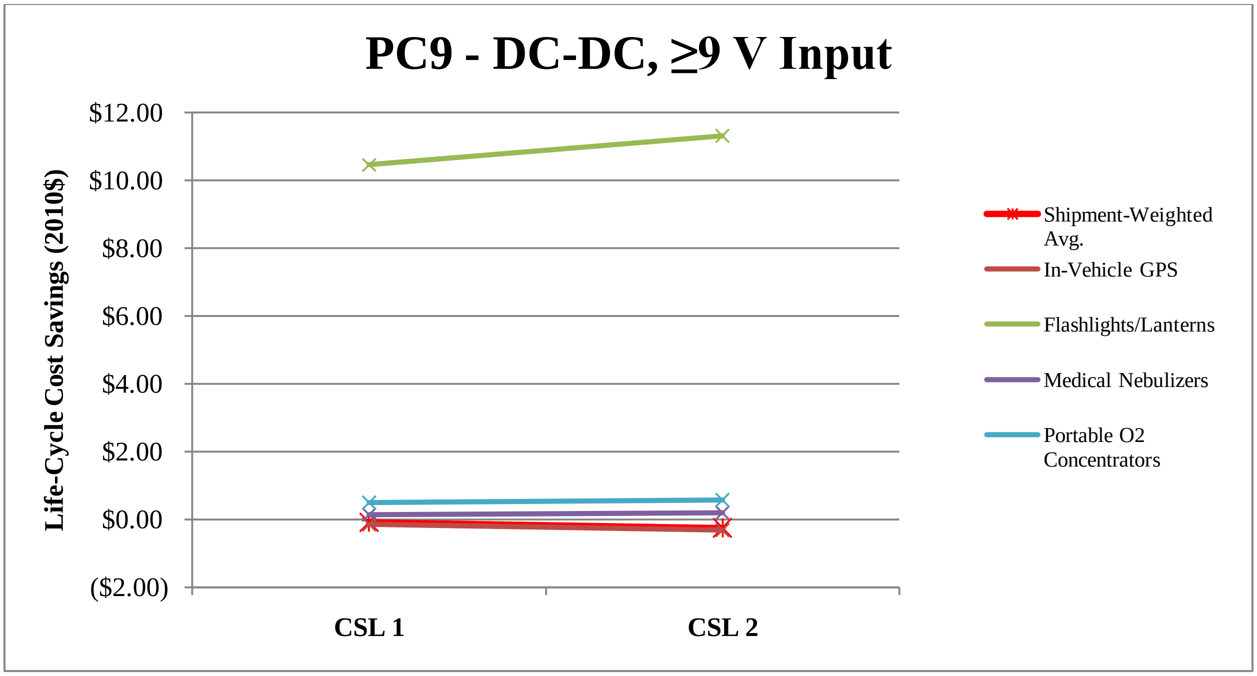


Figure 11.3.15 Specific Applications – LCC Savings for DC-DC, ≥9V Input Battery Chargers (PC9)

Table 11.3.58 Specific Applications – LCC and PBP Results for Low Energy, AC Out Battery Chargers (PC10)

Application	Shipments	Ship. Wgt. [%]	Weighted Average LCC Savings [*2010$*]			
			CSL1	CSL2	CSL3	CSL4
Uninterruptible Power Supplies	8,000,000	100.0	5.66	6.40	7.29	N/A
Shipment-Weighted Avg.	**8,000,000**	**100.0**	**5.66**	**6.40**	**7.29**	**N/A**

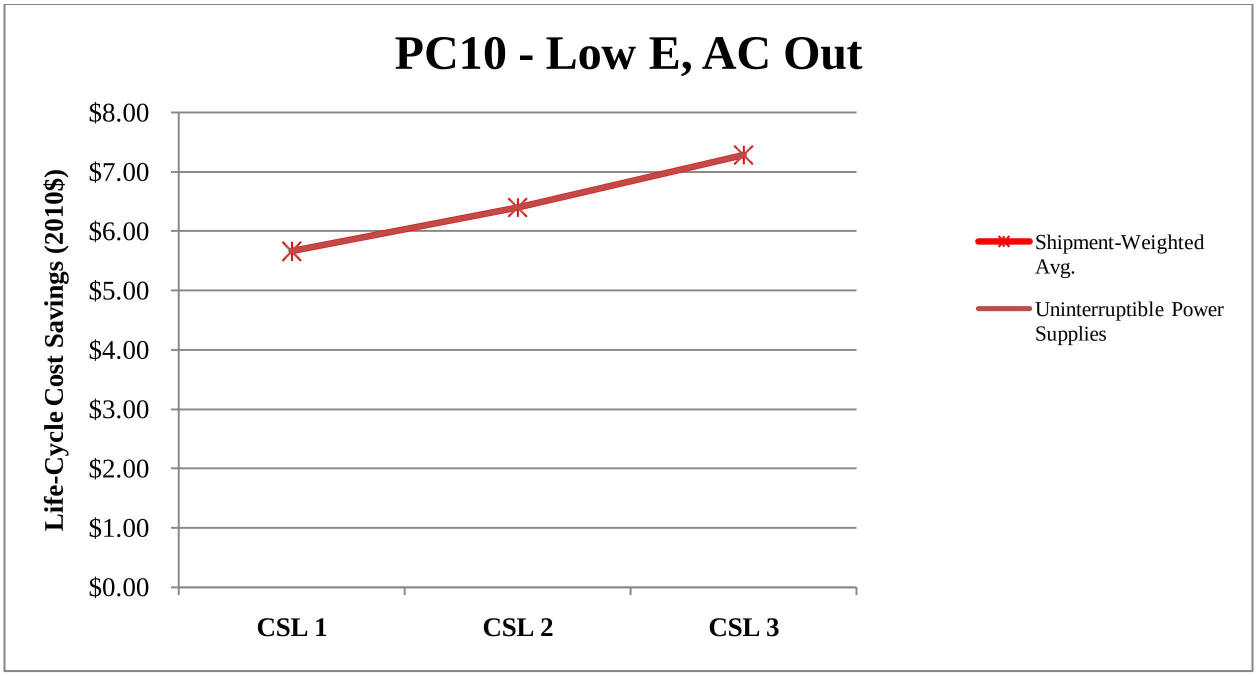


Figure 11.3.16 Specific Applications – LCC Savings for Low Energy, AC Out Battery Chargers (PC10)

REFERENCES

---

[i] U.S. Department of Energy-Energy Information Administration. *RECS Public Use Microdata Files, calendar year 2005*. 2010. Washington, DC.
<http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

[ii] Ibbotsons Associates. Stocks, Bonds, Bills, and Inflation 2007 Yearbook, 2007. Chicago, IL.

[iii] Southern California Edison. Billing and Payment. Understanding Tiered Rates.
http://www.sce.com/customerservice/billing/tiered-rates/

[iv] Pacific Gas & Electric. Electric Rates – Commercial June 2010, A-1 TOU, Summer On-Peak.
http://www.pge.com/tariffs/commercialcurrent.xls

[v] U.S. Census Bureau. *Poverty Thresholds 2005*. 2006. Washington, DC.
http://www.census.gov/hhes/www/poverty/threshld/thresh05.html

[vi] Damodaran Online. *The Data Page: Cost of Capital by Industry Sector*, 2006.
http://pages.stern.nyu.edu/~adamodar/

CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard." (42 U.S.C. 6313(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. *Id*. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of new and amended energy conservation standards on manufacturers of battery chargers (BCs) and external power supplies (EPSs), and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for each product in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of new and amended energy conservation standards for each product by comparing changes in INPV between a base case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE analyzed the impacts of new and amended energy conservation standards on BC and EPS manufacturers separately. For EPSs, DOE analyzed the industry impacts at the original device manufacturer (ODM) level along the EPS distribution chain. Within EPSs, DOE grouped the results into three separate product class groups. Product classes B, C, D, and E encompass the first group, product class X comprises the second group, and product class H comprises the third group. For BCs, DOE analyzed the industry impacts at the original equipment manufacturer (OEM) level of the BC distribution chain. Within BCs, DOE grouped the results into six separate groups. Product class 1 comprises the first group, product classes 2, 3, and 4 encompass the second group, product classes 5 and 6 encompass the third group, product class 7 comprises the fourth group, product class 8 comprises the fifth group, and product class 10 comprises the sixth group. DOE further analyzed the BC results of product classes 2, 3, and 4 into three industry subgroups: small appliances, consumer electronics, and power tools. DOE presents these industry impacts for EPSs in section 12.4.2 and for BCs in section 12.5.2 below.

DOE conducted the MIA in three phases. Phase 1, "Industry Profile," consisted of preparing an industry characterization for the BC and EPS industries, including data on market share, sales volumes and trends, pricing, employment, and financial structure. In Phase 2, "Industry Cash Flow," DOE used the GRIM to assess the impacts of new and amended energy conservation standards on the products in this rulemaking.

In Phase 2, DOE created separate GRIMs and interview guides for BCs and EPSs to gather information on the potential impacts on manufacturers.

In Phase 3, "Subgroup Impact Analysis," DOE interviewed manufacturers representing a wide range of EPS ODMs, OEMs, and internal circuitry (IC) manufacturers, as well as a wide range of BC application manufacturers and BC ODMs. Interviewees included BC and EPS manufacturers with various market shares and product focus, providing a representative cross-section of the two industries. During interviews, DOE discussed financial topics specific to each manufacturer and obtained each manufacturer's view of their particular industry. The interviews provided DOE with valuable information for evaluating the impacts of new and amended energy conservation standards on manufacturer cash flows, investment requirements, and employment.

12.2.1 Phase 1: Industry Profile

In Phase 1 of the MIA, DOE prepared a profile of the BC application and EPS ODM industries that built upon the market and technology assessment prepared for this rulemaking (see chapter 3 of this technical support document (TSD)). Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of each industry. This information included market share data, product shipments, manufacturer markups, and the cost structure for various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment; selling, general and administrative (SG&A) expenses; cost of goods sold, *etc.;* and (4) trends in the BC and EPS markets, including number of firms, technology, sourcing decisions, and pricing.

The industry profile included a top-down cost analysis of manufacturers in each industry that DOE used to derive preliminary financial inputs for the GRIM (e.g., revenues, depreciation, SG&A, and research and development (R&D) expenses).

DOE also used public information to further calibrate its initial characterization of each industry, including Securities and Exchange Commission (SEC) 10–K reports,[1] Standard & Poor's (S&P) stock reports,[2] and corporate annual reports. DOE supplemented this public information with data released by privately held companies.

12.2.2 Phase 2: Industry Cash-Flow Analysis and Interview Guide

Phase 2 focused on the financial impacts of new and amended energy conservation standards on each industry as a whole. More stringent energy conservation standards can affect manufacturer cash flows in three distinct ways: (1) by creating a need for increased investment, (2) by raising production costs per unit, and (3) by altering revenue due to higher per-unit prices and/or possible changes in sales volumes. In Phase 2, DOE performed preliminary industry cash-flow analyses and prepared written guides for manufacturer interviews. DOE used the GRIMs to perform two cash-flow analyses: one for the BC application industry and one for EPS ODM industry. In performing these analyses, DOE used the financial values derived during Phase 1 and the shipment assumptions from the NIA.

12.2.2.1 Industry Cash-Flow Analysis

The GRIM uses several factors to determine a series of annual cash flows from the announcement year of new and amended energy conservation standards until several years after the standards' compliance date. These factors include annual expected revenues, costs of sales, SG&A, taxes, and capital and product conversion expenditures related to the new and amended standards. Inputs to the GRIM include manufacturing costs and selling prices and shipment forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry and estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios for each GRIM based on discussions with manufacturers. DOE's shipments analysis, presented in chapter 9 of this TSD, provided the basis for the shipment projections in each GRIM. The financial parameters were developed using publicly available manufacturer data and were revised with information conveyed confidentially during manufacturer interviews. The GRIM results are compared to base case projections for each industry. The financial impact of new and amended energy conservation standards is the difference between the base case and standards case at each TSL discounted annual cash flows.

12.2.2.2 Interview Guides

During Phase 3 of the MIA, DOE interviewed companies at various steps along the distribution chain to gather information on the effects of new and amended energy conservation on revenues and finances, direct employment, capital assets, and industry competitiveness. Before the interviews, DOE developed separate interview guides for EPS ODM, OEM, and IC manufacturers and a separate interview guide for BCs to better understand the different steps in the BC and EPS distribution chains. The interview guides provided a starting point to identify relevant issues and help identify the impacts of new and amended energy conservation standards on individual manufacturers or subgroups of manufacturers. Most of the information DOE received from these meetings is protected by non-disclosure agreements and resides with DOE's contractors. Before each telephone interview or site visit, DOE provided company representatives with an interview guide that included the topics for which DOE sought input. In addition to numerous engineering follow up issues for the MIA, DOE was interested in interviewing ODM, OEM, IC manufacturers, and component suppliers to gather information about the following topics: (1) key issues to this rulemaking; (2) a company overview and organizational characteristics; (3) manufacturer markups and profitability; (4) shipment projections; (5) financial parameters; (6) conversion costs; (7) cumulative regulatory burden; (8) direct employment impact assessment; (9) manufacturing capacity and non-US sales; (10) impact on competition; and (11) impacts on small business. The interview guides are presented in Appendix 12-A.

12.2.3 Phase 3: Subgroup Analysis

For its analysis, DOE presents the impacts on BCs and EPSs separately. While conducting the MIA, DOE interviewed a representative cross-section of EPS ODM and OEM manufacturers and BC application manufacturers. Since BCs are incorporated into a wide variety of different products, ranging from power tools to small appliances to consumer electronics, the BC manufacturers that DOE interviewed spanned various industries since DOE focused on BC application manufacturers. The MIA interviews broadened the discussion from the engineering interviews to include business-related topics. DOE sought to obtain feedback from manufacturers on the approaches used in the GRIMs and to isolate key issues and concerns. Based on its interviews, DOE determined that several BC application subgroups could be disproportionately impacted by new and amended standards. Therefore, for the BC analysis DOE defined four subgroups of BC application manufacturers—small appliances, consumer electronics, power tools, and high energy appliances. DOE also identified small business manufacturers as a separate BC subgroup that could be disproportionately impacted by energy conservation standards. Only one BC manufacturer was identified as a small business and this company manufactures BCs in product class 7. The small business subgroup is described in detail in the Regulatory Flexibility section of the NOPR (section VI.B of the NOPR). DOE did not identify any subgroups for EPS ODMs.

12.2.3.1 Manufacturing Interviews

DOE manufacturer interviews in Phase 3 supplemented the information gathered in Phase 1 and the cash-flow analysis performed in Phase 2. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor each GRIM to reflect unique financial characteristics of the applicable industries. DOE contacted companies from its database of manufacturers, for the EPS section DOE contacted ODM, OEM, and IC manufacturers of EPSs and for the BC section DOE contacted BC application manufacturers. Small and large companies, subsidiaries and independent firms, and public and private corporations were interviewed to provide a representation of their specific industries. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIMs developed for the product classes.

12.2.3.2 Revised Industry Cash-Flow Analysis

As discussed above, in Phase 2 of the MIA DOE provided manufacturers with preliminary GRIM input financial figures for review and evaluation. During the interviews, DOE requested comments on the values it selected for the parameters. DOE revised its industry cash-flow models based on this feedback. Section 12.4.2 and section 12.5.2 provide more information on how DOE calculated the parameters.

12.2.3.3 Manufacturer Subgroup Analysis

Using average cost assumptions to develop an industry cash-flow estimate does not adequately assess differential impacts of new and amended standards among manufacturer subgroups. For example, small manufacturers, niche players, or manufacturers exhibiting a cost structure that largely differs from the industry average could be more negatively affected. To address this possible impact, DOE used the results of the industry characterization analysis in Phase 1 to group manufacturers that exhibit similar production and cost structure characteristics. Furthermore, interview discussions that focused on financial topics specific to each manufacturer allowed DOE to gauge the potential for differential impacts on any subgroups of manufacturers.

DOE identified four industry subgroups of BC application manufacturers: small appliances, consumer electronics, power tools, and high energy appliances. DOE assigned all 105 BC applications to one of these four industry subgroups. DOE grouped these BC applications into industry subgroups because the range of applications using BCs are so varied. Therefore, DOE grouped BC applications that share similar characteristics into one of four industry subgroups. DOE presents the impacts of standards on each of these four industry subgroups across product classes 2, 3, and 4. The results of this subgroup analysis are in section 12.5.2.3.

DOE identified small business manufacturers as a potential subgroup for a separate analysis. To determine whether manufacturers affected by the rulemaking were small businesses, DOE used the small business size standards published by the Small Business Administration[a] (SBA) for the most appropriate North American Industry Classification System (NAICS) codes, presented in Table 12.2.1. For the product classes and applications that incorporate covered BCs under review, the SBA bases its small business definition on the total number of employees for a business, its subsidiaries, and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business.

---

[a] The size standards are available on the SBA's website at www.sba.gov/idc/groups/public/documents/sba_homepage/serv_sstd_tablepdf.pdf

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by This Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Audio and Video Equipment Manufacturing	NA	750	334310
Telephone Apparatus Manufacturing	NA	1,000	334210
Electronic Computer Manufacturing	NA	1,000	334111
Motorcycle, Bicycle and Parts Manufacturing	NA	500	336991
Other Motor Vehicle Electrical and Electronic Equipment Manufacturing	NA	750	336332
Household Vacuum Cleaner Manufacturing	NA	750	335212
Lawn and Garden Tractor and Home Lawn and Garden Equipment Manufacturing	NA	500	333112
Power-Driven Hand Tool Manufacturing	NA	500	333991
Primary Battery Manufacturing	NA	1,000	335912
All Other Miscellaneous Electrical Equipment and Component Manufacturing	NA	500	335999

DOE reviewed the Small Business Administration database to find any small businesses that were potentially manufacturers and that could be affected by this rule, if promulgated. DOE also asked interested parties and industry representatives if they were aware of other small business manufacturers. Then, DOE consulted publicly available data, reports from vendors such as Dun and Bradstreet (D&B), and manufacturers to determine which manufacturers meet SBA's definition of a small business.

During its research, DOE did not identify any EPS ODMs that manufacture products covered under the EPS portion of this rulemaking and qualify as small businesses per the applicable SBA definition. However, DOE did identify one potential small business for BCs. This small business is a manufacturer of BCs in product class 7. This determination is detailed in section 12.4 of the TSD and in section VI.B of the NOPR. Because no EPS ODMs qualified as a small business, DOE did not analyze a separate subgroup of small business EPS ODMs.

12.2.3.4 Manufacturing Capacity Impact

One significant outcome of new and amended energy conservation standards can be the obsolescence of existing manufacturing assets, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of new and amended standards on manufacturing capacity, specifically capacity utilization and plant location decisions in the United States and North America, with and without new and amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new and amended requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing plant, property, and equipment (PPE). DOE's resulting estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIMs. These conversion cost estimates can be found in section 12.4.1.8 and section 12.5.1.9; DOE's discussion of the capacity impact can be found in section 12.4.4.2 and section 12.5.4.2.

12.2.3.5 Employment Impact

The impact of new and amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, the interviews explored current employment trends in the BC application and EPS ODM industries. The interviews also solicited manufacturer views on changes in employment patterns that may result from more stringent standards. The employment impacts section of the interview guide focused on current employment levels associated with manufacturers at each production facility, expected future employment levels with and without new and amended energy conservation standards, and differences in workforce skills and issues related to the retraining of employees. The employment impacts are reported in sections 12.4.4.1 and 12.5.4.1.

12.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to new and amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple, product-specific regulatory actions. Based on its own research and discussions with manufacturers, DOE identified State and other Federal regulations to which some BC application manufacturers and EPS ODMs may also be subject. Discussion of the cumulative regulatory burden can be found in section 12.6.

12.3 MANUFACTURER IMPACT ANALYSIS KEY ISSUES

DOE interviewed companies at different steps of the BC and EPS production chain representing a wide range of ODMs and OEMs. These interviews were in addition to those DOE conducted as part of the engineering analysis. DOE used these interviews to tailor the BC and EPS GRIMs to incorporate unique financial characteristics for each industry. All interviews provided information that DOE used to evaluate the impacts of new and amended energy conservation standards on manufacturer cash flows, manufacturing capacities, and employment levels. See Appendix 12-A of this TSD for additional information on the MIA interviews.

The following sections describe the most significant issues identified by manufacturers.

12.3.1 Product Groupings

Several manufacturers expressed concern over the approach DOE outlined in which a variety of different applications would be grouped together within the same product class and would have to meet equivalent standards. BC and EPS product classes are defined by characteristics such as type of current conversion, voltage, and output power. However, the proposed BC and EPS product classes do not necessarily group applications performing similar end-use functions. Manufacturers stated that grouping applications that consume a larger amount of electricity over their lifetime with applications that consume only a fraction of electricity over their lifetime can put the applications that are used less frequently at an unfair disadvantage.

Manufacturers were particularly concerned about the potential for groupings to impact specific battery charger applications after finalizing the standard. For BCs, DOE is proposing standards using one Unit Energy Cost (UEC) equation for each product class. Specific applications can be grouped into a product class whose individual usage profile differs from the usual profile of the product class. This is especially true if the shipments of one application are significantly greater than the shipments of another application with a very different usage profile (i.e., the millions of laptop shipments versus do-it-yourself (DIY) power tools). Both laptops and DIY power tools would be regulated using the same usage profile parameters to satisfy a given energy conservation standard. Therefore, there is less potential for consumers to save energy cost effectively with respect to those applications that are not used frequently compared to applications that are used continuously even though both applications would be required to meet the same standard.

DOE recognizes manufacturer concerns over how specific applications are grouped together as a result of the proposed division of product classes. DOE's life-cycle costs (LCC) analysis and manufacturing impact analysis evaluate the impacts on users and manufacturers, respectively, on an applications-specific basis. Although the UEC is established at the product class level, the granularity of these analyses enables DOE to consider the benefits and burdens on users and manufacturers of specific applications, and take those results into consideration in determining which TSLs to select.

12.3.2 Competition from Substitutes

Manufacturers have stated that several of their applications compete directly with applications using other forms of energy, such as products powered by gasoline, disposable alkaline batteries, or corded products. Products that use BCs must remain cost competitive with these alternatively powered products because these products are close substitutes. Manufacturers of lawn care products, such as mowers and trimmers, and mobility units, such as motorized bikes and golf cars, are competing in the same markets as gas-powered versions of these applications. Similarly, manufacturers of smaller electronic devices, such as digital cameras, are competing in the same market as disposable alkaline battery-powered digital cameras. Several applications also have direct competition with similar non-electric applications, such as electric toothbrushes and DIY power tools. Having products powered by a rechargeable battery is a feature that adds value for consumers. A significant increase in the cost of manufacturing the BC could lead manufacturers to remove the rechargeable feature of an application or choose an alternative method to power the device, ultimately reducing the consumer utility for these applications. If energy conservation standards lead to a significant price increase, consumers could switch to these alternatives.

Based on these concerns, DOE considered the impact of price elasticity on application shipment volumes. These price elasticity sensitivity results are presented in Appendix 12-B of this TSD.

12.3.3 Test Procedure Concerns

While most manufacturers agree that using the UEC is an appropriate test procedure metric for BCs, some BC manufacturers stated there is a problem of separating the batter charging function of an application from the other functions being performed by the application. In their view, it is not easy to isolate the battery charging portion of the application for testing and/or creating cost-efficiency curves. Manufacturers stated that the test procedure must clearly separate out the charging portion of the energy consumption in order to regulate its efficiency accurately. DOE specifically took this factor into consideration for uninterruptible power supply (UPS) manufacturers and explains its approach in detail in section IV.C.2.i of the NOPR.

12.3.4 Double Regulation of BCs and EPSs

Manufacturers raised concerns that specific applications that are shipped with both a BC and an EPS would be subject to regulations for both components - one energy conservation standard for the BC and a separate energy conservation standard for the EPS of the same application. Having to meet two separate standards may not allow the manufacturers to maximize the efficiency of both the BC and the EPS together and could add to the overall cost of the application. DOE took these comments into consideration but has tentatively determined that establishing standards for each product was the most appropriate action given the statutory requirements to set standards for these products. For further detail and DOE's rationale for this decision, see section IV.A.1 of the NOPR.

12.3.5 Profitability Impacts

Several manufacturers stated that they expect energy conservation standards to negatively impact the profitability of BCs. At higher candidate standard levels (CSLs), standards could increase MPCs and manufacturers believed these higher costs would not necessarily be passed on to consumers. Several applications use specific price points that consumers expect those applications to have. Consequently, manufacturers believe that cost increases would be at least partly absorbed by manufacturers to keep retail prices from rising sharply.

The BC often represents a significant portion of the overall cost of the application. Any increase in the cost of the BC would have a significant impact on the cost of these applications as a whole. If energy conservation standards led to a significant reduction in profitability, some manufacturers could potentially exit the market and reduce the number of competitors. Additionally, many electronic applications are considered luxury items so consumers could also chose to forgo their purchases altogether if the application prices increased substantially.

As discussed in section IV.I.2.a and IV.I.3.a of the NOPR, DOE evaluates a range of profitability scenarios in the MIA that take these specific concerns into account.

12.3.6 Potential Changes to Product Utility

Manufacturers believe adverse impacts from new and amended standards could also indirectly affect product utility. Several manufacturers indicated that other features that do not affect efficiency could be removed or component quality could be sacrificed to meet new and amended standard levels and maintain current application prices. Manufacturers also stated that the financial burden of developing products to meet new and amended energy conservation standards has an opportunity cost due to limited capital and R&D dollars. Investments incurred to meet new and amended energy conservation standards reflect foregone investments in innovation and the development of new features that consumers value and on which manufacturers earn higher absolute profit.

DOE's engineering analysis only analyzes utility-neutral design changes to meet higher efficiency standards and accounts for the costs incurred to achieve those levels. While there may be cheaper ways to meet a given efficiency level by reducing other features that provide utility, those design paths are not assumed in DOE's analyses. DOE recognizes the opportunity cost of standards-induced investment and accounts for the conversion expenditures manufacturers may incur at each TSL, as discussed in section IV.I.3.a.iv of the NOPR. Whether a given manufacturer chooses to mitigate these costs (and the associated product costs illustrated in the engineering analysis' cost-efficiency curves) by reducing product utility is a business decision and not one mandated by the proposed energy conservation standards.

12.4 EXTERNAL POWER SUPPLY METRICS

DOE analyzed the impact of standards on EPS manufacturers at the ODM level for three basic reasons: (1) the ODM typically certifies compliance with the DOE energy conservation standards and completes most design work for the EPS (even if EPS specifications are given by an OEM); (2) unlike BCs, the EPS is not fully integrated into end-use applications; and (3) most of the EPS final assembly and manufacturing is done by ODMs, which then ship the EPS as a component to OEMs. In essence, unlike a BC, the EPS typically becomes a final product when under the control of the ODM, regardless of any additional steps in the distribution chain to the consumer. EPS product classes are designated by output power, output current type, output voltage, and specific characteristics of the EPS. See section IV.A.3.a of the NOPR for a complete explanation of EPS product class selection.

In the engineering analysis, DOE analyzed four representative product class B units (with output powers at 2.5, 18, 60, and 120 Watts), one multiple voltage representative unit (product class X), and one high power representative unit (product class H). DOE used the engineering production costs and shipments from the LCC and NIA for these six representative units to calculate the impact of new and amended energy conservation standards on all EPS ODMs.

12.4.1 EPS Grim Inputs and Assumptions

The GRIM serves as the main tool for assessing the impacts on industry due to new and amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are inputs to an accounting model that calculates the industry cash flow both with and without new and amended energy conservation standards.

12.4.1.1 EPS Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.4.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2011, and continuing to 2042. The model calculates the INPV by summing the stream of annual discounted cash flows during this period.[3]

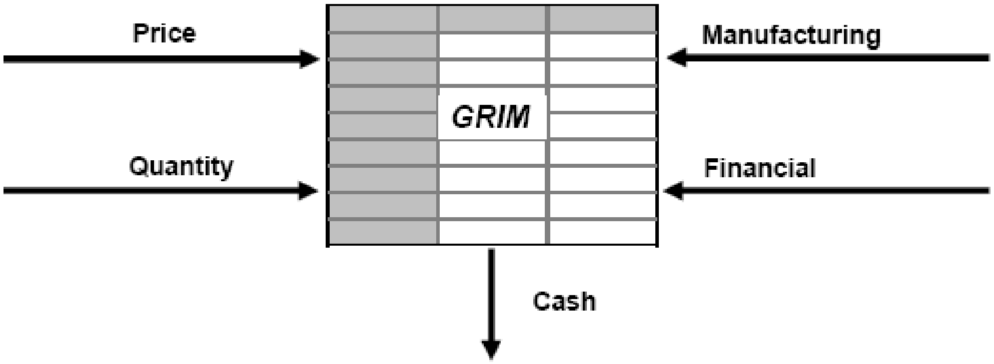


Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard case scenario induced by new and amended energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the new and amended energy conservation standards on manufacturers. Appendix 12-C provides more technical details and user information for the GRIM.

12.4.1.2 EPS Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers primarily engaged in manufacturing lamp ballasts, since many of the same ballast goods manufacturers produce EPSs. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies as its initial estimates of the financial parameters in the EPS GRIM analysis. These figures were later revised using feedback from interviews to be representative of manufacturing for each product. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital
- SG&A
- R&D
- Depreciation
- Capital expenditures

- Net PPE

Standard and Poor's Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). The model relied on historical shipments data for EPSs. Chapter 9 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

Engineering Analysis

During the engineering analysis, DOE used a combination of information from a manufacturing cost model and interviews with EPS ODMs, EPS OEMs, and IC manufacturers to develop MPC estimates for EPSs. The analysis provided the labor, materials, overhead, and total production costs for products at each efficiency level. The engineering analysis also estimated a manufacturer markup to provide the manufacturer selling price (MSP) for each product at every efficiency level.

Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of EPS ODMs, OEMs, and IC manufacturers. DOE also interviewed manufacturers representing a significant portion of sales in every product class. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- capital conversion costs (one-time investments in PPE);
- product conversion costs (one-time investments in research, product development, testing, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- projected total shipment and shipment distribution mix; and
- MPCs estimated in the engineering analysis.

12.4.1.3 EPS Financial Parameters

In the manufacturer interviews, DOE used the initial financial parameters from the 2011 florescent lamp ballast NOPR as a starting point for determining the EPS ODM industry financial parameters (76 FR 20090, April 11, 2011). These initial estimates were used because no other publicly available SEC 10-K reports for EPS ODMs were available. Also, many florescent lamp ballast manufacturers are located in similar locations of the world and use similar electronic components as EPS ODMs. Therefore, DOE believed that using the initial florescent lamp ballast financial parameters as a starting point to estimate EPS ODM was appropriate.

These financial parameters were determined by averaging the values in the annual reports of four publicly traded companies engaged in manufacturing and selling florescent lamp ballasts over a 6-year period (2002 to 2007).

Table 12.4.1 below shows the data used to determine the initial financial parameter estimates for EPS ODMs.

Table 12.4.1 EPS GRIM Financial Parameters Based on 2002-2007 Weighted Florescent Lamp Ballast Company Financial Data

Parameter	Weighted Average	Manufacturer			
		A	B	C	D
Tax Rate ***(% of Taxable Income)***	23.4	11.4	28.4	13.1	32.6
Working Capital ***(% of Revenue)***	8.3	-29.4	17.9	11.9	16.4
SG&A ***(% of Revenue)***	19.4	14.0	20.8	17.8	22.6
R&D ***(% of Revenues)***	3.8	3.6	2.7	6.1	3.9
Depreciation ***(% of Revenues)***	3.7	2.1	3.8	5.9	2.7
Capital Expenditures ***(% of Revenues)***	4.2	3.0	4.6	6.4	2.3
Net Property, Plant, and Equipment ***(% of Revenues)***	14.6	18.2	14.1	13.5	13.7

During interviews, suppliers and manufacturers along the EPS distribution chain were asked to provide their own figures for the parameters listed in

Table 12.4.1. The interview guides with DOE's inquiries about its initial financial parameter estimates can be found in the "Financial Parameters" section of the interview guides in Appendix 12-A. DOE did not receive feedback from EPS ODMs that indicated that the financial parameters preliminarily used in the EPS GRIM should be adjusted. Therefore, DOE used the financial parameters originally obtained from the initial florescent lamp ballast estimates shown in Table 12.4.1 for the EPS ODM industry since the feedback DOE received confirmed this was appropriate. DOE additionally considered using the financial parameters from BC consumer electronics application sector but DOE received feedback that the florescent lamp ballast parameters more accurately reflected the EPS ODM industry.

12.4.1.4 EPS Corporate Discount Rate

DOE used the weighted-average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the EPS industry based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a “safe” benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity for the EPS industry is 12.9 percent (

Table 12.4.2). The representative data was taken from the initial florescent lamp ballast estimates since several of the representative manufacturers are the same in the EPS industry.

Table 12.4.2 Cost of Equity Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
(1) Average Beta	1.29	1.65	1.24	1.48	0.92
(2) Yield on 10-Year T-Bill (1928-2009)	5.2	-	-	-	-
(3) Market Risk Premium (1928-2009)	6.0	-	-	-	-
Cost of Equity (2)+[(1)*(3)]	12.9	-	-	-	-
Equity/Total Capital	87.5	90.8	94.7	75.0	82.4

* Estimated Beta

Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company’s cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate. DOE used this method to calculate the cost of debt for all four manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2009.

For the cost of debt, S&P’s Credit Services provided the average spread of corporate bonds for the four public manufacturers. As stated above, the representative data was taken from the initial florescent lamp ballast estimates several of the representative manufacturers are the same in the EPS industry. DOE added the industry-weighted average spread to the average T-Bill yield over the same period. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 12.4.3 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.* the debt ratio (debt/total capital)).

Table 12.4.3 Cost of Debt Calculation

Parameter	**Industry-Weighted Average %**	**Manufacturer**			
		A	B	C	D
S&P Bond Rating	--	AA+	A-	A+	AA-
(1) Yield on 10-Year T-Bill (1928-2009)	5.2	-	-	-	-
(2) Gross Cost of Debt	8.1	7.2	8.7	7.9	7.7
(3) Tax Rate	23.4	11.4	28.4	13.1	32.6
Net Cost of Debt (2) x ((1)-(3))	6.2	-	-	-	-
Debt/Total Capital	12.5	9.2	5.3	25.0	17.6

Using public information for these four companies from the florescent lamp ballast NOPR, the initial estimate for the EPS ODM industry's WACC was approximately 10.2 percent. Subtracting an inflation rate of 3.1 percent between 1928 and 2009, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 7.1 percent. DOE also asked for feedback on this 7.1 percent discount value during manufacturer interviews with manufacturers all along the EPS distribution chain. DOE received feedback from several EPS ODMs that 7.1 percent was an appropriate value to use at the ODM level for the EPS GRIM.

12.4.1.5 EPS Trial Standard Levels

DOE analyzed the benefits and burdens of multiple TSLs for EPS ODMs. A description of each TSL DOE analyzed is provided below. DOE attempted to limit the number of TSLs considered for the EPS rulemaking by excluding efficiency levels that do not exhibit significantly different economic and/or engineering characteristics from the efficiency levels already selected as a TSL.

Table 12.4.4 presents the TSLs for EPSs and the corresponding efficiency levels. DOE analyzed product class B directly and scaled the results from the engineering analysis to product classes C, D, and E. The TSL levels for these three product classes therefore correspond to the TSLs for product class B. DOE directly analyzed product class B by using four representative units with output powers at 2.5, 18, 60, and 120 Watts. For product classes C, D, and E, each product class is scaled to the representative unit with the most similar attributes. Therefore, product classes C and E are scaled to the representative unit with output power at 2.5 Watts, and product class D is scaled to the representative unit with output power at 18 Watts. Because product classes C, D, and E are scaled to representative units in product class B, the CSLs are the same for each TSL across product classes B, C, D, and E. DOE also groups product classes B, C, D, and E together when reporting the MIA results.

DOE created separate TSLs for the multiple-voltage and high power EPSs, product classes X and H respectively, to determine their standards. The CLSs selected for each TSL in product classes X and H are not dependent on the CSL selected for product class B, unlike product classes C, D, and E.

Table 12.4.4 Trial Standard Levels for EPS

Product Class		Trial Standard Level		
		TSL 1	TSL 2	TSL 3
DC Output, Basic Voltage (B)	**0-10.25 W**	CSL 2	CSL 3	CSL 4
	10.25-39 W	CSL 2	CSL 3	CSL 4
	39-90 W	CSL 2	CSL 3	CSL 4
	91-250 W	CSL 2	CSL 3	CSL 4
DC Output, Low Voltage (C)		CSL 2	CSL 3	CSL 4
AC Output, Basic Voltage (D)		CSL 2	CSL 3	CSL 4
AC Output, Low Voltage (E)		CSL 2	CSL 3	CSL 4
Multiple Voltage (X)		CSL 1	CSL 2	CSL 3
High Power (H)		CSL 2	CSL 3	CSL 4

For EPS product class B, DOE examined three trial standard levels corresponding to each candidate standard level of efficiency developed in the engineering analysis. TSL 1 is an intermediate level of performance above Energy Star, which offers the greatest consumer NPV. TSL 2 is equivalent to the best-in-market CSL and represents an incremental rise in energy savings over TSL 1. TSL 3 is the max-tech level and corresponds to the greatest National Energy Savings (NES). As noted above the CSL assigned to each TSL for product classes C, D, and E mirror the CSLs selected for product class B because these product classes are scaled using the most similar product class B representative unit.

For product class X, DOE examined three TSLs above the baseline. TSL 1 is an intermediate level of performance above the baseline. TSL 2 is equivalent to the best-in-market CSL and corresponds to the maximum consumer NPV. TSL 3 is the max-tech level and corresponds to the greatest NES.

For product class H, DOE examined three TSLs above the baseline. TSL 1 corresponds to an intermediate level of efficiency. TSL 2 is the scaled best-in-market CSL and corresponds to the maximum consumer NPV. TSL 3 is the scaled max-tech level, which provides the highest NES.

12.4.1.6 EPS NIA Shipment Forecast

The EPS GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the EPS GRIM used the NIA shipments forecasts from 2009 to 2042 for EPSs. However, only the shipments in 2011 and after have an impact on INPV because 2011 is the base year to which future cash flows are summed. Chapter 9 of the TSD explains DOE's calculations of total shipments in detail. Table 12.4.5 shows total shipments forecasted in the shipment analysis for EPSs broken out by product class in 2013; Table 12.4.6 shows total shipments forecasted in the shipment analysis for EPSs broken out by representative units for in 2013.

Table 12.4.5 Total EPS NIA Shipments Forecast in 2013 in the Main NIA Shipment Scenario[b]

Product Class	**Total Industry Shipments**
Product Class B	199,174,795
Product Class C[*]	60,630,674
Product Class D[**]	8,236,715
Product Class E[*]	2,318,263
Product Class X	7,909,432
Product Class H	3,091
Total EPS	**278,272,969**

[*] Product class C and E shipments are included in the representative unit with output power at 2.5 Watts' shipments.
[**] Product class D shipments are included in the representative unit with output power at 18 Watts' shipments.

Table 12.4.6 Total EPS Representative Unit Shipments Forecast in 2013

Product Class	**Total Industry Shipments**
Product Class B – 2.5 Watt Representative Unit[*]	133,499,508
Product Class B – 18 Watt Representative Unit[**]	80,625,568
Product Class B – 60 Watt Representative Unit	49,001,874
Product Class B – 120 Watt Representative Unit	7,233,496

[*] Representative unit with output power at 2.5 Watts includes shipments from product class C and E.
[**] Representative unit with output power at 18 Watts includes shipments from product class D.

Base Case Shipments Forecast

In the LCC, total EPS shipments are distributed among all analyzed EPS applications. However, in regards to the MIA, DOE only analyzed the total EPS shipments by product class not by each EPS application. In the MIA, DOE assigns each application's associated EPS shipments to one of the six representative units, resulting in six sets of shipments in the MIA. Any EPS application that uses multiple voltages is assigned to product class X. Any EPS application with an output power of more than 250 Watts is assigned to product class H. For product classes B, C, D, and E shipments, DOE assigns each unit shipped to one of four buckets, corresponding to one of the four representative units (with output powers of 2.5, 18, 60, and 120 Watts), whichever has the closest output power. For example, if an application has an output power of 4 Watts, DOE assigns that application to the 2.5 Watt representative unit category. Using these range definitions, DOE classifies the relevant applications for each representative unit and calculates the total shipments for each application.

The total EPS shipments by application are calculated for 2013 in the NIA. To calculate total EPS shipments from 2013 to the end of the analysis period, DOE assumed a constant compound annual growth rate for total EPS shipments. Since EPS shipments span a range of efficiencies, DOE developed the base-case efficiency forecasts using the 2009 efficiency

---

[b] The estimated compliance date for the BCEPS energy conservation standard is estimated to be July 2013.

distributions from products DOE tested, as described in the market assessment (chapter 3 of the TSD). To extrapolate from the 2009 forward to 2013 (the compliance year of the standard), DOE looked at recent trends in product efficiency and considered factors that could lead EPSs to become more efficient between 2009 and 2013. Once the 2013 efficiency distribution was established, DOE linearly extrapolated the efficiency distributions for the intermediate years between 2009 and 2013.

Total industry revenue is equal to shipments multiplied by the prices for which ODMs sell EPSs to OEMs. As described above, DOE summed the total shipments of all applications at each representative unit to calculate the total shipments of each representative unit. Because the price of each representative unit depends on its efficiency, DOE used the efficiency curves of the representative units, the shipments of each representative unit, and the efficiency distribution for each representative unit to calculate total industry revenue.

Table 12.4.7 Base Case Distribution of Efficiencies for EPS in 2013

Product Class		Baseline	CLS 1	CLS 2	CLS 3	CSL 4
Product Class B – 2.5 Watt Unit	Efficiency	58.3%	67.9%	71.0%	73.5%	74.8%
	No Load Power	0.500	0.300	0.130	0.100	0.039
	% of the Market at EL	42.3%	49.3%	6.0%	2.3%	0.0%
Product Class B – 18 Watt Unit	Efficiency	76.0%	80.3%	83.0%	85.4%	91.1%
	No Load Power	0.500	0.300	0.2	0.1	0.039
	% of the Market at EL	19.4%	52.1%	18.1%	10.3%	0.0%
Product Class B – 60 Watt Unit	Efficiency	85.0%	87.0%	87.0%	88.0%	92.2%
	No Load Power	0.5	0.5	0.2	0.073	0.05
	% of the Market at EL	18.6%	63.1%	17.0%	1.4%	0.0%
Product Class B – 120 Watt Unit	Efficiency	85.0%	87.0%	88.0%	88.4%	93.5%
	No Load Power	0.5	0.5	0.23	0.21	0.089
	% of the Market at EL	25.8%	53.0%	18.2%	3.0%	0.0%
Product Class X	Efficiency	82.4%	86.4%	86.4%	88.5%	-
	No Load Power	12.3	0.4	0.3	0.3	-
	% of the Market at EL	5.0%	95.0%	0.0%	0.0%	-
Product Class H	Efficiency	62.4%	81.3%	84.6%	87.5%	92.0%
	No Load Power	15.43	6.01	0.5	0.5	0.266
	% of the Market at EL	50.0%	50.0%	0.0%	0.0%	0.0%

Standards Case Shipments Forecast

The base-case efficiency distribution and growth rate drive total industry revenue in the base case. In the standards case, DOE assumed that manufacturers will respond to standards by improving those products that do not meet the standards to the standard level but no higher. The shipments of products that were already as or more efficient than the new and amended standard remain unaffected. This is referred to as a “roll-up” scenario.

12.4.1.7 EPS Production Costs

The MIA is concerned with how changes in efficiency impact the MPCs of the four representative product class B units and product class X and H representative units. The MPCs and the corresponding prices for which fully assembled EPSs are sold to OEMs, frequently referred to as "factory costs" in the industry, are major factors in industry value calculations. Regardless of the degree to which the ODM is vertically integrated, the MPC includes the cost of components (including integrated circuits), other direct materials of the finalized EPS, the labor to assemble all parts, factory overhead, and all other costs borne by the OEM to purchase a fully assembled EPS. The MPCs are calculated by various methods based on the available information. For the product class B representative units, DOE based its MPCs on information gathered in interviews, during which manufacturers detailed their costs of achieving increases in energy efficiency at discrete levels of efficiency. The MPC for product class X at lower efficiency levels was calculated based on the engineering analysis creating a complete BOMs derived from the disassembly of the units selected for teardown. The MPC for product class X at higher efficiency levels was calculated based on information gathered in interviewed with manufacturers. The MPC for product class H at lower efficiency levels was calculated based on the retail prices of these products. The MPC can be calculated by backing out the manufacturer markup from the MSP and the MSP can be calculated by backing out the retail markup from the retail price. The MPC for product class H at higher efficiency levels was calculated based on scaling the MPCs from product class B, which were obtained from manufacturer interviews. Sometimes manufacturers would provide the MSP of a product but not the MPC, if that was the case, DOE would calculate the MPC by backing out the manufacturer markup from the MSP to obtain the MPC. DOE calculated the manufacturer markup of 1.36 for all EPS representative units. This value is based on an average of manufacturer markups provided by EPS ODMs during manufacturing interviews with DOE. See chapter 3 of this TSD for a complete description of the EPS MPC calculations.

To calculate the percentage of the MPC that corresponds to labor, material, and overhead, DOE used the average percentages from all teardowns completed as part of the engineering analysis. Table 12.4.8 through Table 12.4.13 show the production cost estimates used in the GRIM in the Flat Markup scenario for the representative product classes for EPSs.

Table 12.4.8 MPC Breakdown in the Flat Markup Scenario for Product Class B – 2.5 Watt Representative Unit

CSL (Efficiency Level)	**TSL**	**Efficiency**	**No Load Power**	**Labor *$***	**Material *$***	**Overhead *$***	**Depreciation *$***	**MPC *$***	**Mfr. Markup**	**MSP *$***
Baseline	-	58.3%	0.500	$0.05	$0.46	$0.02	$0.03	$0.55	1.36	$0.75
CSL 1	-	67.9%	0.300	$0.06	$0.55	$0.03	$0.03	$0.67	1.36	$0.90
CSL 2	1	71.0%	0.130	$0.07	$0.66	$0.04	$0.04	$0.80	1.36	$1.08
CSL 3	2	73.5%	0.100	$0.07	$0.73	$0.04	$0.04	$0.88	1.36	$1.20
CSL 4	3	74.8%	0.039	$0.08	$0.77	$0.04	$0.05	$0.94	1.36	$1.27

Table 12.4.9 MPC Breakdown in the Flat Markup Scenario for Product Class B – 18 Watt Representative Unit

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	-	76.0%	0.500	$0.22	$2.19	$0.12	$0.13	$2.66	1.36	$3.60
CSL 1	-	80.3%	0.300	$0.22	$2.19	$0.12	$0.13	$2.66	1.36	$3.60
CSL 2	1	83.0%	0.2	$0.23	$2.29	$0.12	$0.14	$2.78	1.36	$3.77
CSL 3	2	84.4%	0.1	$0.26	$2.57	$0.14	$0.16	$3.13	1.36	$4.24
CSL 4	3	91.1%	0.039	$0.40	$3.94	$0.21	$0.24	$4.79	1.36	$6.49

Table 12.4.10 MPC Breakdown in the Flat Markup Scenario for Product Class B – 60 Watt Representative Unit

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	-	85.0%	0.5	$0.37	$3.64	$0.19	$0.22	$4.43	1.36	$6.00
CSL 1	-	87.0%	0.5	$0.37	$3.64	$0.19	$0.22	$4.43	1.36	$6.00
CSL 2	1	87.0%	0.2	$0.42	$4.14	$0.22	$0.25	$5.04	1.36	$6.82
CSL 3	2	88.0%	0.073	$0.45	$4.43	$0.24	$0.27	$5.38	1.36	$7.29
CSL 4	3	92.2%	0.05	$0.54	$5.30	$0.28	$0.32	$6.45	1.36	$8.73

Table 12.4.11 MPC Breakdown in the Flat Markup Scenario for Product Class B – 120 Watt Representative Unit

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	-	85.0	0.5	$0.74	$7.29	$0.39	$0.44	$8.86	1.36	$12.00
CSL 1	-	87.0	0.5	$0.74	$7.29	$0.39	$0.44	$8.86	1.36	$12.00
CSL 2	1	88.0	0.23	$0.76	$7.48	$0.40	$0.46	$9.09	1.36	$12.31
CSL 3	2	88.4	0.21	$0.76	$7.56	$0.40	$0.46	$9.19	1.36	$12.45
CSL 4	3	93.5	0.089	$1.13	$11.18	$0.60	$0.68	$13.59	1.36	$18.41

Table 12.4.12 MPC Breakdown in the Flat Markup Scenario for Product Class X

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	-	82.4	12.3	$1.04	$10.26	$0.55	$0.63	$12.47	1.36	$16.90
CSL 1	1	86.4	0.4	$1.19	$11.75	$0.63	$0.72	$14.28	1.36	$19.35
CSL 2	2	86.4	0.3	$1.20	$11.88	$0.63	$0.72	$14.43	1.36	$19.56
CSL 3	3	88.5	0.3	$1.51	$14.95	$0.80	$0.91	$18.16	1.36	$24.61

Table 12.4.13 MPC Breakdown in the Flat Markup Scenario for Product Class H

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Labor $	Material $	Overhead $	Depreciation $	MPC $	Mfr. Markup	MSP $
Baseline	-	62.4	15.43	$8.15	$80.57	$4.29	$4.91	$97.92	1.36	$132.68
CSL 1	-	81.3	6.01	$6.42	$63.47	$3.38	$3.87	$77.14	1.36	$104.52
CSL 2	1	83.5	0.5	$6.42	$63.47	$3.38	$3.87	$77.14	1.36	$104.52
CSL 3	2	85.0	0.5	$6.59	$65.16	$3.47	$3.98	$79.19	1.36	$107.30
CSL 4	3	92.0	0.266	$8.84	$87.40	$4.65	$5.32	$106.21	1.36	$143.92

12.4.1.8 EPS Conversion Costs

New and amended energy conservation standards will cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with the new and amended energy conservation standards. For the MIA, DOE classified these one-time conversion costs into two major groups: (1) product conversion costs and (2) capital conversion costs. Product conversion costs are one-time investments in research, development, testing, marketing, and other non-capitalized costs focused on making product designs comply with the new and amended energy conservation standards. Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled.

To calculate the product conversion costs for the industry, DOE used application lifetimes, shipments of each application from 2011 and 2013, and typical industry research and development expenses. Applications are important for calculating the industry-wide product conversion costs because DOE only included the product conversion costs of applications that would not have been scheduled for a new design. DOE assumed that in the absence of an energy conservation standard, a portion of the applications would be redesigned in between the announcement of an energy conservation standard and the implementation of that energy conservation standard and therefore are those applications scheduled for redesign are not included in the product conversion costs. For example, for an application with a five-year average lifetime, DOE assumed that one-fifth of all these applications would be redesigned each year. Because there is a two-year time period between the announcement of the standard and the compliance date of the standard, two-fifths of the applications with a five-year lifetime will be redesigned in that timeframe whether or not a standard is implemented. This leaves three-fifths of the five-year applications that would be required to be redesigned as a result of new and amended energy conservation standards. In addition only those products below the set energy conservation standard would be required to be redesigned, as the efficiency of products meeting or exceeding the standard would remain unchanged. Table 12.4.14 and Table 12.4.15 contain an example EPS application for each product class B representative unit and each analyzed EPS product class. Table 12.4.14 displays the average production run lifetime of the example EPS applications, the percentage of EPS applications that are scheduled for redesign in the time between the announcement date and the compliance date for this rulemaking (which is two years), and the percentage of EPS applications that would not be redesigned absent standards. Table 12.4.15 displays the percentage of the EPS applications that meet each efficiency level in 2013. DOE does not present every EPS application in the tables below.

Table 12.4.14 Production Lifetime and Percentage of EPS Applications Scheduled for Redesign

Example EPS Application Name	EPS Product Class	Average Production Lifetime	% of Applications That Would Have Redesigned in Between the Announcement of the Standard and the Compliance Date	% of Applications Not Scheduled for Redesign
Answering Machines	Product Class B - 2.5 Watt Representative Unit	5.3 years	37%	63%
LAN Equipment	Product Class B - 18 Watt Representative Unit	4.0 years	50%	50%
Notebooks	Product Class B - 60 Watt Representative Unit	3.7 years	55%	45%
Notebooks	Product Class B - 120 Watt Representative Unit	3.7 years	55%	45%
Mobile Phones	Product Class C	4.0 years	50%	50%
Home Security Systems	Product Class D	10.0 years	20%	80%
Aquarium Accessories	Product Class E	5.0 years	40%	60%
Video Game Consoles	Product Class X	5.0 years	40%	60%
Amateur Radios	Product Class H	10.0 years	20%	80%

Table 12.4.15 Efficiency Distribution of Example EPS Applications in 2013

Application Name	EPS Product Class	Baseline	CSL 1	CSL 2	CSL 3	CSL 4
Answering Machines	Product Class B - 2.5 Watt Representative Unit	46.4%	46.4%	7.1%	0.0%	0.0%
LAN Equipment	Product Class B - 18 Watt Representative Unit	12.5%	45.8%	16.7%	25.0%	0.0%
Notebooks	Product Class B - 60 Watt Representative Unit	25.8%	53.0%	18.2%	3.0%	0.0%
Notebooks	Product Class B - 120 Watt Representative Unit	25.8%	53.0%	18.2%	3.0%	0.0%
Mobile Phones	Product Class C	45.8%	54.2%	0.0%	0.0%	0.0%
Home Security Systems	Product Class D	21.2%	55.8%	19.2%	3.8%	0.0%
Aquarium Accessories	Product Class E	30.2%	52.6%	12.9%	4.3%	0.0%
Video Game Consoles	Product Class X	5.0%	95.0%	0.0%	0.0%	-
Amateur Radios	Product Class H	50.0%	50.0%	0.0%	0.0%	0.0%

For example if the standard for product class B EPSs is set at CSL 2, 63 percent of answering machines in product class B are assumed not to be scheduled for redesign in-between the announcement and the implementation of this standard and 92.8 percent (46.4% plus 46.4%) of answering machines fall below CSL 2 in 2013. Therefore, 58.5 percent (92.8% times 63%) of answering machines would have to be redesigned in the standards case that would not have been redesigned in the base case. For the product conversion costs, this 58.5 percent is multiplied by the typical R&D expenditure that manufacturers would spend on answering machines in the years between the announcement and the implementation of this standard, had a standard not be implemented. Finally, that number is multiplied by the conversion cost multiplier to get the extra product conversion cost for an application. This number represents the additional R&D costs manufacturers would incur in the standards case that they would not incur in the base case. For capital conversion costs, the only difference is that the 58.5 percent is multiplied by the typical capital expenditure that manufacturers would spend on answering machines. The result is the additional capital expenditure costs manufacturers would incur in the standards case that they would not incur in the base case.

For the 2.5 Watt representative unit DOE assumed that the product and capital conversion costs above CSL 1 would require more substantial product and capital conversion costs, since the technology employed with these units are assumed to change from linear to switch mode technology. Therefore, DOE used twice the base case capital expenditure and research and development for CSLs requiring a switch from linear to switch mode technologies. This occurs at all CSL 2 and above for the 2.5 Watt representative unit. For all other product classes and CSLs the base case conversion costs are used. For a complete listing of product and capital conversion cost multipliers used see the table below.

Table 12.4.16 EPS Product and Capital Conversion Cost Multiplier

Product and Capital Conversion Cost Multiplier	Baseline	CSL 1	CSL 2	CSL 3	CSL 4
Product Class B, 2.5 W Rep Unit	0.00	1.00	2.00	2.00	2.00
Product Class B, 18 W Rep Unit	0.00	1.00	1.00	1.00	1.00
Product Class B, 60 W Rep Unit	0.00	1.00	1.00	1.00	1.00
Product Class B, 120 W Rep Unit	0.00	1.00	1.00	1.00	1.00
Product Class X	0.00	1.00	1.00	1.00	-
Product Class H	0.00	1.00	1.00	1.00	1.00

DOE uses a similar approach to calculate capital conversion costs, using application lifetimes and the shipments of each application between 2011 and 2013 as the key assumptions. Whereas product conversion costs are based on a multiple of typical industry R&D expenditures, capital conversion costs are based on a multiple of typical industry capital expenditures. DOE assumed that the changes for the actual EPS designs would take less extraordinary capital than BCs because changes affect only the external housing of components of final products (and would not also alter application housing, as major BC changes may require for some select applications). Table 12.4.17 through Table 12.4.22 show DOE's estimates of the product and capital conversion costs necessary for each EPS representative unit at each CSL.

Table 12.4.17 Product and Capital Conversion Costs for Product Class B – 2.5 Watt Representative Unit by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	58.3%	0.500	-	-
CSL 1	-	67.9%	0.300	$1.91	$2.11
CSL 2	1	71.0%	0.130	$8.26	$9.13
CSL 3	2	73.5%	0.100	$8.80	$9.73
CSL 4	3	74.8%	0.039	$9.01	$9.96

Table 12.4.18 Product and Capital Conversion Costs for Product Class B – 18 Watt Representative Unit by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	76.0%	0.500	-	-
CSL 1	-	80.3%	0.300	$2.49	$2.75
CSL 2	1	83.0%	0.2	$9.16	$10.12
CSL 3	2	85.4%	0.1	$11.47	$12.68
CSL 4	3	91.1%	0.039	$12.80	$14.15

Table 12.4.19 Product and Capital Conversion Costs for Product Class B – 60 Watt Representative Unit by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	85.0%	0.5	-	-
CSL 1	-	87.0%	0.5	$2.14	$2.36
CSL 2	1	87.0%	0.2	$9.37	$10.36
CSL 3	2	88.0%	0.073	$11.32	$12.51
CSL 4	3	92.2%	0.05	$11.47	$12.68

Table 12.4.20 Product and Capital Conversion Costs for Product Class B – 120 Watt Representative Unit by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	85.0%	0.5	-	-
CSL 1	-	87.0%	0.5	$0.77	$0.85
CSL 2	1	88.0%	0.23	$2.35	$2.60
CSL 3	2	88.4%	0.21	$2.89	$3.20
CSL 4	3	93.5%	0.089	$2.99	$3.30

Table 12.4.21 Product and Capital Conversion Costs for Product Class X by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	82.4%	12.3	-	-
CSL 1	1	86.4%	0.4	$0.34	$0.38
CSL 2	2	86.4%	0.3	$6.86	$7.58
CSL 3	3	88.5%	0.3	$6.86	$7.58

Table 12.4.22 Product and Capital Conversion Costs for Product Class H by CSL

CSL (Efficiency Level)	TSL	Efficiency	No Load Power	Product Conversion Costs *2010$ millions*	Capital Conversion Costs *2010$ millions*
Baseline	-	62.4%	15.43	-	-
CSL 1	-	81.3%	6.01	$0.01	$0.01
CSL 2	1	84.6%	0.5	$0.02	$0.02
CSL 3	2	87.5%	0.5	$0.02	$0.02
CSL 4	3	92.0%	0.266	$0.02	$0.02

12.4.1.9 EPS Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of new and amended energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all product classes. In the standards case, DOE modeled two markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of new and amended energy conservation standards: (1) a flat markup scenario, and (2) a preservation of operation profit scenario. These scenarios lead to different markups values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

Flat Markup Scenario

The flat markup scenario assumes that the cost of goods sold for each product is marked up by a flat percentage to cover standard SG&A expenses, R&D expenses, and profit. In this scenario the 1.36 manufacturer markup is maintained by EPS ODMs in both the base case and the standards case. This scenario represents the upper bound of industry profitability in the standards case because manufacturers are able to fully pass through additional costs to their customers due to standards, which may not be possible since the EPS OEMs exert pressure on the ESP ODMs to keep costs down.

Preservation of Operating Profit Scenario

DOE also modeled a lower-bound profitability scenario. During interviews, ODMs and OEMs indicated that the electronics industry is extremely price sensitive throughout the distribution chain. Because of the highly competitive market, this scenario models the case in which ODMs' higher production costs for more efficient EPSs cannot be fully passed through to OEMs. In this scenario, the manufacturer markups are lowered such that manufacturers are only able to maintain the base-case total operating profit in absolute dollars in the standards case, despite higher product costs and required investment. DOE implemented this scenario in the GRIM by lowering the manufacturer markups at each TSL to yield approximately the same earnings before interest and taxes in the standards case in the year after the compliance date of the amended standards as in the base case. This scenario represents the lower bound of industry profitability following new and amended energy conservation standards because higher production costs and the investments required to comply with the new and amended energy conservation standards do not yield additional operating profit. This scenario incorporates many concerns EPS ODMs brought up during manufacturer interviews. EPS ODMs believe that cost increases at higher efficiencies would not be able to be passed on to OEMs because consumers except electronics prices to continue to decline over time. Consumers may not be willing to accept an increase in the price of electronics even if these products are more efficient. Therefore, EPS ODMs believe they may not be able to maintain the 1.36 markup that is assumed in the flat markup scenario if higher efficiency standards are adopted. Table 12.4.23 through Table 12.4.28 lists the products DOE analyzed with the corresponding markups at each TSL for EPSs.

Preservation of Operating Profit Manufacturer Markups

Table 12.4.23 Preservation of Operating Profit Markups for Product Class B – 2.5 Watt Representative Unit

CSL (Efficiency)	**Markups by TSL**			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355			
CSL 2	1.355	1.343		
CSL 3	1.355	1.355	1.340	
CSL 4	1.355	1.355	1.355	1.338

Table 12.4.24 Preservation of Operating Profit Markups for Product Class B – 18 Watt Representative Unit

CLS (Efficiency)	**Markups by TSL**			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355			
CSL 2	1.355	1.353		
CSL 3	1.355	1.355	1.348	
CSL 4	1.355	1.355	1.355	1.332

Table 12.4.25 Preservation of Operating Profit Markups for Product Class B – 60 Watt Representative Unit

CLS (Efficiency)	**Markups by TSL**			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355			
CSL 2	1.355	1.350		
CSL 3	1.355	1.355	1.347	
CSL 4	1.355	1.355	1.355	1.339

Table 12.4.26 Preservation of Operating Profit Markups for Product Class B – 120 Watt Representative Unit

CLS (Efficiency)	Markups by TSL			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355			
CSL 2	1.355	1.354		
CSL 3	1.355	1.355	1.353	
CSL 4	1.355	1.355	1.355	1.337

Table 12.4.27 Preservation of Operating Profit Markups for Product Class X

CLS (Efficiency)	Markups by TSL			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355	1.355		
CSL 2	1.355	1.355	1.354	
CSL 3	1.355	1.355	1.355	1.343

Table 12.4.28 Preservation of Operating Profit Markups for Product Class H

CLS (Efficiency)	Markups by TSL			
	Baseline	**TSL 1**	**TSL 2**	**TSL 3**
Baseline	1.355			
CSL 1	1.355			
CSL 2	1.355	1.362		
CSL 3	1.355	1.355	1.361	
CSL 4	1.355	1.355	1.355	1.346

12.4.2 EPS Industry Financial Impacts

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the EPS industry. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.4.2.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's NPV, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The EPS GRIM estimates cash flows from 2011 to 2042. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2011 until an estimated compliance date of July 2013) and a long-term assessment over the 30 year analysis period used in the NIA (2013 – 2042).

In the MIA, DOE compares the INPV of the base case (no new and amended energy conservation standards) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the EPS industry, DOE examined the two markup scenarios described above: the flat markup and the preservation of operating profit. While INPV is useful for evaluating the long-term effects of new and amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual net cash flows, Figure 12.4.2 through Figure 12.4.7 below present the annual net or free cash flows from 2010 through 2025 for the base case and different TSLs in the standards case.

Annual cash flows are discounted to the base year, 2011. Between 2011 and the 2013 compliance date of the new and amended energy conservation standards, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new and amended energy conservation standards. The more stringent the new and amended energy conservation standards, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the new and amended energy conservation standards take effect is driven by an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. More stringent TSLs typically have a positive impact on cash flows relative to the base case under the flat markup scenario because manufacturers are able to earner higher operating profit at each TSL in the standards case, which increases cash flow from operations. There is less of an impact on cash flow from operations under the preservation of operating profit scenario following standards because this scenario is calibrated to have the same operating income in the standards case as the base case. In this scenario, the industry value is impacted because production costs increase, but operating profit remains approximately equal to the base case which decreases profit margins as a percentage of revenue. Overall cash flow declines following standards because of higher non-production costs to produce more costly products following standards.

12.4.2.2 Product Class B, C, D, and E Industry Financial Impacts

Table 12.4.29 and Table 12.4.30 provide the INPV estimates for product class B, C, D, and E EPSs. Figure 12.4.1 and Figure 12.4.3 present the annual net cash flows for product class B, C, D, and E EPSs for each of the different markup scenarios.

Table 12.4.29 Changes in EPS Industry Net Present Value for Product Classes B, C, D, and E (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*(2010$ millions)*	231.9	193.0	196.7	249.8
Change in INPV	*(2010$ millions)*	-	(38.9)	(35.2)	17.9
	(%)	-	-16.8%	-15.2%	7.7%

Table 12.4.30 Changes in EPS Industry Net Present Value for Product Classes B, C, D, and E (Preservation of Operating Profit Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*(2010$ millions)*	231.9	169.4	150.5	108.4
Change in INPV	*(2010$ millions)*	-	(62.5)	(81.4)	(123.5)
	(%)	-	-26.9%	-35.1%	-53.2%

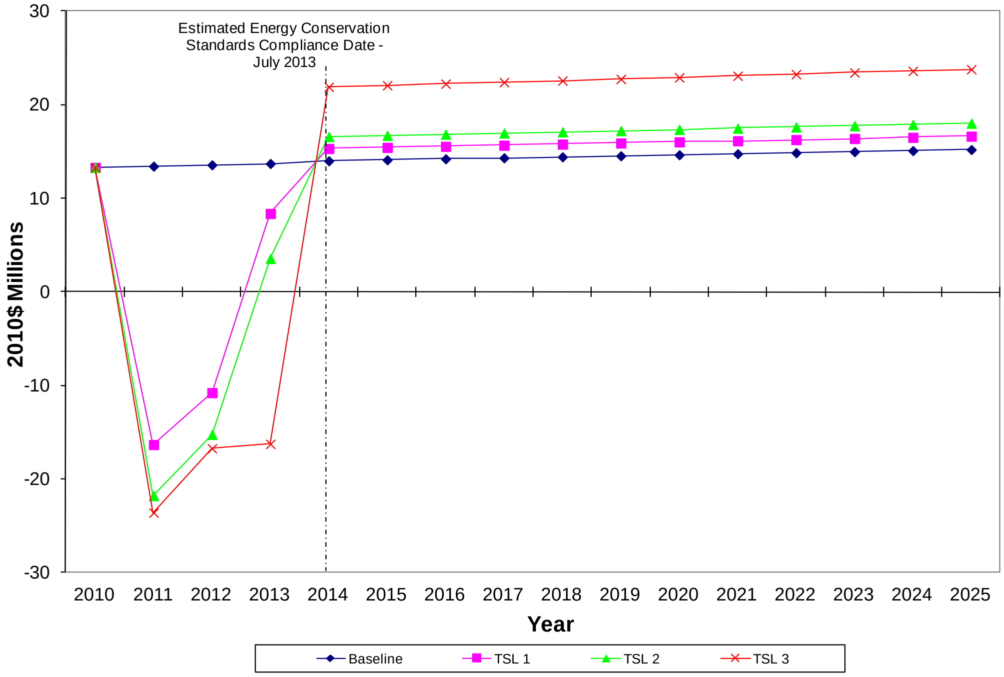


Figure 12.4.2 Annual EPS Industry Net Cash Flows for Product Class B, C, D, and E (Flat Markup Scenario)

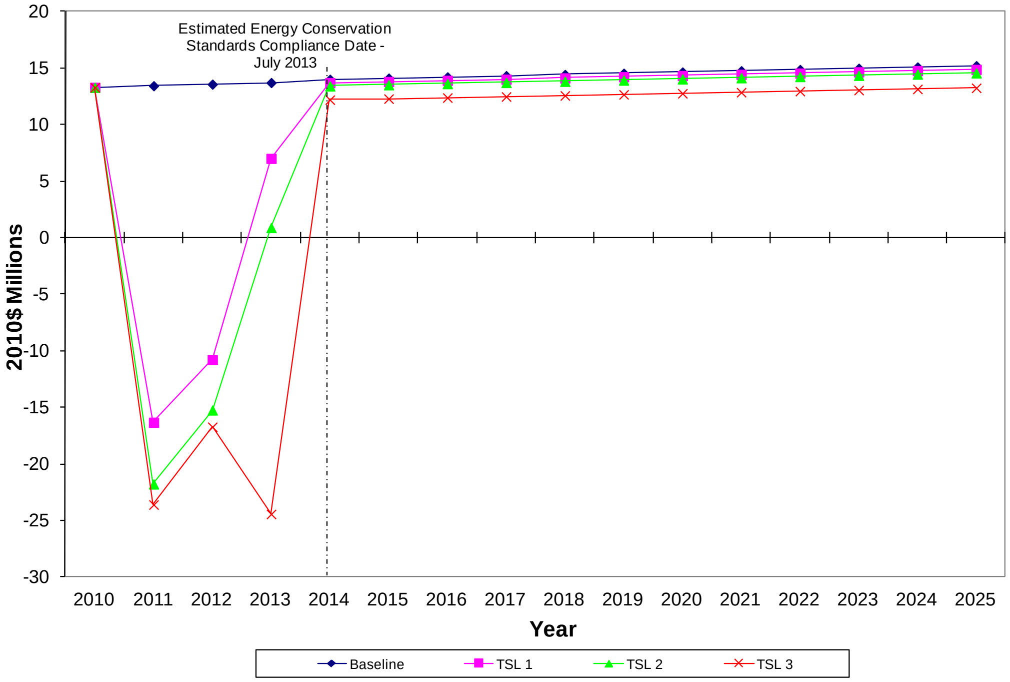


Figure 12.4.3 Annual EPS Industry Net Cash Flows for Product Class B, C, D, and E (Preservation of Operating Profit Scenario)

12.4.2.3 Product Class X Industry Financial Impacts

Table 12.4.31 and Table 12.4.32 provide the INPV estimates for product class X EPSs. Figure 12.4.4 and Figure 12.4.5 present the annual net cash flows for product class X EPSs for each of the different markup scenarios.

Table 12.4.31 Changes in EPS Industry Net Present Value for Product Class X (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	44.1	43.7	32.2	39.6
Change in INPV	*(2010$ millions)*	-	(0.4)	(12.0)	(4.6)
	(%)	-	-1.0%	-27.1%	-10.3%

Table 12.4.32 Changes in EPS Industry Net Present Value for Product Class X (Preservation of Operating Profit Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	44.1	43.4	31.4	26.3
Change in INPV	*(2010$ millions)*	-	(0.7)	(12.8)	(17.9)
	(%)	-	-1.7%	-28.9%	-40.5%

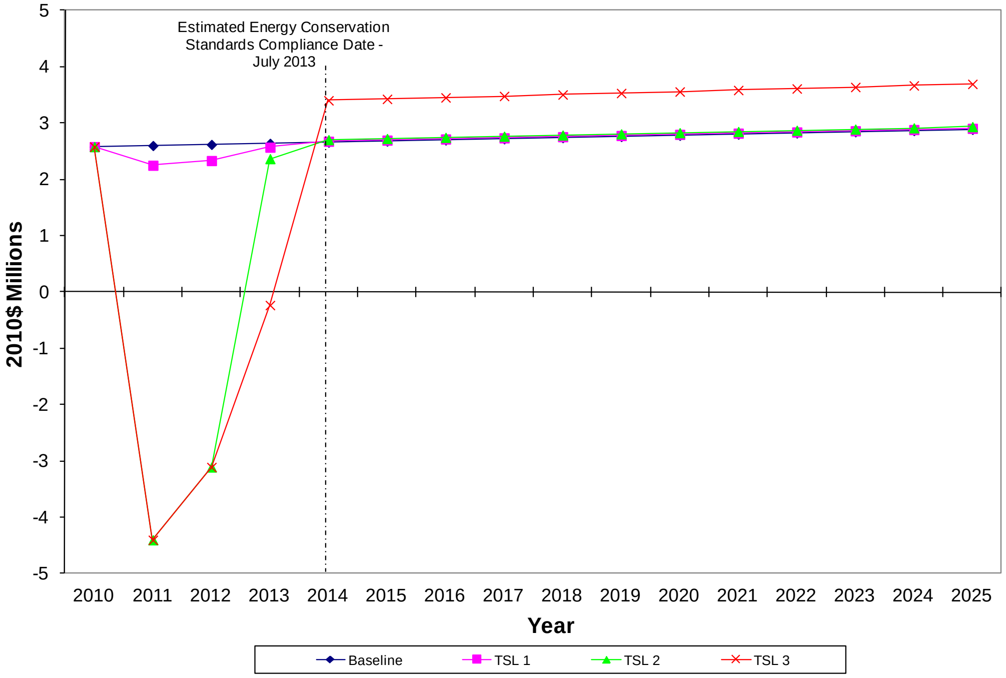


Figure 12.4.4 Annual EPS Industry Net Cash Flows for Product Class X (Flat Markup Scenario)

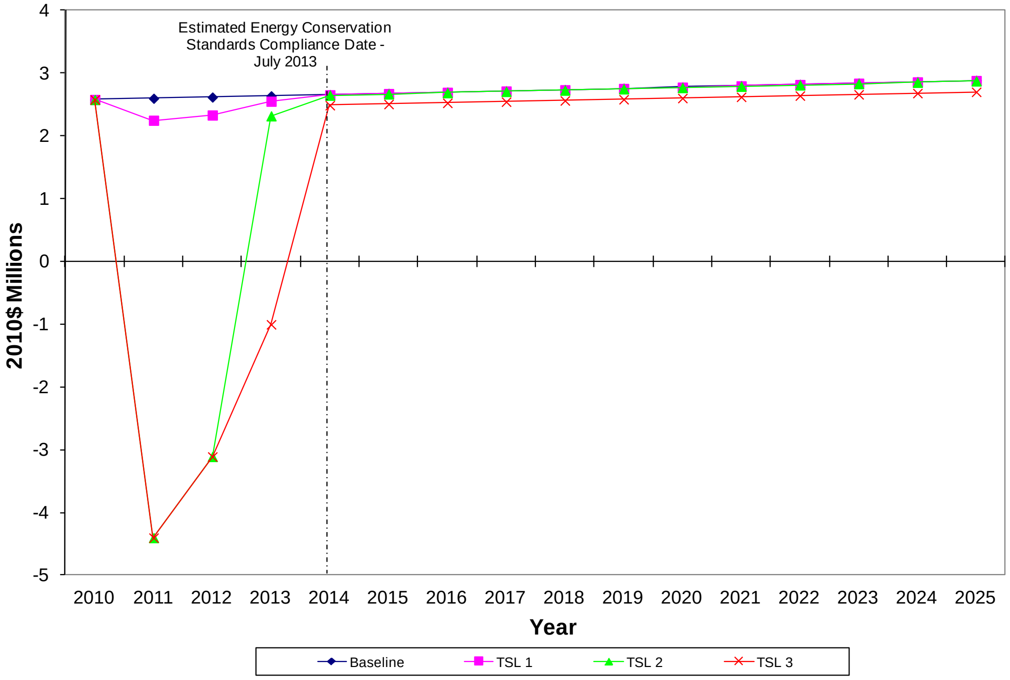


Figure 12.4.5 Annual EPS Industry Net Cash Flows for Product Class X (Preservation of Operating Profit Scenario)

12.4.2.4 Product Class H EPS Industry Financial Impacts

Table 12.4.33 and Table 12.4.34 provide the INPV estimates for product class H EPSs. Figure 12.4.6 and Figure 12.4.7 present the annual net cash flows for product class H EPSs for each of the different markup scenarios.

Table 12.4.33 Changes in EPS Industry Net Present Value for Product Class H (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*(2010$ millions)*	0.11	0.06	0.06	0.08
Change in INPV	*(2010$ millions)*	-	(0.05)	(0.05)	(0.03)
	(%)	-	-45.5%	-44.0%	-24.4%

Table 12.4.34 Changes in EPS Industry Net Present Value for Product Class H (Preservation of Operating Profit Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*(2010$ millions)*	0.11	0.07	0.07	0.06
Change in INPV	*(2010$ millions)*	-	(0.04)	(0.04)	(0.05)
	(%)	-	-32.7%	-33.8%	-47.3%

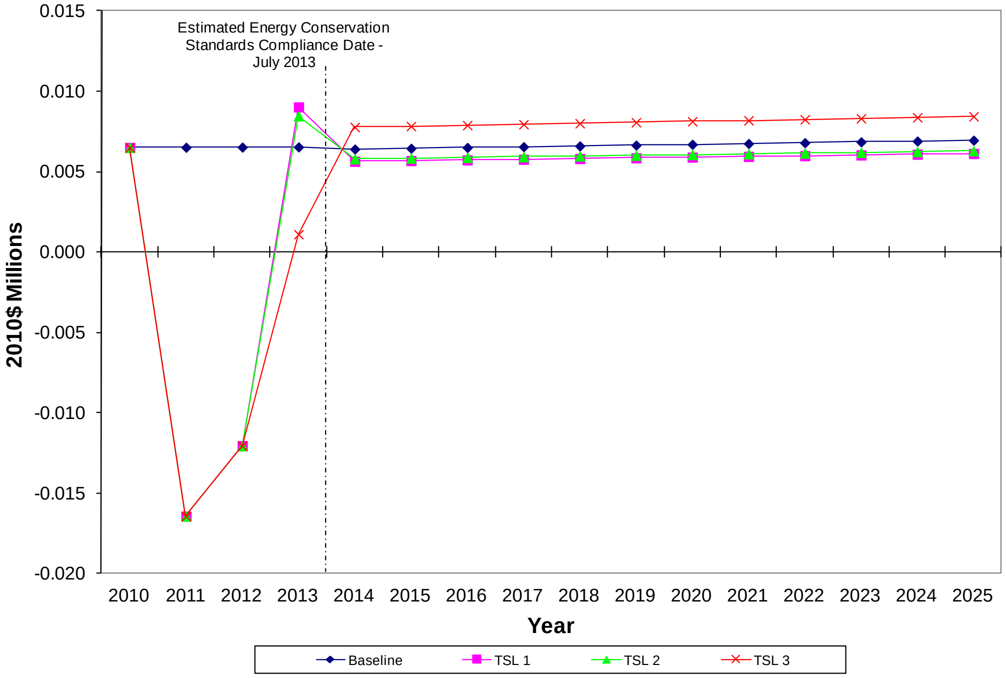


Figure 12.4.6 Annual EPS Industry Net Cash Flows for Product Class H (Flat Markup Scenario)

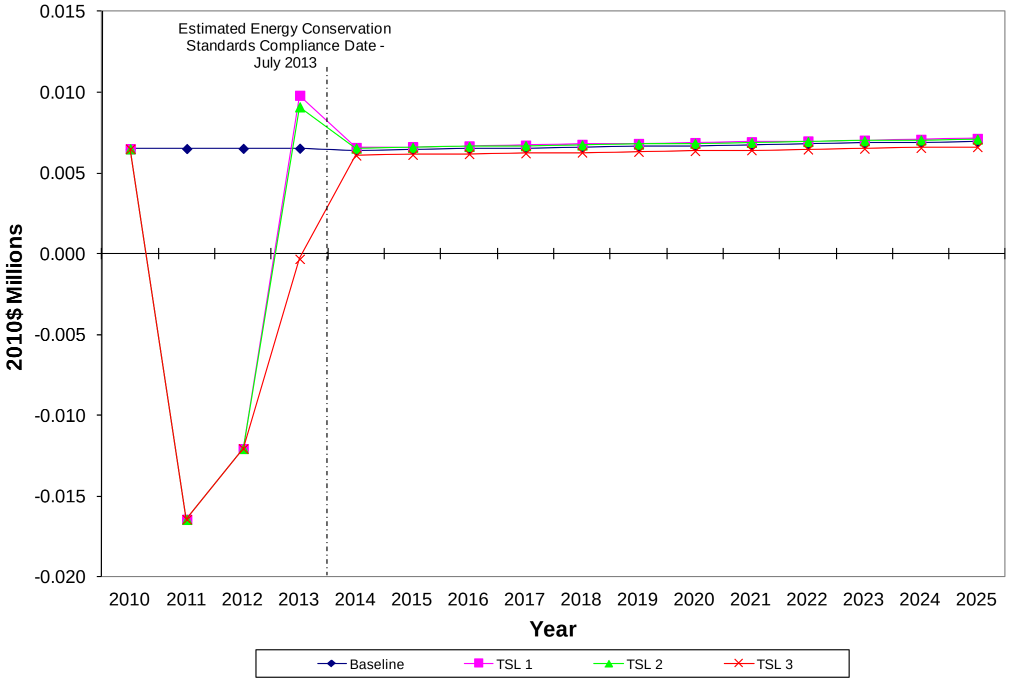


Figure 12.4.7 Annual EPS Industry Net Cash Flows for Product Class H (Preservation of Operating Profit Scenario)

12.4.3 EPS Impacts on Small Manufacturers

DOE did not identify any small business manufacturers of EPSs. DOE also did not identify any domestic manufacturers of EPSs (i.e., all residential EPSs sold in the United States are imported). Because there are no small business manufacturers of EPSs, DOE did not conduct a subgroup analysis for small business EPS manufacturers.

12.4.4 EPS Other Impacts

12.4.4.1 EPS Employment

DOE's research suggests that currently no EPSs are manufactured domestically. Most OEMs or their domestic distributors have employees in the United States that work on design, technical support, sales, training, certification, and other requirements. However, DOE did not identify any domestic manufacturing for EPSs and DOE does not anticipate any changes in domestic production employment in response to new and amended energy conservation standards.

12.4.4.2 EPS Production Capacity

DOE does not anticipate that the standards proposed in today's rule would adversely impact manufacturer capacity. For EPSs, EISA has set a statutory compliance date. The EPS industry is characterized by rapid product development lifecycles. DOE believes the compliance date proposed in the NOPR provides sufficient time for manufacturers to ramp up capacity to meet the proposed standards for EPSs.

12.4.5 EPS Conclusions

12.4.5.1 Product Class B, C, D, and E

At TSL 1, DOE estimates impacts on INPV to range from -$38.9 million to -$62.5 million, or a change in INPV of -16.8 percent to -26.9 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 179.2 percent to -$10.8 million, compared to the base-case value of $13.6 million in the year leading up to the proposed energy conservation standards.

At TSL 1, manufacturers of product classes B, C, D, and E EPSs face a relatively moderate loss in INPV. For these product classes, the required efficiencies at TSL 1 correspond to an intermediate level above the ENERGY STAR 2.0 levels but below the best in market efficiencies. The conversion costs are a major contribution of the decrease in INPV because the vast majority of the shipments fall below CSL 2. Manufactures will incur product and capital conversion costs of approximately $61.4 million at TSL 1. In 2013 approximately 84% of all product class B, C, D, and E shipments fall below the amended energy conservation standards. In addition, at TSL 1 92% of the products in 2013 for the 2.5 Watt representative unit fall below the efficiency standard and would incur more substantial conversion costs since achieving the efficiency standard requires 2.5 Watt representative units to change from using linear technology to switch mode technology. This significantly adds to the conversion costs for these 2.5 Watt representative units, which account for approximately half of all the product class B, C, D, and E shipments. At TSL 1 the MPC increases 45% for the 2.5 Watt representative units, 5% for the 18 Watt representative units, 14% for the 60 Watt representative units, and 3% for the 120 Watt representative units over the baseline. The moderate increases in MPCs drive the different INPVs for the two scenarios. The conversion costs are significant enough to cause a slight negative industry impact even if the incremental change in MPCs is fully passed on to OEMs. Impacts are more significant under the preservation of operating profit scenario as manufactures are not able to pass on the full increase in cost of their product as they are in the flat markup scenario.

At TSL 2, DOE estimates impacts on INPV to range -$35.2 million to -$81.4 million, or a change in INPV of -15.2 percent to -35.1 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 212.1 percent to -$15.2 million, compared to the base-case value of $13.6 million in the year leading up to the proposed energy conservation standards.

TSL 2 represents the best in market efficiencies for product classes B, C, D, and E EPSs. The difference in conversion costs and incremental production costs at TSL 2 make the INPV impacts slightly better than TSL 1 in the flat markup scenario and worse under the preservation of operating profit scenario. The product conversion costs increase by $5.2 million and the capital conversion costs increase by $5.7 million from TSL 1 because the vast majority of current products fall below the efficiency requirements at TSL 2. Also, at TSL 2 the MPC increases 60% for the 2.5 Watt representative units, 18% for the 18 Watt representative units, 22% for the 60 Watt representative units, and 4% for the 120 Watt representative units over the baseline.

However, the similar conversion costs and relatively minor additional incremental costs make the industry impacts at TSL 2 similar to those at TSL 1.

At TSL 3, DOE estimates impacts on INPV to range $17.9 million to -$123.5 million, or a change in INPV of 7.7 percent to -53.2 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 223.0 percent to -$16.7 million, compared to the base-case value of $13.6 million in the year leading up to the proposed energy conservation standards.

TSL 3 represents the max-tech CSL for product class B, C, D, and E EPSs. At TSL 3, DOE estimates industry impacts to range from slightly positive to significantly negative. None of the existing products on the market meet the efficiency requirements at TSL 3. However, since most of the products at TSL 2 also fall below the standard level, there is almost no difference between the conversion costs at TSL 2 and TSL 3. The different INPV impacts occur due to the large changes in incremental MPCs at the max-tech level. At TSL 3 the MPC increases 69% for the 2.5 Watt representative units, 80% for the 18 Watt representative units, 46% for the 60 Watt representative units, and 53% for the 120 Watt representative units over the baseline. If manufactures are able to fully pass on these costs to OEM (the flat markup scenario) the increase in cash flow from operations is enough to overcome the conversion costs to meet the max-tech level and INPV increases slightly. However, if the manufactures are not able to pass on these costs and only maintain the current operating profit (the preservation of operating profit markup scenario), there is a large, negative impact on INPV. The conversion costs associated with switching the entire market, the large increase in incremental MPCs, and the extreme pressure from OEMs to keep product prices down make it more likely that ODMs will not be able to fully pass on these costs and face a substantial loss instead of a slight gain in INPV at TSL 3.

12.4.5.2 Product Class X

At TSL 1, DOE estimates impacts on INPV to range -$0.4 million to -$0.7 million, or a change in INPV of -1.0 percent to -1.7 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 10.9 percent to $2.3 million, compared to the base-case value of $2.6 million in the year leading up to the proposed energy conservation standards.

At TSL 1, manufacturers of product class X face a very slight decline in INPV. The total conversion costs are approximately $0.7 million. Conversion costs are low because 95% of the products already meet the TSL 1 efficiency requirements. Since most of the market is not impacted at TSL 1, there are only slight impacts on INPV.

At TSL 2, DOE estimates impacts on INPV to range -$12.0 million to -$12.8 million, or a change in INPV of -27.1 percent to -28.9 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 218.6 percent to -$3.1 million, compared to the base-case value of $2.6 million in the year leading up to the proposed energy conservation standards.

At TSL 2, manufacturers face a more noticeable loss in industry value. DOE estimates that manufacturers will incur total product and capital conversion costs of $14.4 million at TSL 2. The conversion costs increase at TSL 2 because the entire market falls below the efficiency requirements at TSL 2. However, the total impacts are also driven by the incremental MPCs at TSL 2. At TSL 2 the MPC only slightly increases 16% over the baseline. Therefore, the difference in INPV in the flat markup scenario is similar to the INPV in the preservation of operating profit scenario.

At TSL 3, DOE estimates impacts on INPV to range -$4.6 million to -$17.9 million, or a change in INPV of -10.3 percent to -40.5 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 218.6 percent to $3.1 million, compared to the base-case value of $2.6 million in the year leading up to the proposed energy conservation standards.

TSL 3 could result in substantial impacts on INPV. As with TSL 2, the entire market falls below the required efficiency at TSL 3 and total industry conversion costs are also $14.4 million. However, the main difference at TSL 3 is the increase in the MPC. At TSL 3 the MPC increases 46% over the baseline. If ODM can past on the higher price of these products to the OEM at TSL 3 the decline in INPV is not too severe. However, if the ODM cannot pass on these higher MPC to OEM then the loss in INPV is much more substantial.

12.4.5.3 Product Class H

At TSL 1, DOE estimates impacts on INPV to range -$0.04 million to -$0.05 million, or a change in INPV of -32.7 percent to -45.5 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 284.4 percent to -$0.01 million, compared to the base-case value of $0.01 million in the year leading up to the proposed energy conservation standards.

At TSL 1 manufacturers of product class H face a significant relative loss in industry value. The base case industry value of $100,000 is low and since DOE estimates that total conversion costs at TSL 1 would be approximately $50,000, the conversion costs represent a substantial portion of total industry value. The conversion costs are high relative to the base case INPV because the entire market in 2013 would fall below an efficiency standard set at TSL 1. In addition, the MPC at TSL 1 declines by 21% compared to the baseline since the switching technology is less costly to manufacturer than baseline products that use linear technology. This lowers the MSP and revenue earned by manufactures that make baseline products, further decreasing INPV and augmenting the impacts on INPV due to standards.

At TSL 2, DOE estimates impacts on INPV to range -$0.04 million to -$0.05 million, or a change in INPV of -33.8 percent to -44.0 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 284.4 percent to -$0.01 million, compared to the base-case value of $0.01 million in the year leading up to the proposed energy conservation standards.

The impacts on INPV at TSL 2 are similar to TSL 1. The conversion costs are the same since the entire market in 2013 would fall below the required efficiency at both TSL 1 and TSL 2. Also, the MPC decreases by 19% at TSL 2 compared to the baseline, which is also similar to the 21% decrease at TSL 1. Overall, the similar conversion costs and lower industry revenue for the minimally compliant products make the INPV impacts at TSL 2 similar to TSL 1.

At TSL 3, DOE estimates impacts on INPV to range -$0.03 million to -$0.05 million, or a change in INPV of -24.4 percent to -47.3 percent. At this proposed level, industry free cash flow is estimated to decrease by approximately 284.4 percent to -$0.01 million, compared to the base-case value of $0.01 million in the year leading up to the proposed energy conservation standards.

Impacts on INPV at TSL range from moderately to substantially negative at TSL 3. As with TSL 1 and TSL 2, the entire market falls below the required efficiency and the total industry conversion costs estimated by DOE remain at $50,000. However, at TSL 3 the MPC increases relative to estimated cost of the baseline unit and changes the possible impacts on INPV at TSL 3. If ODMs can fully pass on the higher production cost of these products to the OEM at TSL 3, the decline in INPV is less severe. However, if the ODM cannot pass on these higher MPC to OEM then the loss in INPV is much more substantial.

12.5 BATTERY CHARGER METRICS

DOE chose to analyze the BC OEM market as opposed to the BC ODM market. DOE decided to analyze BC OEMs because BCs are almost always sold with an application and not as a standalone product like EPSs. Also BC OEMs usually are responsible for any costs required to alter the application if the new BC design requires it. Lastly, BC OEMs are usually responsible for the costs associated with compliance and product testing associated with new standards.

BC applications are divided into nine product classes; 1, 2, 3, 4, 5, 6, 7, 8, and 10. DOE also grouped these applications into four industry subgroups; small appliances, consumer electronics, power tools, and high energy application. These industry subgroups span across the product class groupings. DOE also grouped various product classes together when presenting the results of the MIA. BC product classes 2, 3, and 4 are grouped together and BC product classes 5 and 6 are grouped together. All other BC product classes are presented individually.

12.5.1 BC Grim Inputs and Assumptions

The GRIM serves as the main tool for assessing the impacts on industry due to new BC energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without new energy conservation standards.

12.5.1.1 BC Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.5.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses a number of inputs to arrive at a series of annual cash flows, beginning with the base year of the analysis, 2011, and continuing to 2042. The model calculates the INPV by summing the stream of annual discounted cash flows during this period.[4]

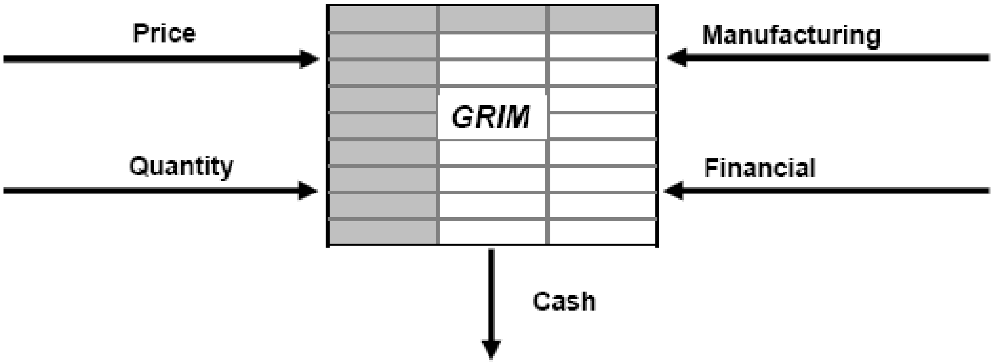


Figure 12.5.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base case and the standard case scenario induced by new energy conservation standards. The difference in INPV between the base case and the standard case(s) represents the estimated financial impact of the new energy conservation standard on manufacturers. Appendix 12-C provides more technical details and user information for the GRIM.

12.5.1.2 BC Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, Census data, credit ratings, the shipments model, the engineering analysis, the manufacturer interviews, market research, and price surveys.

Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the financial inputs to the GRIM. These reports exist for publicly held companies and are freely available to the general public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly-traded manufacturers of products that are sold with and/or incorporate covered BCs. Because these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire companies as its initial estimates of the financial parameters in the BC GRIM analysis. DOE categorized these companies into four broad industries—small appliances, consumer electronics, power tools, and high energy appliances—and developed a set of financial parameters for each group. These figures were later revised using feedback from interviews to be representative of manufacturing for each industry group. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital
- SG&A

- R&D
- Depreciation
- Capital expenditures
- Net PPE

Standard and Poor Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the national impact analysis (NIA). The model relied on historical shipments data for BC applications. Chapter 9 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

Engineering Analysis

During the engineering analysis, DOE used a manufacturing cost model to develop MPC estimates for BCs. The analysis provided a detailed bill of material and total production costs for products at each efficiency level. The engineering analysis also estimated a manufacturer markup for each product class to provide the manufacturer selling price (MSP) for each BC product class at every efficiency level.

Manufacturer Interviews

During the course of the MIA, DOE conducted interviews with a representative cross-section of BC manufacturers and original equipment manufacturers (OEMs) of battery-operated products. DOE also interviewed manufacturers representing a significant portion of sales in most product classes. During these discussions, DOE obtained information to determine and verify GRIM input assumptions in each industry. Key topics discussed during the interviews and reflected in the GRIM include:

- capital conversion costs (one-time investments in PPE);
- product conversion costs (one-time investments in research, product development, testing, and marketing);
- product cost structure, or the portion of the MPCs related to materials, labor, overhead, and depreciation costs;
- projected total shipment and shipment distribution mix; and
- MPCs estimated in the engineering analysis.

12.5.1.3 BC Financial Parameters

As discussed above, in the manufacturer interviews DOE used publicly available annual financial reports of original equipment manufacturers of battery-operated products to estimate each BC industry subgroup's financial parameters. Table 12.5.1 through Table 12.5.4 below shows the result of averaging of all available companies' financial parameters for each BC subgroup.

Table 12.5.1 GRIM Financial Parameters for Consumer Electronics Based on 2006-2010 Company Financial Data

Parameter	Industry Average
Tax Rate ***(% of Taxable Income)***	28.6%
Working Capital ***(% of Revenue)***	24.0%
SG&A ***(% of Revenue)***	17.7%
R&D ***(% of Revenues)***	5.7%
Depreciation ***(% of Revenues)***	3.3%
Capital Expenditures ***(% of Revenues)***	2.9%
Net Property, Plant, and Equipment ***(% of Revenues)***	13.1%

Table 12.5.2 GRIM Financial Parameters for Small Appliances Based on 2006-2010 Company Financial Data

Parameter	Industry Average
Tax Rate ***(% of Taxable Income)***	24.7%
Working Capital ***(% of Revenue)***	15.5%
SG&A ***(% of Revenue)***	20.9%
R&D ***(% of Revenues)***	4.5%
Depreciation ***(% of Revenues)***	4.1%
Capital Expenditures ***(% of Revenues)***	4.1%
Net Property, Plant, and Equipment ***(% of Revenues)***	16.6%

Table 12.5.3 GRIM Financial Parameters for Power Tools Based on 2006-2010 Company Financial Data

Parameter	Industry Average
Tax Rate ***(% of Taxable Income)***	25.6%
Working Capital ***(% of Revenue)***	27.6%
SG&A ***(% of Revenue)***	19.8%
R&D ***(% of Revenues)***	3.6%
Depreciation ***(% of Revenues)***	3.1%
Capital Expenditures ***(% of Revenues)***	3.3%
Net Property, Plant, and Equipment ***(% of Revenues)***	16.6%

Table 12.5.4 GRIM Financial Parameters for High Energy Based on 2006-2010 Company Financial Data

Parameter	Industry Average
Tax Rate ***(% of Taxable Income)***	27.3%
Working Capital ***(% of Revenue)***	15.6%
SG&A ***(% of Revenue)***	19.0%
R&D ***(% of Revenues)***	3.6%
Depreciation ***(% of Revenues)***	3.0%
Capital Expenditures ***(% of Revenues)***	3.0%
Net Property, Plant, and Equipment ***(% of Revenues)***	15.0%

When data was not available from a sufficient number of manufacturers within an industry subgroup, DOE included broader market data to generate the financial parameters shown. During interviews, manufacturers were asked to provide their own figures compared to their industry subgroup's financial parameters listed in Table 12.5.1 through Table 12.5.4. DOE did not receive feedback from BC manufacturers or OEMs that indicated that the financial parameters for any industry subgroups in the GRIM should be adjusted. Therefore, DOE used the financial parameters of each industry subgroup consistent with those shown in Table 12.5.1 through Table 12.5.4.

12.5.1.4 BC Corporate Discount Rate

DOE used the weighted-average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the BC industry based on several representative companies, using the following formula:

WACC = After-Tax Cost of Debt x (Debt Ratio) + Cost of Equity x (Equity Ratio) Eq. 1

The cost of equity is the rate of return that equity investors (including, potentially, the company) expect to earn on a company's stock. These expectations are reflected in the market price of the company's stock. The capital asset pricing model (CAPM) provides one widely used means to estimate the cost of equity. According to the CAPM, the cost of equity (expected return) is:

Cost of Equity = Riskless Rate of Return + β x Risk Premium Eq. 2

where:

Riskless rate of return is the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield.

Risk premium is the difference between the expected return on stocks and the riskless rate.

Beta (β) is the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE determined that the industry average cost of equity is 13.4 percent for the consumer electronics industry (Table 12.5.5); 13.3 percent for the small appliances industry (Table 12.5.6); 13.6 percent for the power tools industry (Table 12.5.7); 17.2 percent for the high energy appliances industry (Table 12.5.8).

Table 12.5.5 Cost of Equity Calculation for Consumer Electronics

Parameter	**Industry Average %**
(1) Average Beta*	1.35
(2) Yield on 10-Year T-Bill (1928-2010)	5.2
(2) Market Risk Premium (1928-2010)	6.1
Cost of Equity (2)+[(1)*(3)]	13.4
Equity/Total Capital	85.5%

* Estimated Beta

Table 12.5.6 Cost of Equity Calculation for Small Appliances

Parameter	**Industry Average %**
(1) Average Beta*	1.34
(3) Yield on 10-Year T-Bill (1928-2010)	5.2
(3) Market Risk Premium (1928-2010)	6.1
Cost of Equity (2)+[(1)*(3)]	13.3
Equity/Total Capital	81.5%

Table 12.5.7 Cost of Equity Calculation for Power Tools

Parameter	**Industry Average %**
(1) Average Beta*	1.39
(2) Yield on 10-Year T-Bill (1928-2010)	5.2
(4) Market Risk Premium (1928-2010)	6.1
Cost of Equity (2)+[(1)*(3)]	13.6
Equity/Total Capital	83.9%

Table 12.5.8 Cost of Equity Calculation for High Energy

Parameter	**Industry Average %**
(1) Average Beta*	1.98
(2) Yield on 10-Year T-Bill (1928-2010)	5.2
(3) Market Risk Premium (1928-2010)	6.1
Cost of Equity (2)+[(1)*(3)]	17.2
Equity/Total Capital	72.1%

Bond ratings are a tool to measure default risk and arrive at a cost of debt. Each bond rating is associated with a particular spread. One way of estimating a company's cost of debt is to treat it as a spread (usually expressed in basis points) over the risk-free rate. DOE used this method to calculate the cost of debt for all application manufacturers by using S&P ratings and adding the relevant spread to the risk-free rate.

In practice, investors use a variety of different maturity Treasury bonds to estimate the risk-free rate. DOE used the 10-year Treasury bond return because it captures long-term inflation expectations and is less volatile than short-term rates. The risk free rate is estimated to be approximately 5.2 percent, which is the average 10-year Treasury bond return between 1928 and 2010.

For the cost of debt, S&P's Credit Services provided the average spread of corporate bonds for most public BC manufacturers. DOE added the industry average spread to the average T-Bill yield. Since proceeds from debt issuance are tax deductible, DOE adjusted the gross cost of debt by the industry average tax rate to determine the net cost of debt for the industry. Table 12.5.9 through Table 12.5.12 presents the derivation of the cost of debt and the capital structure of each subgroup industry (*i.e.* the debt ratio (debt/total capital)).

Table 12.5.9 Cost of Debt Calculation for Consumer Electronics

Parameter	**Industry Average %**
S&P Bond Rating	-
(1) Yield on 10-Year T-Bill (1928-2010)	5.2
(2) Gross Cost of Debt	6.2
(3) Tax Rate	28.6
Net Cost of Debt (2) x (1-(3))	4.4
Debt/Total Capital	14.5%

Table 12.5.10 Cost of Debt Calculation for Small Appliances

Parameter	Industry Average %
S&P Bond Rating	-
(1) Yield on 10-Year T-Bill (1928-2010)	5.2
(2) Gross Cost of Debt	6.5
(3) Tax Rate	24.7
Net Cost of Debt (2) x (1-(3))	4.9
Debt/Total Capital	18.5%

Table 12.5.11 Cost of Debt Calculation for Power Tools

Parameter	Industry Average %
S&P Bond Rating	-
(1) Yield on 10-Year T-Bill (1928-2010)	5.2
(2) Gross Cost of Debt	6.4
(3) Tax Rate	25.6
Net Cost of Debt (2) x (1-(3))	4.8
Debt/Total Capital	16.1%

Table 12.5.12 Cost of Debt Calculation for High Energy

Parameter	Industry Average %
S&P Bond Rating	-
(1) Yield on 10-Year T-Bill (1928-2010)	5.2
(2) Gross Cost of Debt	6.7
(3) Tax Rate	27.3
Net Cost of Debt (2) x (1-(3))	4.9
Debt/Total Capital	27.9%

Using public information for these application manufacturers, the initial estimate for the BC industry's WACC was approximately 12.1 percent. Subtracting an inflation rate of 3.1 percent, the inflation-adjusted WACC and the initial estimate of the discount rate used in the straw-man GRIM is 9.1 percent. DOE also asked for feedback on the 9.1 percent discount during manufacturer interviews and used this feedback to determine that 9.1 percent was an appropriate discount rate for use in the BC GRIM.

12.5.1.5 BC Trial Standard Levels

DOE analyzed the benefits and burdens of multiple TSLs for the products that are the subject of today's proposed rule. A description of each TSL DOE analyzed is provided below. DOE attempted to limit the number of TSLs considered for the NOPR by excluding efficiency levels that do not exhibit significantly different economic and/or engineering characteristics from the efficiency levels already selected as a TSL.

Table 12.5.13 presents the TSLs and corresponding candidate standard levels for BCs. For BCs, DOE examined most product classes individually; however, there were two groups of product classes that use generally similar technology options and cover the exact same range of battery energies. Because of this, DOE grouped all three low energy, non-inductive, product classes (*i.e.* 2, 3, and 4) together and examined the results. Similarly, DOE grouped the two medium energy product classes, 5 and 6, together when it examined those results.

Table 12.5.13 Trial Standard Levels for BC

Product Class	**Trial Standard Level**			
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**
Low Energy, Inductive (1)	CSL 1	CSL 2	CSL 3	-
Low Energy, Low Voltage (2)	CSL 1	CSL 2	CSL 3	CSL 4
Low Energy, Med. Voltage (3)	CSL 1	CSL 1	CSL 2	CSL 3
Low Energy, High Voltage (4)	CSL 1	CSL 1	CSL 2	CSL 3
Med. Energy, Low Voltage (5)	CSL 1	CSL 2	CSL 3	-
Med. Energy, High Voltage (6)	CSL 1	CSL 2	CSL 3	-
High Energy (7)	CSL 1	CSL 2	-	-
Low Voltage DC Input (8)	CSL 1	CSL 2	CSL 3	-
High Voltage DC Input (9)	No TSLs Directly Analyzed			
AC Output (10)	CSL 1	CSL 2	CSL 3	-

12.5.1.6 Application Grouping

Table 12.5.14 Applications in Product Class 1

Product Class 1
Rechargeable Toothbrushes
Rechargeable Water Jets

For BC product class 1, DOE examined three trial standard levels corresponding to each candidate standard level developed in the engineering analysis. TSL 1 is an intermediate level of performance above the baseline. TSL 2 is equivalent to the best-in-market and corresponds to the maximum consumer NPV. TSL 3 is the max-tech level and corresponds to the greatest NES.

Table 12.5.15 Applications in Product Class 2, 3, and 4

Product Class 2	Product Class 3	Product Class 4
Answering Machines	Air Mattress Pumps	DIY Power Tools (External)
Baby Monitors	Blenders	Flashlights/ Lanterns
Beard and Moustache Trimmers	Camcorders	Handheld Vacuums
Bluetooth Headsets	DIY Power Tools (External)	Medical Nebulizers
Can Openers	DIY Power Tools (Integral)	Netbooks
Consumer Two-Way Radios	Handheld Vacuums	Notebooks
Cordless Phones	Mixers	Portable Printers
Digital Cameras	Portable DVD Players	Professional Power Tools
DIY Power Tools (Integral)	Portable Printers	Professional Power Tools
E-Books	RC Toys	Rechargeable Garden Care Products
Hair Clippers	Stick Vacuums	Robotic Vacuums
Handheld GPS	Toy Ride-On Vehicles	Sleep Apnea Machines
Home Security Systems	Universal Battery Chargers	Stick Vacuums
In-Vehicle GPS	VoIP Adapters	Universal Battery Chargers
Media Tablets	Wireless Speakers	
Mobile Internet Hotspots		
Mobile Phones		
MP3 Players		
MP3 Speaker Docks		
Personal Digital Assistants		
Portable Video Game Systems		
Shavers		
Smartphone		
Video Game Consoles		
Wireless Headphones		

DOE’s second set of TSLs is the grouping of product classes 2, 3, and 4. For this grouping, DOE examined four TSLs which were different combinations of the various efficiency levels found for each product class in the engineering analysis. In this grouping, TSL 1 is an intermediate efficiency level above the baseline for each product class and corresponds to the maximum consumer NPV. For 2 of the 3 product classes, TSL 2 corresponds to the same efficiency level, but for the third product class, product class 2, TSL 2 represents an incremental efficiency level below best-in-market. TSL 3 corresponds to the best-in-market efficiency level for all product classes. Finally, TSL 4 corresponds to the max-tech efficiency level for all product classes and therefore, the maximum NES.

Table 12.5.16 Applications in Product Class 5 and 6

Product Class 5	Product Class 6
Marine/Automotive/RV Chargers	Electric Scooters
Mobility Scooters	Lawn Mowers
Portable O2 Concentrators	Motorized Bicycles
Toy Ride-On Vehicles	Wheelchairs
Wheelchairs	

DOE’s third set of TSLs correspond to the grouping of product classes 5 and 6. For this grouping, three TSLs corresponding to different combinations of efficiency levels were examined. For both product classes, TSL 1 is an intermediate efficiency level above the baseline.

TSL 2 corresponds to the best-in-market efficiency level for both product classes and is the level with the highest consumer NPV. Finally, TSL 3 corresponds to the max-tech efficiency level for both product classes and, consequently, the maximum NES.

Table 12.5.17 Applications in Product Class 7

Product Class 7
Golf Carts

For product class 7, DOE only examined two TSLs because of the paucity of products available on the market. TSL 1 corresponds to an efficiency level equivalent to the best-in-market and at this TSL consumer NPV is maximized. TSL 2 is the max-tech level and corresponds to the level with the maximum NES.

Table 12.5.18 Applications in Product Class 8

Product Class 8
Bluetooth Headsets
Camcorders
Digital Cameras
E-Books
Handheld GPS
Mobile Phones
MP3 Players
Personal Digital Assistants

For product class 8, DOE examined three TSLs at incremental levels above the baseline. TSL 1 is the first incremental level between the baseline and best-in-market. At TSL 1 consumer NPV is maximized. TSL 2 is the best-in-market efficiency level and show additional NES over TSL 1. Finally, at TSL 3, or the max-tech efficiency level, NES is maximized.

Table 12.5.19 Applications in Product Class 10

Product Class 10
Uninterruptible Power Supplies

For product class 10, DOE examined three TSLs, each corresponding to an efficiency level developed in the engineering analysis. TSL 1 corresponds to an incremental level of performance above the baseline. TSL 2 is equivalent to what manufacturers stated would be equivalent to the best-in-market level. TSL 3, which shows a maximized NPV and NES, is equivalent to the max-tech efficiency level for product class 10.

DOE also grouped all BC applications into one of four industry subgroups; consumer electronics, small appliances, power tools, and high energy. Table 12.5.20 below lists the applications by industry subgroup.

Table 12.5.20 Applications by Industry Subgroup

Consumer Electronics	Small Appliances	Power Tools	High Energy
Answering Machines	Air Mattress Pumps	DIY Power Tools (External)	Electric Scooters
Baby Monitors	Beard and Moustache Trimmers	DIY Power Tools (Integral)	Golf Carts
Bluetooth Headsets	Blenders	Lawn Mowers	Marine/Automotive /RV Chargers
Camcorders	Can Openers	Professional Power Tools	Mobility Scooters
Consumer Two-Way Radios	Flashlights/Lanterns	Rechargeable Garden Care Products	Motorized Bicycles
Cordless Phones	Hair Clippers		Portable O2 Concentrators
Digital Cameras	Handheld Vacuums		Toy Ride-On Vehicles (PC 5)
E-Books	Mixers		Wheelchairs
Handheld GPS	Rechargeable Toothbrushes		
Home Security Systems	Rechargeable Water Jets		
In-Vehicle GPS	Robotic Vacuums		
LAN Equipment	Shavers		
Media Tablets	Stick Vacuums		
Medical Nebulizers			
Mobile Internet Hotspots			
Mobile Phones			
MP3 Players			
MP3 Speaker Docks			
Netbooks			
Notebooks			
Personal Digital Assistants			
Portable DVD Players			
Portable O2 Concentrators			
Portable Printers			
Portable Video Game Systems			
RC Toys			
Sleep Apnea Machines			
Smartphone			
Toy Ride-On Vehicles (PC 3)			
Uninterruptible Power Supplies			
Universal Battery Chargers			
Video Game Consoles			
Wireless Headphones			
Wireless Speakers			

12.5.1.7 BC NIA Shipment Forecast

The GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM used the NIA shipments forecasts from 2009 to 2042 for BCs. However, only the shipments in 2011 and after have an impact on INPV because 2011 is the base year to which future cash flows are discounted and summed. Chapter 9 of the TSD explains DOE's calculations of total shipments in detail. Table 12.5.21 shows total shipments forecasted in the shipment analysis for BCs broken out by subgroups in 2013. Table 12.5.22 shows total shipments forecasted in the shipment analysis for BCs broken out by product class in 2013.

Table 12.5.21 Total NIA Shipments Forecast in 2013 in the Main NIA Shipment Scenario[c] by Product Class (BC)

Product Class	**Total Industry Shipments**
Product Class 1	15,558,122
Product Class 2	256,572,693
Product Class 3	23,760,117
Product Class 4	62,774,117
Product Class 5	5,013,905
Product Class 6	642,578
Product Class 7	217,000
Product Class 8	67,188,254
Product Class 9	9,873,998
Product Class 10	8,242,714
Total	**449,843,507**

Table 12.5.22 Total NIA Shipments Forecast in 2013 in the Main NIA Shipment Scenario by Subgroups (BC)

Product Class	**Total Industry Shipments**
Consumer Electronic Applications	382,707,984
Small Appliances	37,083,575
Power Tools	24,366,124
High Energy	5,685,825
Total	**449,843,507**

Base Case Shipments Forecast

As with EPS shipments, DOE estimated total domestic 2013 shipments of each analyzed application that is sold with a BC. The applications and their associated shipments are then distributed among the 10 product classes and among the four industry categories. To calculate total BC shipments from 2013 to the end of the analysis period, DOE assumed a constant compound annual growth rate for each product class.

Additionally, on January 12th, 2012, the California Energy Commission (CEC) established energy conservation standards for BCs in the state of California. The majority of these standards go into effect on February 1st, 2013 and will likely have an effect on DOE's base case efficiency distributions for BCs. In the reference case, DOE has assumed that the effects of these standards will only be felt in California. Therefore, DOE adjusted its base case efficiency distributions, where only 13 percent of shipments are affected by the California standards. The 13 percent corresponds to the percentage of national gross domestic product attributable to the California economy. In an effort to show the breadth of the potential affects from the CEC BC standards, DOE has created a sensitivity analysis in which it models an alternative base case

---

[c] The estimated compliance date for the BC energy conservation standard is estimated to be July 2013.

efficiency distribution. In this alternative base case, DOE assumes that all shipments of BCs in the nation are affected by the California standards and that all products shipped meet the CEC regulations in the base case. The INPV results of this alternative base case shipment scenario are presented in Appendix 12-D.

Table 12.5.23 Base Case Distribution of Efficiencies for BC in 2013 by Product Class*

Product Class		Baseline	CLS 1	CLS 2	CLS 3	CLS 4
Product Class 1	UEC (kWh/yr)	8.73	6.10	3.04	1.29	-
	% of the Market at EL	78%	11%	11%	0%	-
Product Class 2	UEC (kWh/yr)	8.66	6.47	2.86	1.03	0.81
	% of the Market at EL	18%	22%	57%	3%	0%
Product Class 3	UEC (kWh/yr)	11.90	4.68	0.79	0.75	-
	% of the Market at EL	17%	62%	21%	0%	-
Product Class 4	UEC (kWh/yr)	37.73	9.91	4.57	3.01	-
	% of the Market at EL	9%	39%	52%	0%	-
Product Class 5	UEC (kWh/yr)	84.60	56.09	29.26	15.35	-
	% of the Market at EL	28%	52%	7%	13%	-
Product Class 6	UEC (kWh/yr)	120.60	81.72	38.33	16.79	-
	% of the Market at EL	36%	29%	22%	13%	-
Product Class 7	UEC (kWh/yr)	255.05	191.74	136.77	-	-
	% of the Market at EL	44%	57%	0%	-	-
Product Class 8	UEC (kWh/yr)	0.90	0.66	0.24	0.19	-
	% of the Market at EL	50%	40%	10%	0%	-
Product Class 9	UEC (kWh/yr)	0.79	0.26	0.13	-	-
	% of the Market at EL	25%	50%	25%	-	-
Product Class 10	UEC (kWh/yr)	19.27	6.13	4.00	1.50	-
	% of the Market at EL	87%	0%	0%	13%	-

* This efficiency distribution takes into account the 13 percent shift in efficiency caused by the California standards.

Standards Case Shipments Forecast

The base case efficiency distribution and growth rate drive total industry revenue in the base case. As with EPS shipments, in the standards case DOE assumed that manufacturers will respond to standards by improving those products that do not meet the new standards to the standard level, but not higher. Products that were already as or more efficient than the DOE standard, including those affected by the California standard, remain unaffected in DOE's standard case. This is referred to as a "roll-up" scenario. DOE did not consider elasticity or substitution away from BCs in the standards case in the main NIA scenario. However, this was considered as a sensitivity analysis. The INPV results of this price elasticity shipment sensitivity scenario are presented in Appendix 12-B.

12.5.1.8 BC Production Costs

Calculating the manufacturer impacts at the OEM level for BCs involves two critical cost components: the price the application OEM charges for its finished product and the portion of that price that the BC represents at each CSL. DOE calculated the latter figure—the price of the BC itself at each CSL—in the engineering analysis. The engineering analysis calculated a separate cost efficiency curve for each of the 10 BC product classes. Based on product testing and tear-down data and manufacturer feedback, DOE created a BOM at the ODM level to which markups were applied to calculate the MSP of the BC at each CSL. For the MIA, each application is assigned the BC MSP of the product class to which the application belongs.

DOE then determined representative retail prices for each application. To do this, DOE surveyed popular online retailer websites to sample a number of price points of the most commonly sold products for each application. The price of each application can vary greatly depending on many factors (such as the features of each individual product). For each application, DOE used the average application price found in the product survey. DOE then discounted this representative retail price back to the application MSP using the retail markups derived from annual SEC 10-K reports in the product price determination. Table 12.5.24 through Table 12.5.32 show the production cost estimates used in the GRIM for the product classes for BCs when a flat markup is applied to all products, including those that are sold in California which are affected by the CEC standard, in the base case.

Table 12.5.24 Base Case MSPs for Product Class 1

Application	**BC MSP ($)**				**Application MSP ($)**			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Rechargeable Toothbrushes	$2.98	$3.34	$4.07	$9.88	$58.45	$58.81	$59.54	$65.35
Rechargeable Water Jets	$2.98	$3.34	$4.07	$9.88	$21.03	$21.40	$22.12	$27.93

Table 12.5.25 Base Case MSPs for Product Class 2

Application	BC MSP ($)					Application MSP ($)				
	Baseline	CSL 1	CSL 2	CSL 3	CSL 4	Baseline	CSL 1	CSL 2	CSL 3	CSL 4
Mobile Phone	$0.94	$1.08	$3.24	$5.84	$8.69	$127.64	$127.77	$129.93	$132.53	$135.38
Smartphone	$0.94	$1.08	$3.24	$5.84	$8.69	$344.80	$344.93	$347.09	$349.69	$352.54
Digital Camera	$0.95	$1.09	$3.26	$5.87	$8.74	$160.96	$161.09	$163.26	$165.88	$168.75
Answering Machine	$0.91	$1.04	$3.13	$5.65	$8.41	$32.00	$32.13	$34.22	$36.74	$39.50
Cordless Phones	$0.91	$1.04	$3.13	$5.65	$8.41	$15.83	$15.96	$18.05	$20.57	$23.33
Bluetooth Headsets	$0.94	$1.08	$3.24	$5.84	$8.69	$49.67	$49.81	$51.96	$54.56	$57.42
Portable Video Game Systems	$1.00	$1.15	$3.44	$6.20	$9.23	$115.45	$115.59	$117.89	$120.65	$123.68
Shavers	$0.90	$1.03	$3.09	$5.58	$8.30	$57.95	$58.08	$60.15	$62.63	$65.36
Consumer Two-Way Radios	$0.94	$1.08	$3.24	$5.84	$8.69	$37.77	$37.91	$40.07	$42.66	$45.52
Media Tablets	$0.84	$0.96	$2.88	$5.19	$7.73	$278.67	$278.79	$280.71	$283.02	$285.56
Video Game Consoles	$1.00	$1.15	$3.44	$6.20	$9.23	$177.60	$177.75	$180.04	$182.80	$185.83
Home Security Systems	$0.85	$0.98	$2.93	$5.28	$7.86	$84.14	$84.26	$86.21	$88.56	$91.14
MP3 Players	$0.88	$1.01	$3.03	$5.47	$8.14	$78.65	$78.78	$80.80	$83.23	$85.91
Baby Monitors	$0.92	$1.05	$3.16	$5.70	$8.48	$71.09	$71.22	$73.33	$75.87	$78.65
In-Vehicle GPS	$1.15	$1.32	$3.97	$7.15	$10.64	$93.00	$93.17	$95.82	$99.00	$102.49
Beard and Moustache Trimmers	$0.90	$1.03	$3.09	$5.58	$8.30	$16.36	$16.49	$18.55	$21.04	$23.76
DIY Power Tools (Integral)	$0.94	$1.07	$3.22	$5.80	$8.63	$28.52	$28.65	$30.80	$33.38	$36.21
E-Books	$0.92	$1.05	$3.16	$5.70	$8.48	$164.60	$164.73	$166.84	$169.38	$172.16
Hair Clippers	$0.90	$1.03	$3.09	$5.58	$8.30	$22.48	$22.62	$24.68	$27.16	$29.89
MP3 Speaker Docks	$0.88	$1.01	$3.03	$5.47	$8.14	$56.78	$56.90	$58.93	$61.36	$64.03
Mobile Internet Hotspots	$0.84	$0.96	$2.88	$5.19	$7.73	$193.61	$193.73	$195.65	$197.96	$200.50
Wireless Headphones	$0.88	$1.01	$3.03	$5.47	$8.14	$37.64	$37.77	$39.79	$42.22	$44.90
Can Openers	$0.92	$1.05	$3.16	$5.70	$8.48	$15.59	$15.72	$17.83	$20.37	$23.15
Personal Digital Assistants	$0.84	$0.96	$2.88	$5.19	$7.73	$175.04	$175.16	$177.08	$179.39	$181.93
Handheld GPS	$1.15	$1.32	$3.97	$7.15	$10.64	$133.86	$134.03	$136.67	$139.86	$143.35
Universal Battery Chargers	$0.92	$1.05	$3.16	$5.70	$8.48	$24.55	$24.68	$26.79	$29.32	$32.11

Table 12.5.26 Base Case MSPs for Product Class 3

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Camcorders	$1.18	$3.02	$8.36	$8.42	$165.31	$167.15	$172.49	$172.55
Toy Ride-On Vehicles	$1.19	$3.07	$8.48	$8.54	$77.37	$79.24	$84.65	$84.71
Portable DVD Players	$1.14	$2.93	$8.12	$8.17	$86.24	$88.03	$93.21	$93.27
DIY Power Tools (Integral)	$1.16	$2.99	$8.26	$8.31	$28.52	$30.34	$35.61	$35.67
RC Toys	$1.24	$3.19	$8.83	$8.89	$37.74	$39.69	$45.33	$45.39
DIY Power Tools (External)	$1.16	$2.99	$8.26	$8.31	$65.69	$67.51	$72.78	$72.84
Handheld Vacuums	$1.09	$2.79	$7.72	$7.77	$60.28	$61.98	$66.91	$66.96
LAN Equipment	$1.04	$2.67	$7.40	$7.45	$71.10	$72.74	$77.46	$77.51
Stick Vacuums	$1.09	$2.79	$7.72	$7.77	$62.94	$64.65	$69.58	$69.63
Air Mattress Pumps	$1.14	$2.93	$8.12	$8.17	$20.84	$22.63	$27.82	$27.87
Wireless Speakers	$1.04	$2.67	$7.40	$7.45	$90.64	$92.27	$97.00	$97.05
Portable Printers	$1.13	$2.91	$8.06	$8.12	$139.23	$141.01	$146.16	$146.21
Universal Battery Chargers	$1.14	$2.93	$8.12	$8.17	$24.55	$26.34	$31.52	$31.57
Blenders	$1.14	$2.93	$8.12	$8.17	$106.77	$108.56	$113.74	$113.80
Mixers	$1.14	$2.93	$8.12	$8.17	$106.77	$108.56	$113.74	$113.80

Table 12.5.27 Base Case MSPs for Product Class 4

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Notebooks	$5.13	$9.14	$17.19	$24.80	$388.76	$392.78	$400.83	$408.43
Professional Power Tools	$5.72	$10.20	$19.19	$27.68	$100.23	$104.71	$113.69	$122.19
Netbooks	$5.13	$9.14	$17.19	$24.80	$213.22	$217.24	$225.29	$232.90
DIY Power Tools (External)	$5.72	$10.20	$19.19	$27.68	$65.69	$70.17	$79.15	$87.64
Handheld Vacuums	$5.35	$9.54	$17.94	$25.88	$60.28	$64.47	$72.87	$80.80
Stick Vacuums	$5.35	$9.54	$17.94	$25.88	$62.94	$67.14	$75.54	$83.47
Robotic Vacuums	$5.35	$9.54	$17.94	$25.88	$186.79	$190.98	$199.38	$207.32
Sleep Apnea Machines	$7.32	$13.06	$24.55	$35.42	$358.65	$364.39	$375.88	$386.75
Medical Nebulizers	$7.32	$13.06	$24.55	$35.42	$51.27	$57.01	$68.50	$79.37
Portable Printers	$5.59	$9.96	$18.73	$27.02	$139.23	$143.61	$152.38	$160.67
Rechargeable Garden Care Products	$5.72	$10.20	$19.19	$27.68	$67.91	$72.39	$81.38	$89.87
Universal Battery Chargers	$5.62	$10.03	$18.86	$27.21	$24.55	$28.95	$37.78	$46.13
Flashlights/ Lanterns	$5.62	$10.03	$18.86	$27.21	$17.70	$22.11	$30.94	$39.29

Table 12.5.28 Base Case MSPs for Product Class 5

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Toy Ride-On Vehicles	$28.65	$33.66	$24.33	$196.92	$77.37	$82.37	$73.04	$245.63
Marine/Automotive / RV Chargers	$28.65	$33.66	$24.33	$196.92	$321.70	$326.70	$317.37	$489.96
Mobility Scooters	$28.65	$33.66	$24.33	$196.92	$676.10	$681.11	$671.77	$844.37
Wheelchairs	$28.65	$33.66	$24.33	$196.92	$2,647.85	$2,652.86	$2,643.52	$2,816.12
Portable O2 Concentrators	$35.70	$41.93	$30.30	$245.31	$2,350.42	$2,356.66	$2,345.03	$2,560.03

Table 12.5.29 Base Case MSPs for Product Class 6

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Electric Scooters	$28.65	$33.66	$24.33	$196.92	$109.63	$114.64	$105.31	$277.90
Lawn Mowers	$27.90	$32.77	$23.68	$191.72	$193.02	$197.89	$188.80	$356.84
Motorized Bicycles	$28.65	$33.66	$24.33	$196.92	$524.30	$529.31	$519.97	$692.56
Wheelchairs	$28.65	$33.66	$24.33	$196.92	$2,647.85	$2,652.86	$2,643.52	$2,816.12

Table 12.5.30 Base Case MSPs for Product Class 7

Application	BC MSP ($)			Application MSP ($)		
	Baseline	CSL 1	CSL 2	Baseline	CSL 1	CSL 2
Golf Carts	$136.55	$94.36	$253.47	$4,043.97	$4,001.78	$4,160.89

Table 12.5.31 Base Case MSPs for Product Class 8

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
MP3 Players	$8.40	$4.64	$8.22	$8.48	$78.65	$74.89	$78.46	$78.73
Mobile Phones	$8.97	$4.95	$8.77	$9.05	$127.64	$123.62	$127.44	$127.72
Digital Cameras	$9.02	$4.98	$8.82	$9.10	$160.96	$156.92	$160.76	$161.04
Camcorders	$9.02	$4.98	$8.82	$9.10	$165.31	$161.27	$165.11	$165.39
Bluetooth Headsets	$8.97	$4.95	$8.77	$9.05	$49.67	$45.66	$49.47	$49.75
Personal Digital Assistants	$7.98	$4.41	$7.80	$8.05	$175.04	$171.47	$174.86	$175.11
E-Books	$8.75	$4.83	$8.56	$8.83	$164.60	$160.68	$164.41	$164.68
Handheld GPS	$10.98	$6.07	$10.74	$11.08	$133.86	$128.94	$133.62	$133.96

Table 12.5.32 Base Case MSPs for Product Class 10

Application	BC MSP ($)				Application MSP ($)			
	Baseline	CSL 1	CSL 2	CSL 3	Baseline	CSL 1	CSL 2	CSL 3
Uninterruptible Power Supplies	$3.72	$5.30	$5.73	$6.26	$288.76	$290.34	$290.77	$291.29

12.5.1.9 BC Conversion Costs

DOE received various comments about the impact of product and capital conversion costs on manufacturers of applications that incorporate covered BCs. Based on interviews and comments received, DOE believes that testing and engineering costs could represent a substantial cost burden to manufacturers, depending on the efficiency levels eventually selected. DOE therefore included the testing costs for BC applications to comply with the energy conservation standards in its calculation of conversion costs. At the higher CSLs, manufacturers could be compelled to redesign products that would have been redesigned years later in the base case. DOE accounts for the additional testing and engineering time by assuming that energy conservation standards would require manufacturers to alter products before the end of their natural lifecycle, resulting in extraordinary product conversion costs.

The extent of the product conversion costs incurred by manufacturers depends largely on whether a given standard level requires a technology change—moving from nickel-metal hydride (NiMH) to lithium ion (Li-ion) chemistry, for example—or only minor design tweaks. Within a given product class, some applications will face technology changes and the associated major redesigns at much lower CSLs than other applications. Therefore, DOE estimates product conversion costs for each individual application, rather than by aggregate product class.

Because of the large number of applications, DOE approximates the impacts of standards-driven conversion costs by assuming manufacturers will incur a multiple of normal R&D and capital expenditures at each CSL. Intuitively, this multiple means the product cycle is accelerated, squeezing resources that would normally be spent over a number of years into a shorter timeframe. This is in addition to, not in place of, normal engineering, testing and equipment costs. The R&D multiple used varies based on the current technology employed in baseline products for that application. For example, in product class 2, laptops would not be impacted at CSL 2 whereas power tools would face more substantial conversion costs. Therefore, these applications, despite incorporating BCs in the same product class, are assumed to incur different levels of conversion costs.

DOE believes that in some circumstances changes to the BCs may alter the external housing in the application, triggering design costs and expenses for injection molds. DOE believes these changes would most likely occur in certain applications incorporating BCs for which standards induced a substantial technology shift. DOE includes the associated housing costs in its estimates of the capital conversions costs and believes its methodology accounts for these changes.

DOE also estimated these costs as part of stranded assets, which are treated as a non-cash expense in the compliance year of the standard. DOE estimate 50 percent of required capital expenditure investments would replace stranded assets.

DOE separately calculated the capital conversion, products conversion and stranded assets costs as a result of the CEC standard. These costs were included in the base case scenario and are not part of the DOE standard case conversion costs listed below. These CEC conversion costs are shown in section V.B.2.e in the NOPR. Table 12.5.33 through Table 12.5.41 show DOE’s estimates of the product and capital conversion costs necessary for each BC product class at each CSL. These conversion costs do not include the conversion costs associated with the CEC standard.

Product and Capital Conversion Costs by Product Class

Table 12.5.33 Product and Capital Conversion Costs for Product Class 1 by CSL

Application	**Capital Conversion Costs (2010$ million)**			**Product Conversion Costs (2010$ million)**		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Rechargeable Toothbrushes-Res.	$0.00	$1.75	$1.97	$0.84	$1.91	$4.31
Rechargeable Water Jets-Res.	$0.00	$0.01	$0.01	$0.01	$0.01	$0.03

Table 12.5.34 Product and Capital Conversion Costs for Product Class 2 by CSL

Application	**Capital Conversion Costs (2010$ million)**				**Product Conversion Costs (2010$ million)**			
	CSL 1	CSL 2	CSL 3	CSL 4	CSL 1	CSL 2	CSL 3	CSL 4
Mobile Phones-Res.	$0.00	$1.26	$10.44	$10.44	$0.00	$4.90	$40.59	$40.59
Smartphone-Res.	$0.00	$0.65	$5.39	$5.39	$0.00	$2.53	$20.93	$20.93
Digital Cameras-Res.	$0.19	$0.64	$2.23	$2.42	$0.75	$2.50	$8.68	$9.40
Answering Machines-Res.	$0.14	$0.37	$0.89	$0.89	$0.55	$1.45	$3.45	$3.45
Cordless Phones-Res.	$0.11	$0.29	$0.69	$0.69	$0.43	$1.14	$2.69	$2.69
Bluetooth Headsets-Res.	$0.10	$0.34	$1.18	$1.28	$0.40	$1.32	$4.58	$4.96
Portable Video Game Systems-Res.	$0.11	$0.35	$1.22	$1.33	$0.41	$1.37	$4.76	$5.15
Shavers-Res.	$0.00	$0.00	$2.02	$2.70	$0.00	$0.00	$4.41	$5.88
Mobile Phones-Comm.	$0.00	$0.14	$1.16	$1.16	$0.00	$0.54	$4.51	$4.51
Consumer Two-Way Radios-Comm.	$0.07	$0.24	$0.82	$0.89	$0.28	$0.92	$3.19	$3.45
Media Tablets-Res.	$0.00	$0.14	$0.83	$0.83	$0.00	$0.54	$3.22	$3.22
Smartphone-Comm.	$0.00	$0.11	$0.95	$0.95	$0.00	$0.45	$3.69	$3.69
Video Game Consoles-Res.	$0.05	$0.15	$0.53	$0.57	$0.18	$0.59	$2.06	$2.23
Home Security Systems-Res.	$0.04	$0.12	$0.42	$0.46	$0.14	$0.47	$1.64	$1.78
MP3 Players-Res.	$0.03	$0.11	$0.26	$0.26	$0.12	$0.41	$1.00	$1.00
Consumer Two-Way Radios-Res.	$0.03	$0.12	$0.40	$0.44	$0.14	$0.45	$1.57	$1.70
Baby Monitors-Res.	$0.03	$0.11	$0.37	$0.40	$0.12	$0.41	$1.43	$1.55
In-Vehicle GPS-Res.	$0.02	$0.12	$0.35	$0.35	$0.08	$0.46	$1.34	$1.34
Answering Machines-Comm.	$0.03	$0.08	$0.19	$0.19	$0.12	$0.31	$0.73	$0.73
Beard and Moustache Trimmers-Res.	$0.03	$0.10	$0.35	$0.38	$0.07	$0.22	$0.77	$0.83
Cordless Phones-Comm.	$0.02	$0.06	$0.14	$0.14	$0.09	$0.23	$0.55	$0.55
DIY Power Tools (Integral)-Res.	$0.01	$0.08	$0.20	$0.20	$0.02	$0.17	$0.46	$0.46
Bluetooth Headsets-Comm.	$0.02	$0.06	$0.21	$0.23	$0.07	$0.23	$0.81	$0.88
E-Books-Res.	$0.02	$0.05	$0.19	$0.21	$0.06	$0.21	$0.74	$0.80
Hair Clippers-Res.	$0.02	$0.07	$0.23	$0.25	$0.04	$0.14	$0.50	$0.54
MP3 Speaker Docks-Res.	$0.01	$0.04	$0.14	$0.16	$0.05	$0.16	$0.56	$0.61
Digital Cameras-Comm.	$0.01	$0.03	$0.12	$0.13	$0.04	$0.13	$0.46	$0.49
Mobile Internet Hotspots-Comm.	$0.01	$0.02	$0.08	$0.08	$0.03	$0.09	$0.30	$0.33
Media Tablets-Comm.	$0.00	$0.02	$0.09	$0.09	$0.00	$0.06	$0.36	$0.36
Mobile Internet Hotspots-Res.	$0.01	$0.02	$0.06	$0.07	$0.02	$0.07	$0.25	$0.27
Wireless	$0.00	$0.01	$0.05	$0.06	$0.02	$0.06	$0.20	$0.22

Headphones-Res.								
Can Openers-Res.	$0.00	$0.01	$0.03	$0.03	$0.00	$0.03	$0.06	$0.06
Personal Digital Assistants-Res.	$0.00	$0.00	$0.01	$0.01	$0.00	$0.01	$0.05	$0.05
Handheld GPS-Res.	$0.00	$0.00	$0.02	$0.02	$0.01	$0.02	$0.06	$0.07
Universal Battery Chargers-Res.	$0.00	$0.00	$0.01	$0.01	$0.00	$0.01	$0.04	$0.04
DIY Power Tools (Integral)-Comm.	$0.00	$0.00	$0.01	$0.01	$0.00	$0.01	$0.02	$0.02
Personal Digital Assistants-Comm.	$0.00	$0.00	$0.01	$0.01	$0.00	$0.01	$0.02	$0.02

Table 12.5.35 Product and Capital Conversion Costs for Product Class 3 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Camcorders-Res.	$0.04	$0.34	$0.82	$0.16	$1.33	$3.17
Toy Ride-On Vehicles-Res.	$0.03	$0.30	$0.71	$0.14	$1.16	$2.77
Portable DVD Players-Res.	$0.00	$0.28	$0.60	$0.00	$1.09	$2.34
DIY Power Tools (Integral)-Res.	$0.02	$0.19	$0.51	$0.05	$0.42	$1.14
RC Toys-Res.	$0.02	$0.16	$0.38	$0.07	$0.63	$1.50
DIY Power Tools (External)-Res.	$0.02	$0.10	$0.22	$0.05	$0.21	$0.48
Handheld Vacuums-Res.	$0.01	$0.13	$0.35	$0.03	$0.29	$0.76
LAN Equipment-Res.	$0.01	$0.07	$0.16	$0.03	$0.27	$0.63
Stick Vacuums-Res.	$0.01	$0.08	$0.24	$0.03	$0.19	$0.52
DIY Power Tools (External)-Comm.	$0.00	$0.02	$0.04	$0.01	$0.04	$0.09
Air Mattress Pumps-Res.	$0.00	$0.03	$0.06	$0.01	$0.05	$0.13
Wireless Speakers-Res.	$0.00	$0.01	$0.04	$0.01	$0.06	$0.14
LAN Equipment-Comm.	$0.00	$0.01	$0.03	$0.01	$0.05	$0.13
Portable Printers-Comm.	$0.00	$0.01	$0.02	$0.00	$0.04	$0.09
Universal Battery Chargers-Res.	$0.00	$0.01	$0.03	$0.01	$0.03	$0.10
DIY Power Tools (Integral)-Comm.	$0.00	$0.01	$0.03	$0.00	$0.02	$0.06
Portable Printers-Res.	$0.00	$0.01	$0.02	$0.00	$0.03	$0.07
Blenders-Res.	$0.00	$0.01	$0.01	$0.00	$0.01	$0.03
Mixers-Res.	$0.00	$0.01	$0.02	$0.00	$0.01	$0.04

Table 12.5.36 Product and Capital Conversion Costs for Product Class 4 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Notebooks-Comm.	$0.00	$2.11	$6.15	$0.00	$8.20	$49.04
Notebooks-Res.	$0.00	$1.73	$5.03	$0.00	$6.71	$40.12
Professional Power Tools-Res.	$0.00	$1.92	$2.51	$0.57	$4.28	$11.81
Netbooks-Comm.	$0.00	$0.65	$1.90	$0.00	$2.54	$15.17
DIY Power Tools (External)-Res.	$0.00	$1.05	$1.10	$0.56	$2.33	$5.22
Professional Power Tools-Comm.	$0.00	$1.03	$1.35	$0.31	$2.30	$6.36
Netbooks-Res.	$0.00	$0.53	$1.56	$0.00	$2.08	$12.41
Handheld Vacuums-Res.	$0.00	$0.83	$1.03	$0.18	$1.82	$4.75
Stick Vacuums-Res.	$0.00	$0.52	$0.69	$0.18	$1.12	$3.16
Robotic Vacuums-Res.	$0.00	$0.29	$0.39	$0.10	$0.64	$1.81
DIY Power Tools (External)-Comm.	$0.00	$0.18	$0.19	$0.10	$0.41	$0.92
Sleep Apnea Machines-Res.	$0.00	$0.14	$0.19	$0.09	$0.55	$1.55
Medical Nebulizers-Res.	$0.00	$0.12	$0.15	$0.07	$0.45	$1.26
Portable Printers-Comm.	$0.00	$0.09	$0.10	$0.04	$0.35	$0.84
Portable Printers-Res.	$0.00	$0.07	$0.08	$0.03	$0.29	$0.69
Rechargeable Garden Care Products-Res.	$0.00	$0.02	$0.03	$0.01	$0.05	$0.14
Universal Battery Chargers-Res.	$0.00	$0.01	$0.02	$0.01	$0.05	$0.15
Flashlights/ Lanterns-Res.	$0.00	$0.01	$0.02	$0.01	$0.03	$0.07

Table 12.5.37 Product and Capital Conversion Costs for Product Class 5 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Toy Ride-On Vehicles-Res.	$0.00	$1.57	$3.45	$0.87	$7.46	$12.31
Marine/Automotive/RV Chargers-Res.	$0.00	$0.18	$0.38	$0.41	$0.87	$1.38
Mobility Scooters-Res.	$0.00	$0.08	$0.15	$0.15	$0.36	$0.54
Wheelchairs-Res.	$0.00	$0.05	$0.10	$0.10	$0.23	$0.35
Portable O2 Concentrators-Res.	$0.00	$0.00	$0.00	$0.00	$0.01	$0.02

Table 12.5.38 Product and Capital Conversion Costs for Product Class 6 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Electric Scooters-Res.	$0.00	$0.07	$0.19	$0.11	$0.32	$0.68
Lawn Mowers-Res.	$0.00	$0.06	$0.16	$0.02	$0.27	$0.53
Motorized Bicycles-Res.	$0.00	$0.04	$0.11	$0.07	$0.19	$0.41
Wheelchairs-Res.	$0.00	$0.02	$0.03	$0.03	$0.08	$0.12

Table 12.5.39 Product and Capital Conversion Costs for Product Class 7 by CSL

Application	Capital Conversion Costs (2010$ million)		Product Conversion Costs (2010$ million)	
	CSL 1	CSL 2	CSL 1	CSL 2
Golf Carts-Comm.	$0.15	$1.32	$0.52	$2.32
Golf Carts-Res.	$0.02	$0.16	$0.06	$0.27

Table 12.5.40 Product and Capital Conversion Costs for Product Class 8 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
MP3 Players-Res.	$0.00	$3.30	$3.67	$7.13	$19.26	$42.80
Mobile Phones-Res.	$0.00	$1.66	$1.84	$3.58	$9.66	$21.47
Digital Cameras-Res.	$0.00	$0.49	$0.55	$1.06	$2.87	$6.37
Mobile Phones-Comm.	$0.00	$0.18	$0.20	$0.40	$1.07	$2.39
Camcorders-Res.	$0.00	$0.15	$0.17	$0.33	$0.90	$1.99
Bluetooth Headsets-Res.	$0.00	$0.12	$0.13	$0.25	$0.67	$1.50
Personal Digital Assistants-Res.	$0.00	$0.10	$0.11	$0.21	$0.56	$1.24
Personal Digital Assistants-Comm.	$0.00	$0.04	$0.05	$0.09	$0.24	$0.53
E-Books-Res.	$0.00	$0.04	$0.05	$0.09	$0.24	$0.54
Digital Cameras-Comm.	$0.00	$0.03	$0.03	$0.06	$0.15	$0.34
Bluetooth Headsets-Comm.	$0.00	$0.02	$0.02	$0.04	$0.12	$0.26
Handheld GPS-Res.	$0.00	$0.00	$0.00	$0.01	$0.02	$0.05

Table 12.5.41 Product and Capital Conversion Costs for Product Class 10 by CSL

Application	Capital Conversion Costs (2010$ million)			Product Conversion Costs (2010$ million)		
	CSL 1	CSL 2	CSL 3	CSL 1	CSL 2	CSL 3
Uninterruptible Power Supplies-Res.	$0.00	$0.24	$0.97	$0.47	$1.41	$2.83
Uninterruptible Power Supplies-Comm.	$0.00	$0.14	$0.56	$0.27	$0.82	$1.64

12.5.1.10 BC Markup Scenarios

DOE used several standards case markup scenarios to represent the uncertainty about the impacts of new energy conservation standards on prices and profitability. In the base case, DOE used the same baseline markups calculated in the engineering analysis for all product classes. In the standards case, DOE modeled three markup scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of new energy conservation standards: (1) a flat markup scenario, (2) a pass through markup scenario, and (3) a constant price scenario. These three scenarios lead to different markups values, which, when applied to the inputted MPCs, result in varying revenue and cash flow impacts.

Flat Markup Scenario

DOE considers a Flat Markup scenario to analyze the upper bound (most positive) of profitability impacts following the compliance date of new standards. In this scenario, manufacturers are able to maintain their baseline gross margin, as a percentage of revenue, at higher CSLs, despite higher product costs of more efficient BCs. In other words, manufacturers are able pass on, and fully mark up, the higher incremental product costs due to more efficient BCs. This scenario is a more likely outcome for high-value, differentiated products, for which energy efficiency indirectly drives customer-valued benefits such as lighter weight and greater transportability. For other applications, particularly low-cost products for which energy efficiency is not an important selling attribute, the scenario is less likely.

Pass Through Markup Scenario

In the pass through scenario, DOE assumes that manufacturers are able to pass through the incremental costs of more efficient BCs to their customers, but without earning any additional operating profit on those higher costs. Therefore, though less severe than the constant price scenario in which manufacturers absorb all incremental costs, this scenario also results in margin compression and adverse financial impacts as BC costs increase.

Constant Price Scenario

The constant price scenario analyzes the situation in which manufacturers of applications are unable to pass on *any* incremental costs of more efficient BCs to their customers. This scenario is reflective of some manufacturers' description of the negotiating power of large retailers, who account for the vast majority of shipments of some applications. Manufacturers believe these large retailers would be unwilling to accept any price increases. This scenario results in the most significant negative impacts because no incremental costs added to the application—either because of higher BC component costs or because of investments in tooling and design—can be recouped. As a result, manufacturer gross margins decline as cost-of-goods-sold increase, on dollar-for-dollar basis. The higher the incremental cost of the BC, with respect to the total application price, the greater the impacts on the manufacturer. For example, the margin impact of a $2.00 increase in the cost of the BC is much greater on a product that sells for $50 than on a product that retails for $500.

For some applications in some product classes, the max-tech BC price is nearly as expensive of the total base case application price itself. Under the constant price scenario, such circumstances can obviously yield highly negative results, which are not meaningful because, in reality, producers would not continue to produce at prices that did not cover variable costs. If prices fell below the level necessary to cover variable costs, then a firm would be better off not producing anything at all. Therefore, DOE applies a boundary condition in the constant price scenario, which assumes that as BC costs increases, application prices remain constant (and gross margin would continue to decline) only until manufacturers cease to cover their variable costs (gross margin is zero). At that point, DOE assumes manufacturers can pass on any further incremental costs of the BC on a dollar-for-dollar basis to their customers.

12.5.2 BC Industry Financial Impacts

Using the inputs and scenarios described in the previous sections, the GRIM estimated indicators of financial impacts on the BC industry. The main results of the MIA are also reported in this section. The MIA consists of two key financial metrics: INPV and annual cash flows.

12.5.2.1 Introduction

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's NPV, which is applied to the U.S. economy. The INPV is the sum of all net cash flows discounted at the industry's cost of capital, or discount rate. The BC GRIM estimate cash flows from 2011 to 2042. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance date (2011 until an estimated compliance date of July 2013) and a long-term assessment over the 30 year analysis period used in the NIA (2013 – 2042).

In the MIA, DOE compares the INPV of the base case (no new national energy conservation standards, however, the effects of the CEC standard are included in this base case) to that of each TSL in the standards case. The difference between the base case and a standards case INPV is an estimate of the economic impacts that DOE implementing that particular TSL would have on the BC industry. For the BC industry, DOE examined the three markup scenarios described above: the flat markup, the pass through markup, and the constant price. While INPV is useful for evaluating the long-term effects of new energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual net cash flows, Figure 12.5.2 through Figure 12.5.22 below present the annual net or free cash flows from 2010 through 2023 for the base case and different TSLs in the standards case.

Annual cash flows are discounted to the base year, 2011. Between 2011 and the 2013 compliance date of the new energy conservation standard, cash flows are driven by the level of conversion costs and the proportion of these investments spent every year. After the standard announcement date (*i.e.*, the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new energy conservation standard. The more stringent the new energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash inflows from operations and capital conversion costs increase cash outflows for capital expenditures.

Free cash flow in the year the new energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, new energy conservation standards could create stranded assets, *i.e.*, tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment whose value is affected by the new energy conservation standard. This one time write down acts as a tax shield that alleviates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. More stringent TSLs typically have a positive impact on cash flows relative to the base case under the flat markup scenario because manufacturers are able to earner higher operating profit at each TSL in the standards case, which increases cash flow from operations. In other words, manufacturers can fully pass on—and mark up—the higher incremental product costs associated with more efficient BCs. Conversely, the constant price scenario analyzes the situation in which application manufacturers are unable to pass on any incremental costs of more efficient BCs to their customers. This scenario generally results in the most significant negative impacts because no incremental costs added to the application—whether driven by higher BC component costs or depreciation of required capital investments—can be recouped. In the pass through scenario, DOE assumes that manufacturers are able to pass the incremental costs of more efficient BCs through to their customers, but not with any markup to cover overhead and profit. Therefore, though less severe than the constant price scenario in which manufacturers absorb all incremental costs, this scenario results in negative cash flow impacts to due margin compression and greater working capital requirements.

12.5.2.2 Product Class 1 BC Industry Financial Impacts

Table 12.5.42 through Table 12.5.44 provide the INPV estimates for the product class 1 BCs. Figure 12.5.2 through Figure 12.5.4 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.42 Changes in Product Class 1 Net Present Value for BC (Flat Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	491	492	493	520
Change in INPV	*(2010$ millions)*	-	1	1	29
	(%)	-	0.1%	0.3%	5.9%

*For tables in section 12.5.2, values in parenthesis indicate negative numbers

Table 12.5.43 Changes in Product Class 1 Net Present Value for BC (Pass Through Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	491	479	461	318
Change in INPV	*(2010$ millions)*	-	(12)	(31)	(173)
	(%)	-	-2.5%	-6.2%	-35.3%

Table 12.5.44 Changes in Product Class 1 Net Present Value for BC (Constant Price Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	491	450	390	51
Change in INPV	*(2010$ millions)*	-	(41)	(101)	(441)
	(%)	-	-8.4%	-20.6%	-89.7%

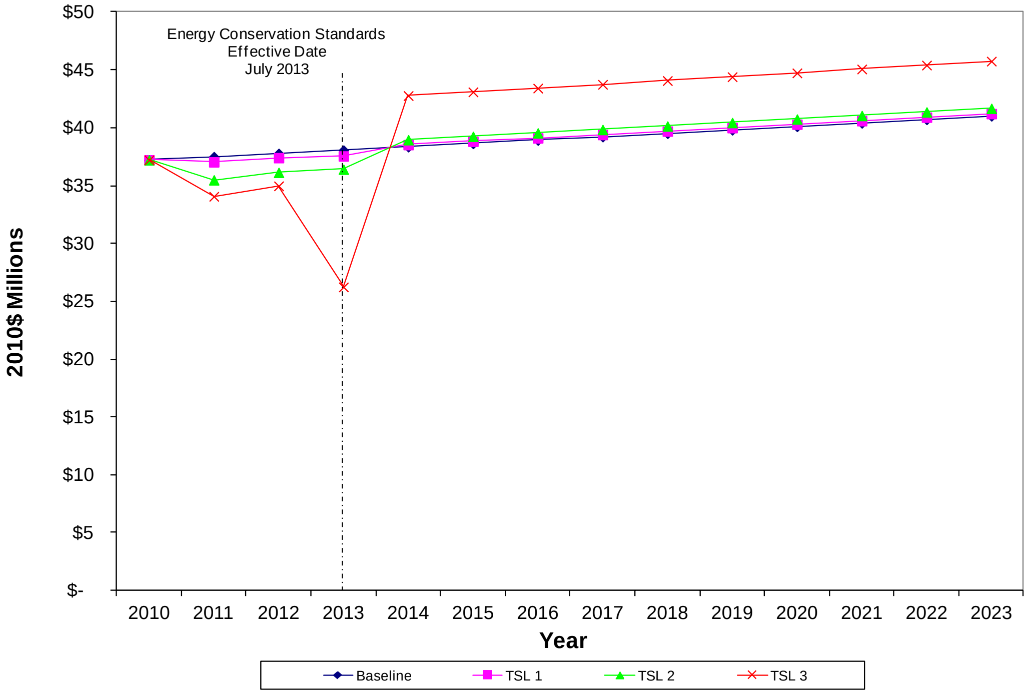


Figure 12.5.2 Annual Industry Net Cash Flows for Product Class 1 BCs (Flat Markup Scenario)

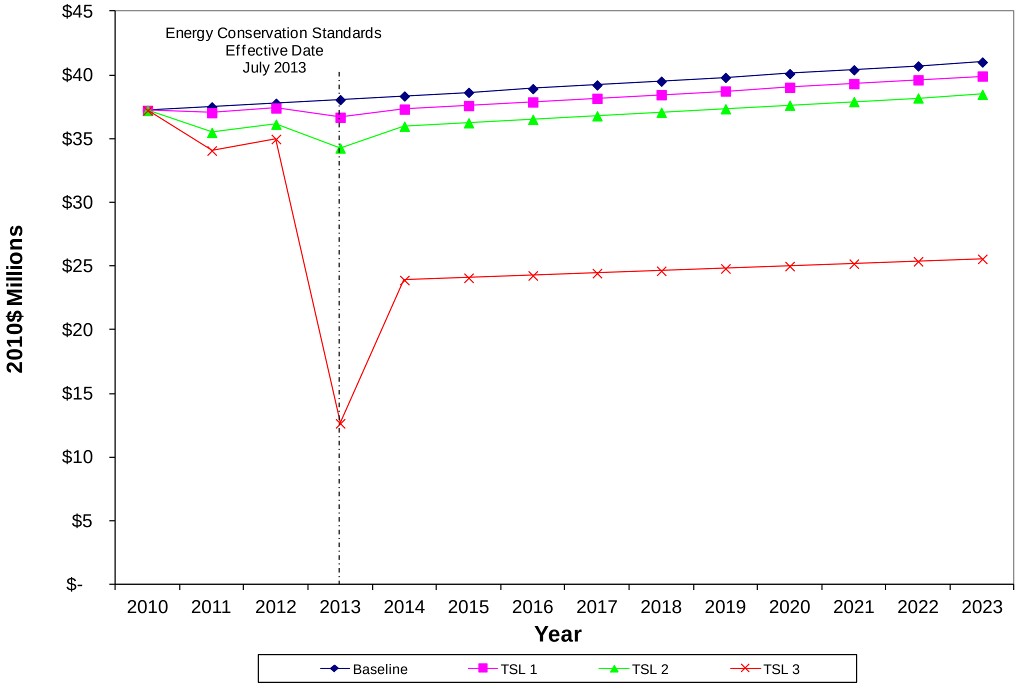


Figure 12.5.3 Annual Industry Net Cash Flows for Product Class 1 BCs (Pass Through Markup Scenario)

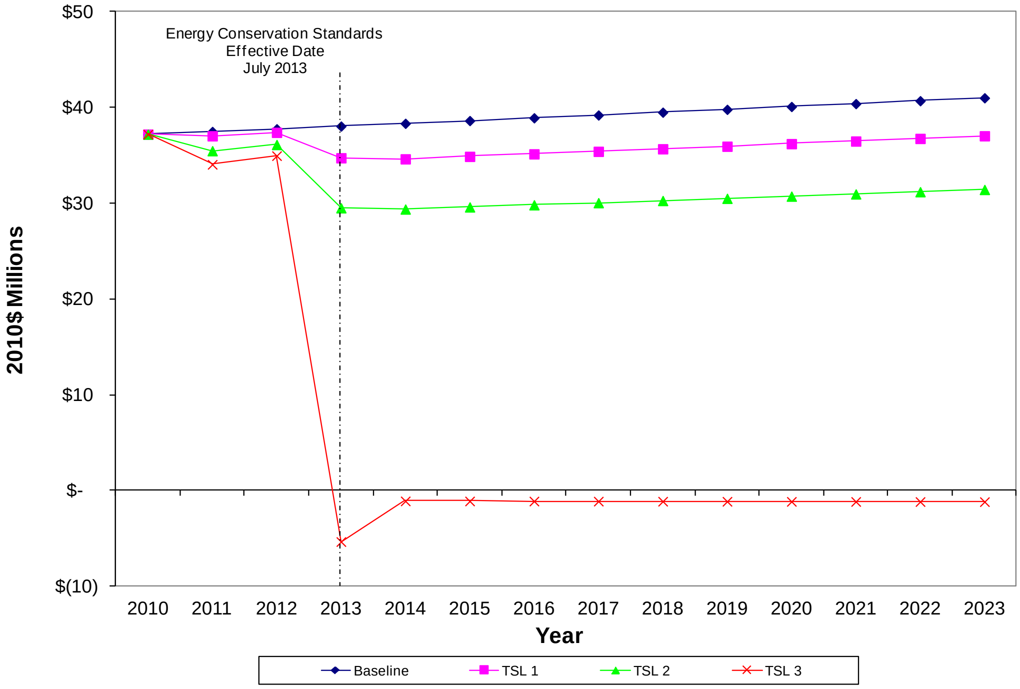


Figure 12.5.4 Annual Industry Net Cash Flows for Product Class 1 BCs (Constant Price Markup Scenario)

12.5.2.3 Product Class 2, 3, & 4 BC Industry Financial Impacts

Table 12.5.45 through Table 12.5.50 provide the INPV estimates for the product class 2, 3, & 4 BCs. Figure 12.5.5 through Figure 12.5.10 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.45 Changes in Product Class 2, 3, & 4 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*(2010$ millions)*	44,492	44,506	44,625	45,020	45,467
Change in INPV	*(2010$ millions)*	-	15	134	528	975
	(%)	-	0.0%	0.3%	1.2%	2.2%

Table 12.5.46 Changes in Product Class 2, 3, & 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*(2010$ millions)*	44,268	42,679	42,360	40,810	38,949
Change in INPV	*(2010$ millions)*	-	(1,589)	(1,908)	(3,458)	(5,318)
	(%)	-	-3.6%	-4.3%	-7.8%	-12.0%

Table 12.5.47 Changes in Product Class 2, 3, & 4 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*(2010$ millions)*	43,808	38,911	37,752	32,944	29,246
Change in INPV	*(2010$ millions)*	-	(4,897)	(6,055)	(10,863)	(14,562)
	(%)	-	-11.2%	-13.8%	-24.8%	-33.2%

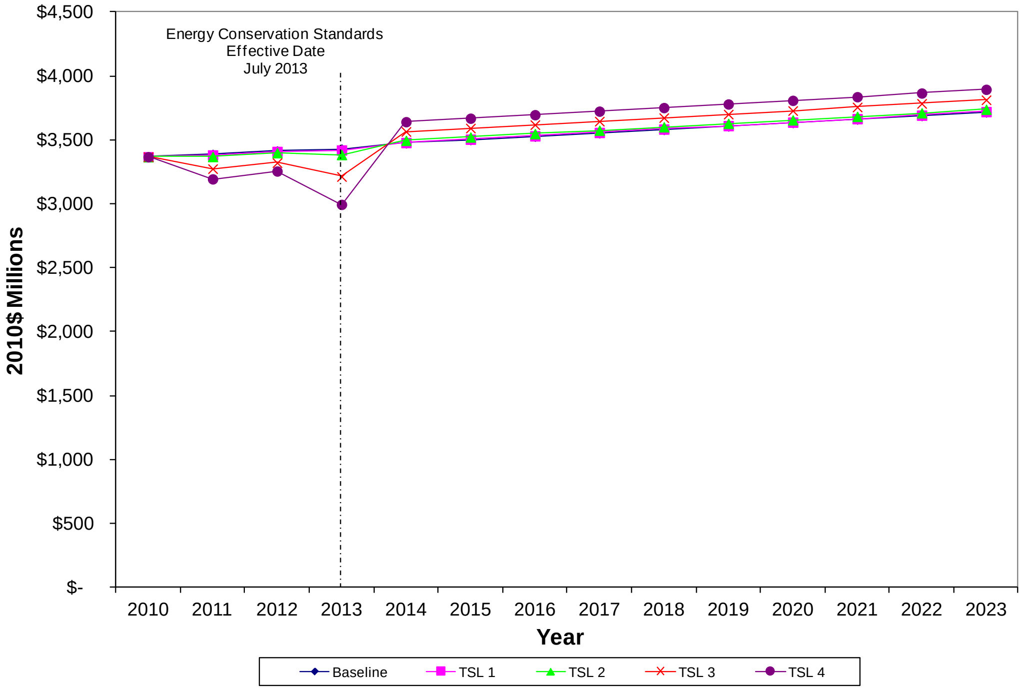


Figure 12.5.5 Annual Industry Net Cash Flows for Product Class 2, 3, & 4 BCs (Flat Markup Scenario)

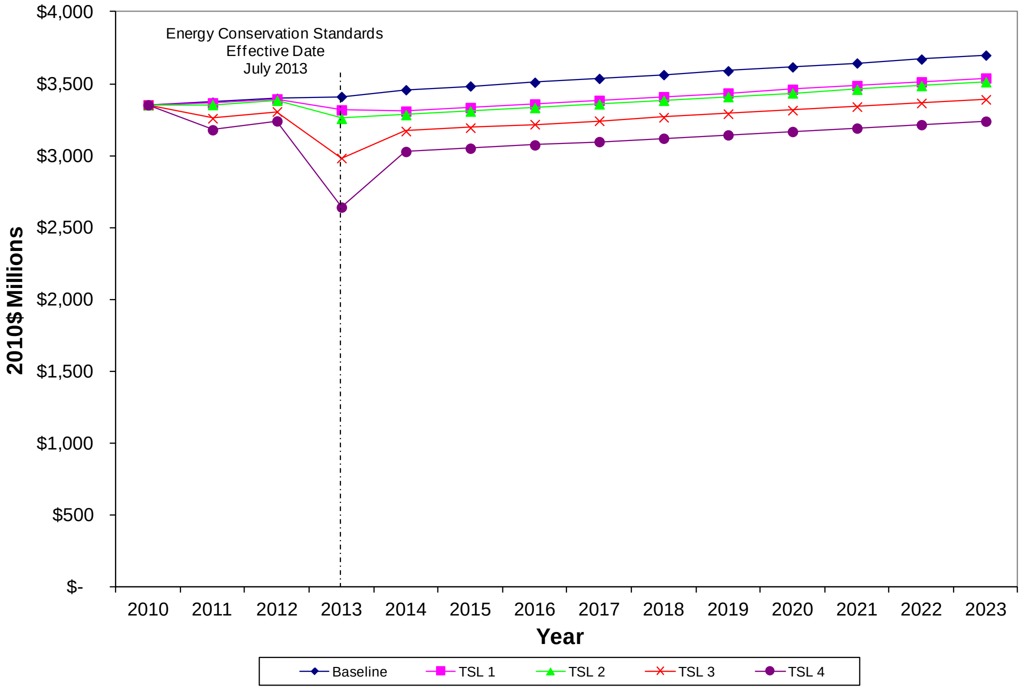


Figure 12.5.6 Annual Industry Net Cash Flows for Product Class 2, 3, & 4 BCs (Pass Through Markup Scenario)

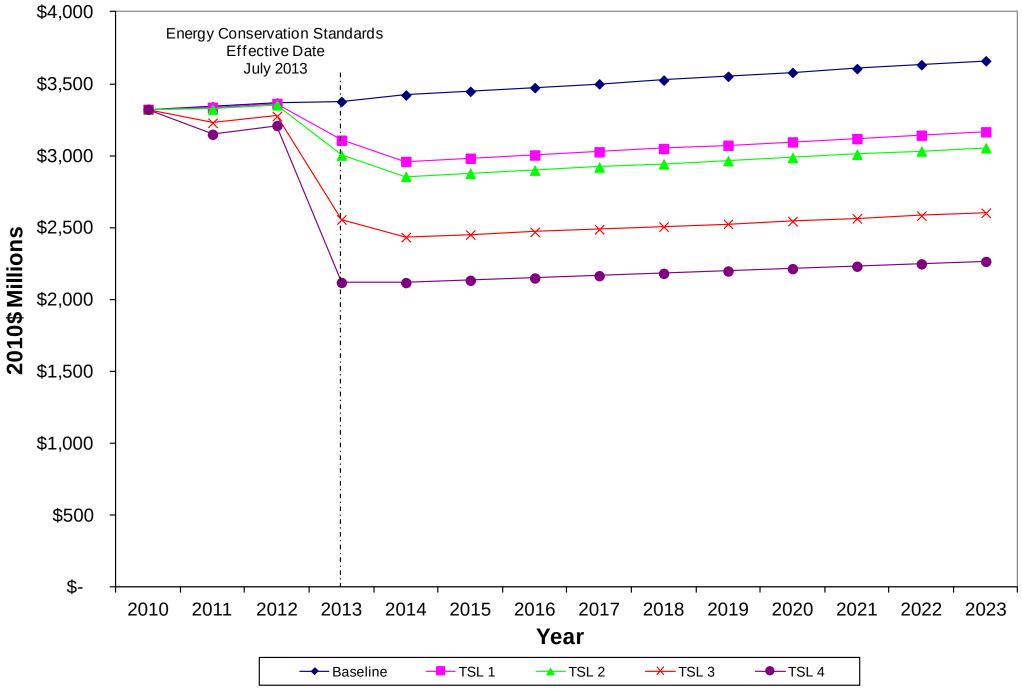


Figure 12.5.7 Annual Industry Net Cash Flows for Product Class 2, 3, & 4 BCs (Constant Price Markup Scenario)

Product Class 2, 3, & 4 Results by Industry Group

Consumer Electronics

Table 12.5.48 Changes in Consumer Electronics in Product Class 2, 3, & 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*(2010$ millions)*	41,894	40,679	40,373	39,160	37,683
Change in INPV	*(2010$ millions)*	-	(1,215)	(1,521)	(2,734)	(4,211)
	(%)	-	-2.9%	-3.6%	-6.5%	-10.1%

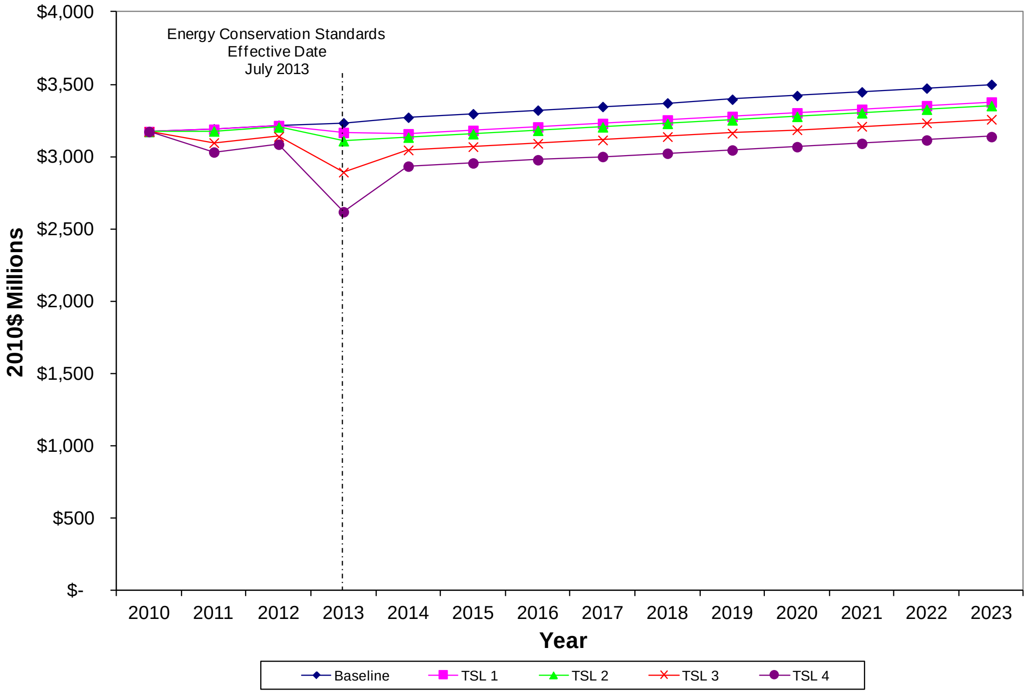


Figure 12.5.8 Annual Industry Net Cash Flows for Consumer Electronics in Product Class 2, 3, & 4 BCs (Pass Through Markup Scenario)

Power Tools

Table 12.5.49 Changes in Power Tools in Product Class 2, 3, & 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*(2010$ millions)*	1,814	1,566	1,560	1,344	1,098
Change in INPV	*(2010$ millions)*	-	(248)	(254)	(470)	(716)
	(%)	-	-13.7%	-14.0%	-25.9%	-39.5%

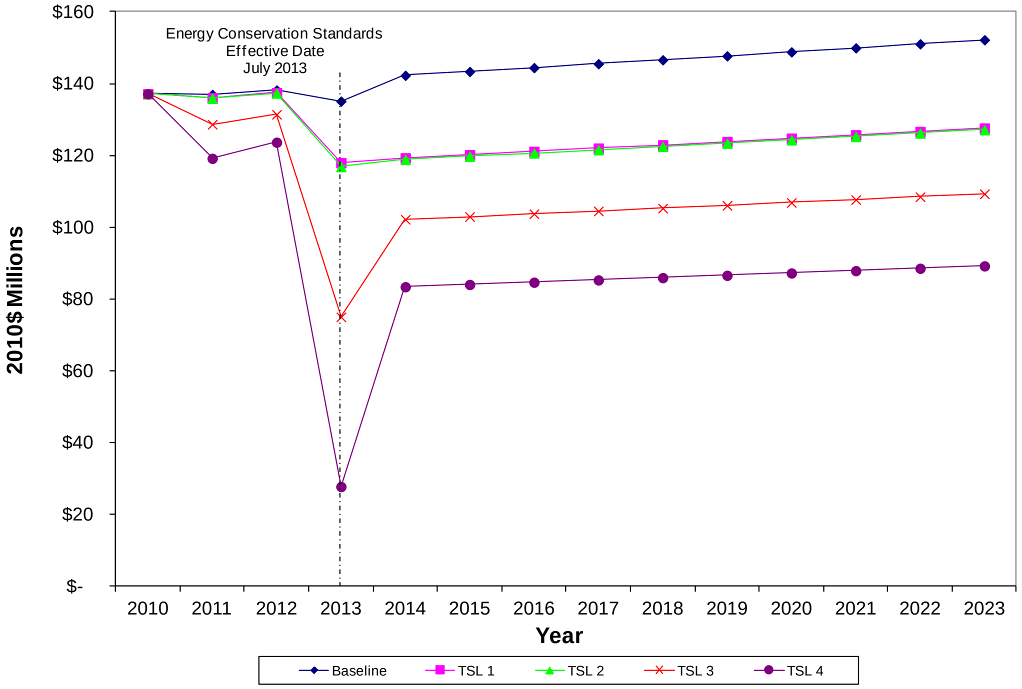


Figure 12.5.9 Annual Industry Net Cash Flows for Power Tools in Product Class 2, 3, & 4 BCs (Pass Through Markup Scenario)

Small Appliances

Table 12.5.50 Changes in Small Appliances in Product Class 2, 3, & 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**			
			1	**2**	**3**	**4**
INPV	*(2010$ millions)*	560	435	427	305	168
Change in INPV	*(2010$ millions)*	-	(125)	(133)	(255)	(392)
	(%)	-	-22.4%	-23.7%	-45.4%	-70.0%

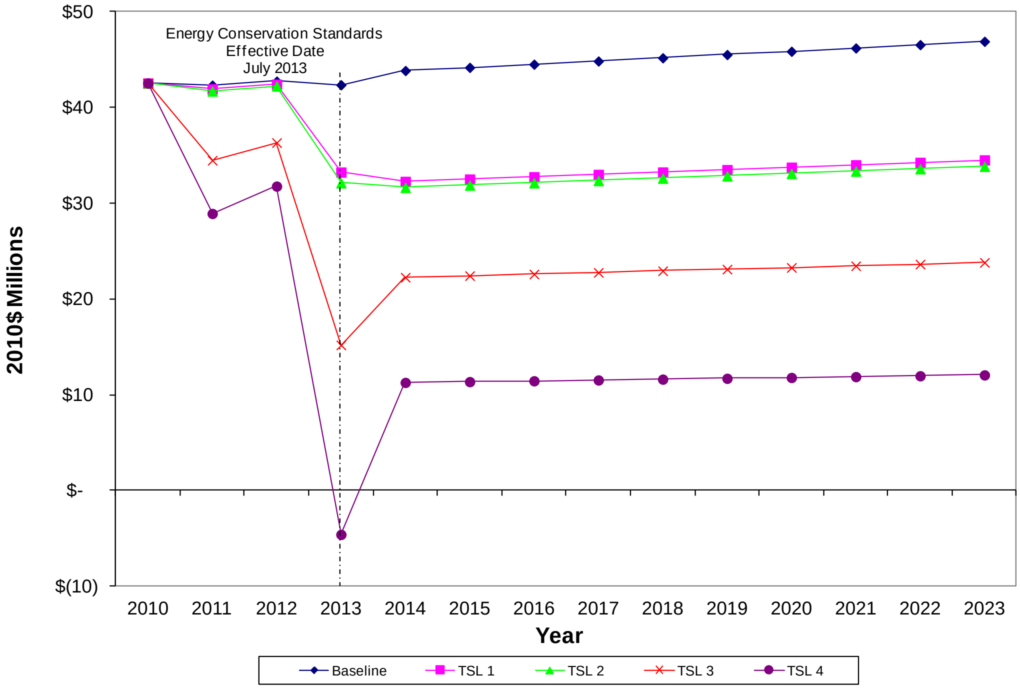


Figure 12.5.10 Annual Industry Net Cash Flows for Small Appliances in Product Class 2, 3, & 4 BCs (Pass Through Markup Scenario)

12.5.2.4 Product Class 5 & 6 BC Industry Financial Impacts

Table 12.5.51 through Table 12.5.53 provide the INPV estimates for the product class 5 & 6 BCs. Figure 12.5.11 through Figure 12.5.13 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.51 Changes in Product Class 5 & 6 Net Present Value for BC (Flat Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	1,584	1,589	1,543	2,275
Change in INPV	*(2010$ millions)*	-	6	(40)	692
	(%)	-	0.3%	-2.5%	43.7%

Table 12.5.52 Changes in Product Class 5 & 6 Net Present Value for BC (Pass Through Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	1,549	1,281	1,324	235
Change in INPV	*(2010$ millions)*	-	(268)	(225)	(1,314)
	(%)	-	-17.3%	-14.5%	-84.8%

Table 12.5.53 Changes in Product Class 5 & 6 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	1,552	1,226	1,429	409
Change in INPV	*(2010$ millions)*	-	(327)	(123)	(1,143)
	(%)	-	-21.0%	-7.9%	-73.6%

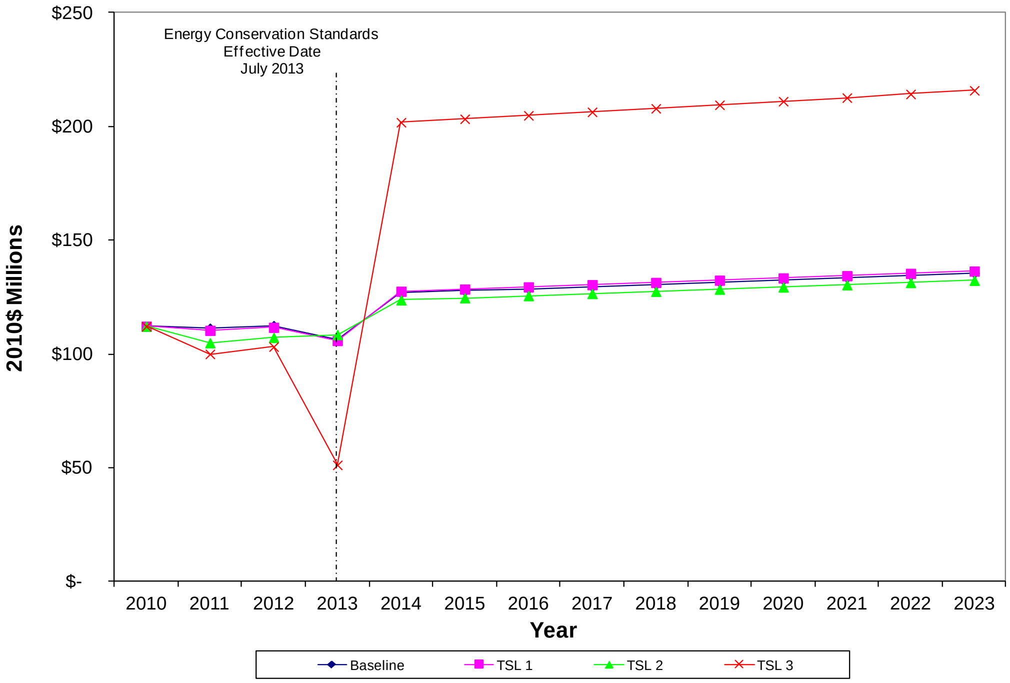


Figure 12.5.11 Annual Industry Net Cash Flows for Product Class 5 & 6 BCs (Flat Markup Scenario)

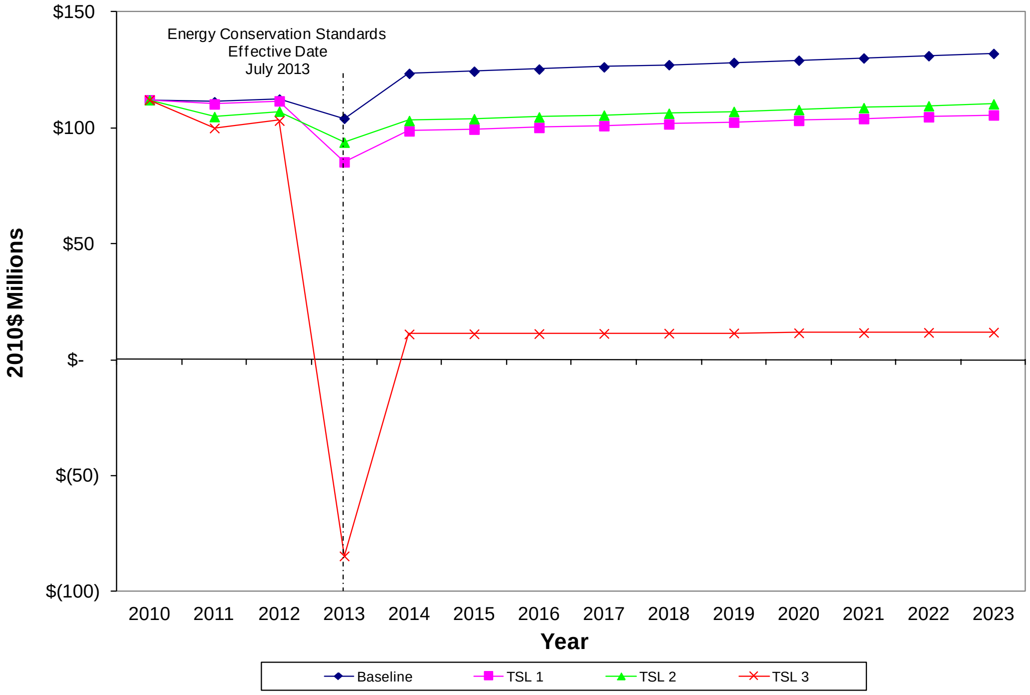


Figure 12.5.12 Annual Industry Net Cash Flows for Product Class 5 & 6 BCs (Pass Through Markup Scenario)

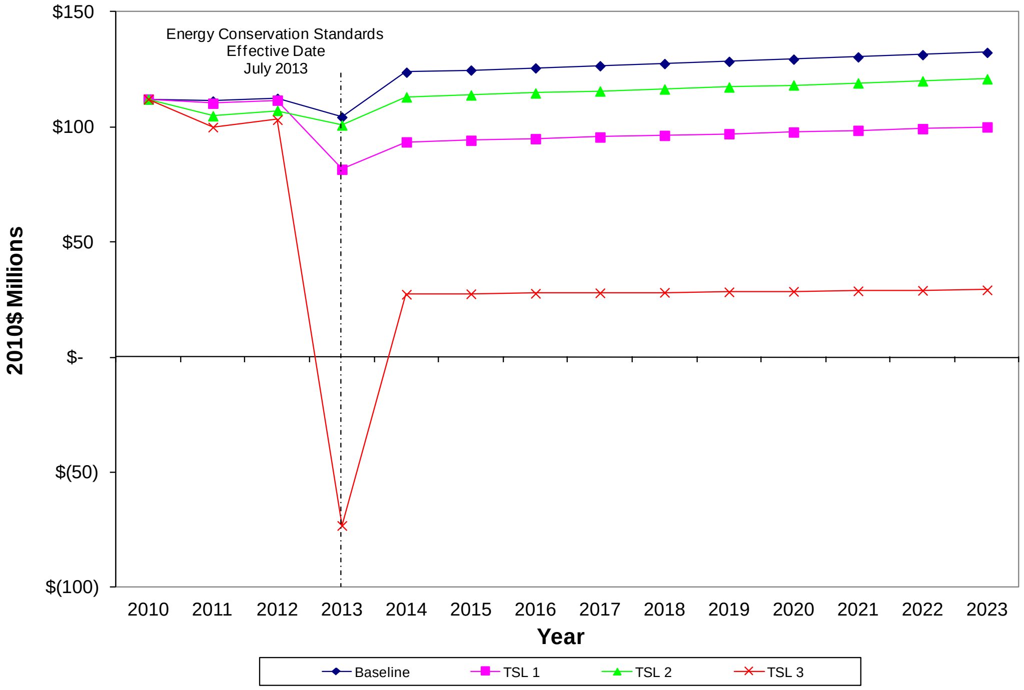


Figure 12.5.13 Annual Industry Net Cash Flows for Product Class 5 & 6 BCs (Constant Price Markup Scenario)

12.5.2.5 Product Class 7 BC Industry Financial Impacts

Table 12.5.54 through Table 12.5.56 provide the INPV estimates for the product class 7 BCs. Figure 12.5.14 through Figure 12.5.16 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.54 Changes in Product Class 7 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*(2010$ millions)*	1,034	1,030	1,057
Change in INPV	*(2010$ millions)*	-	(4)	23
	(%)	-	-0.4%	2.2%

Table 12.5.55 Changes in Product Class 7 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*(2010$ millions)*	1,036	1,050	1,003
Change in INPV	*(2010$ millions)*	-	14	(33)
	(%)	-	1.4%	-3.2%

Table 12.5.56 Changes in Product Class 7 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*(2010$ millions)*	1,039	1,086	903
Change in INPV	*(2010$ millions)*	-	47	(136)
	(%)	-	4.5%	-13.1%

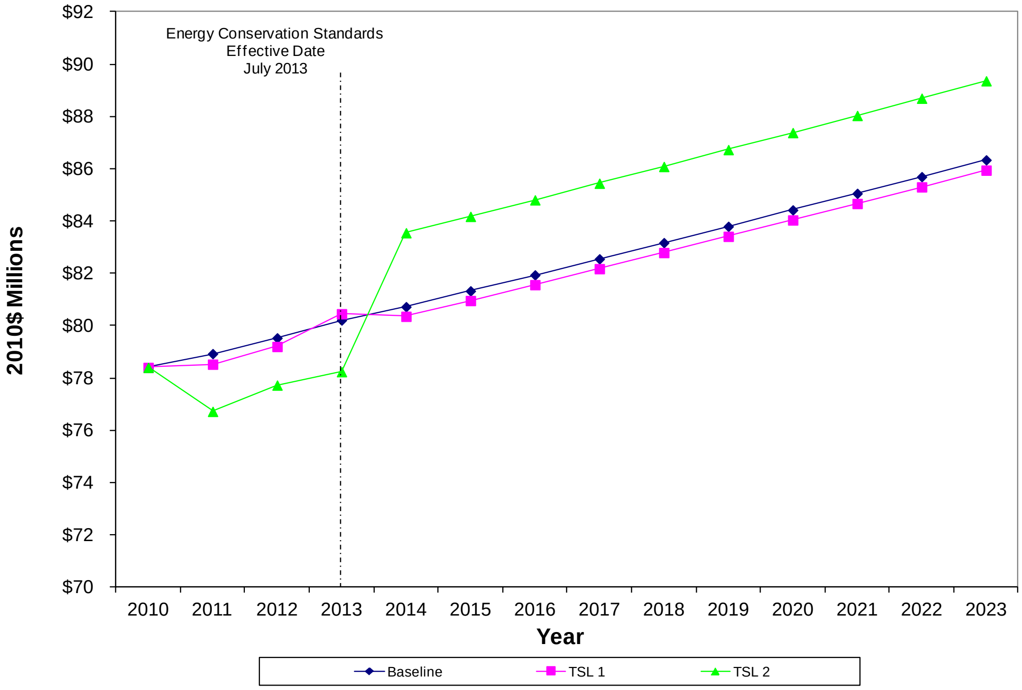


Figure 12.5.14 Annual Industry Net Cash Flows for Product Class 7 BCs (Flat Markup Scenario)

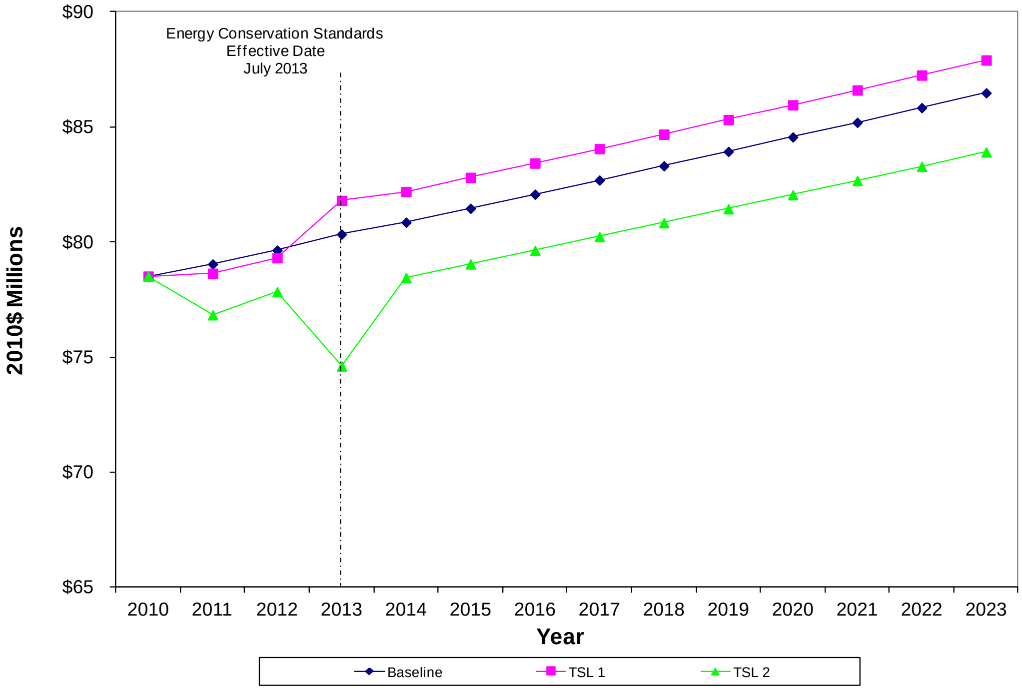


Figure 12.5.15 Annual Industry Net Cash Flows for Product Class 7 BCs (Pass Through Markup Scenario)

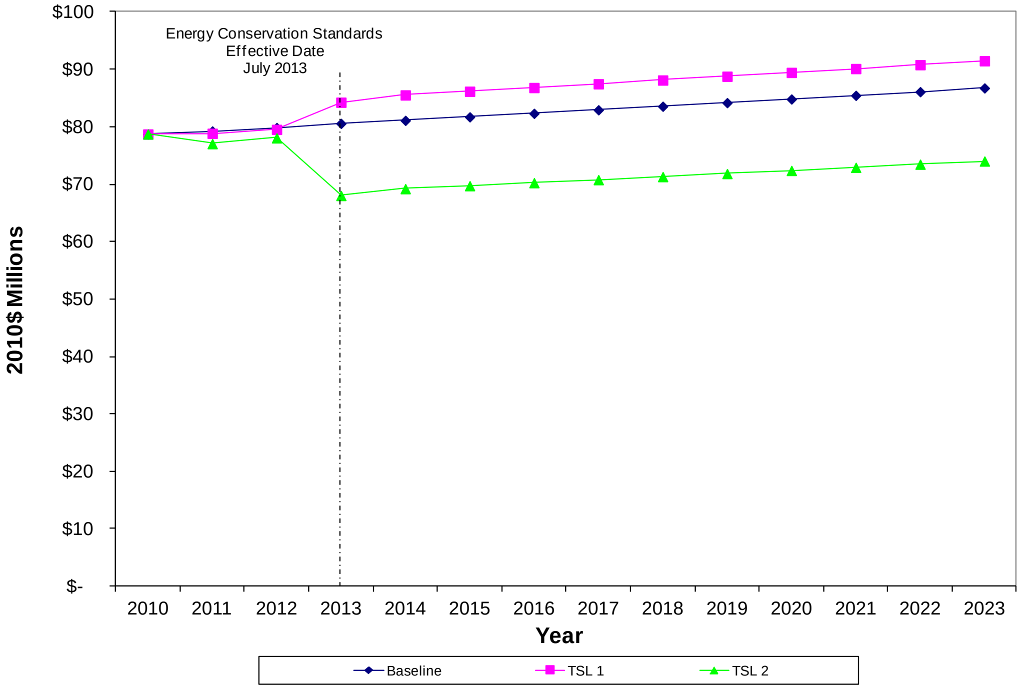


Figure 12.5.16 Annual Industry Net Cash Flows for Product Class 7 BCs (Constant Price Markup Scenario)

12.5.2.6 Product Class 8 BC Industry Financial Impacts

Table 12.5.57 through Table 12.5.59 provide the INPV estimates for the product class 8 BCs. Figure 12.5.17 through Figure 12.5.19 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.57 Changes in Product Class 8 Net Present Value for BC (Flat Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	5,703	5,628	5,707	5,672
Change in INPV	*(2010$ millions)*	-	(75)	4	(30)
	(%)	-	-1.3%	0.1%	-0.5%

Table 12.5.58 Changes in Product Class 8 Net Present Value for BC (Pass Through Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*(2010$ millions)*	5,703	6,064	5,730	5,663
Change in INPV	*(2010$ millions)*	-	361	27	(40)
	(%)	-	6.3%	0.5%	-0.7%

Table 12.5.59 Changes in Product Class 8 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	5,703	7,002	5,781	5,642
Change in INPV	*(2010$ millions)*	-	1,300	78	(61)
	(%)	-	22.8%	1.4%	-1.1%

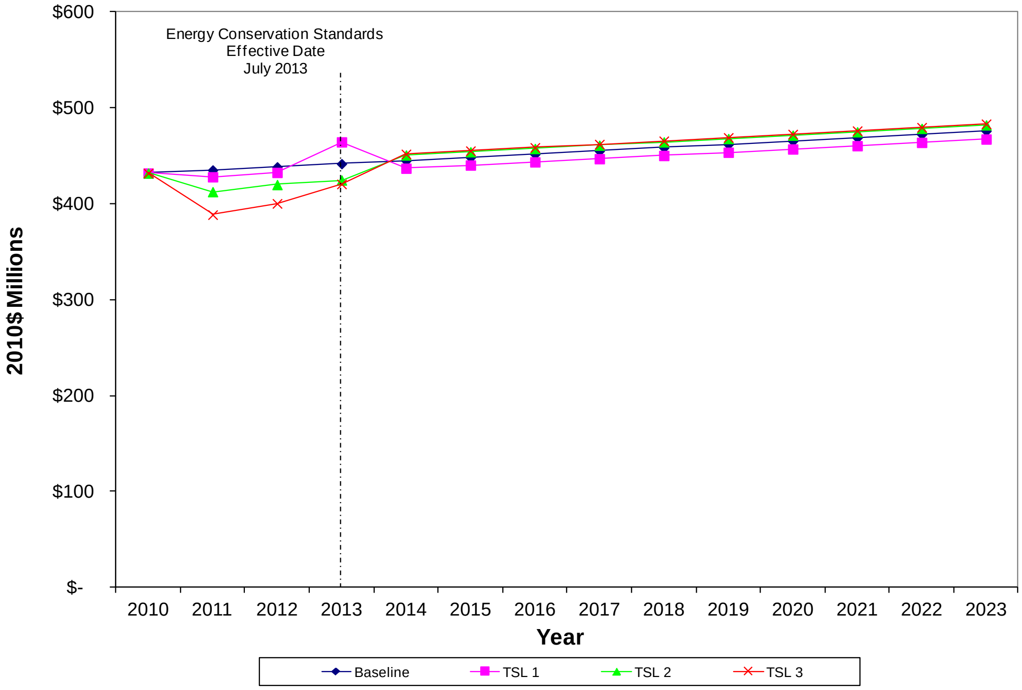


Figure 12.5.17 Annual Industry Net Cash Flows for Product Class 8 BCs (Flat Markup Scenario)

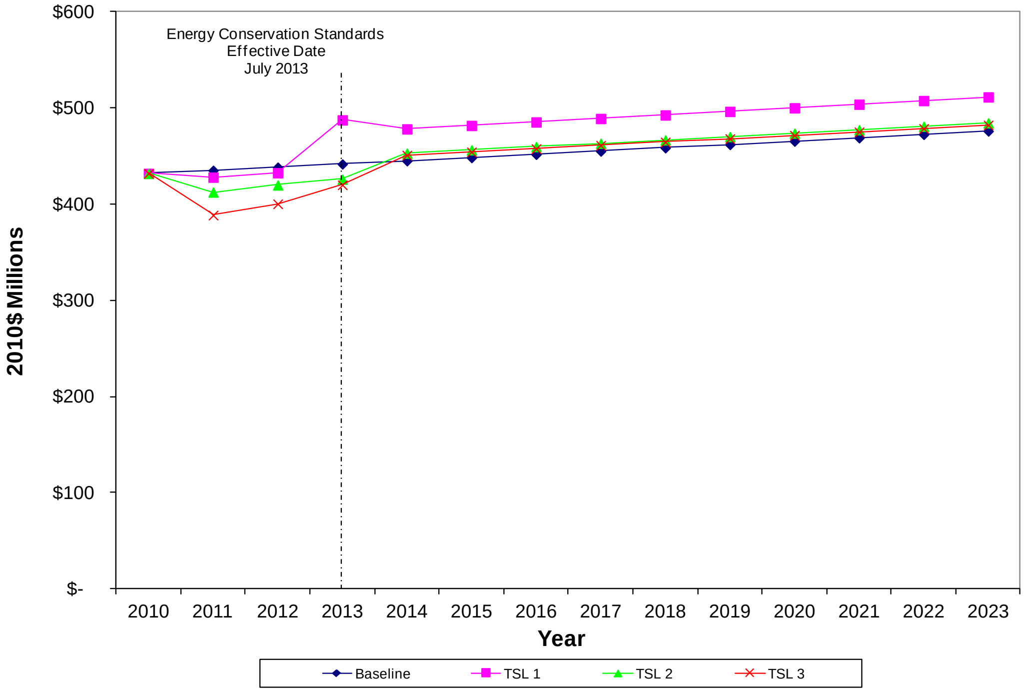


Figure 12.5.18 Annual Industry Net Cash Flows for Product Class 8 BCs (Pass Through Markup Scenario)

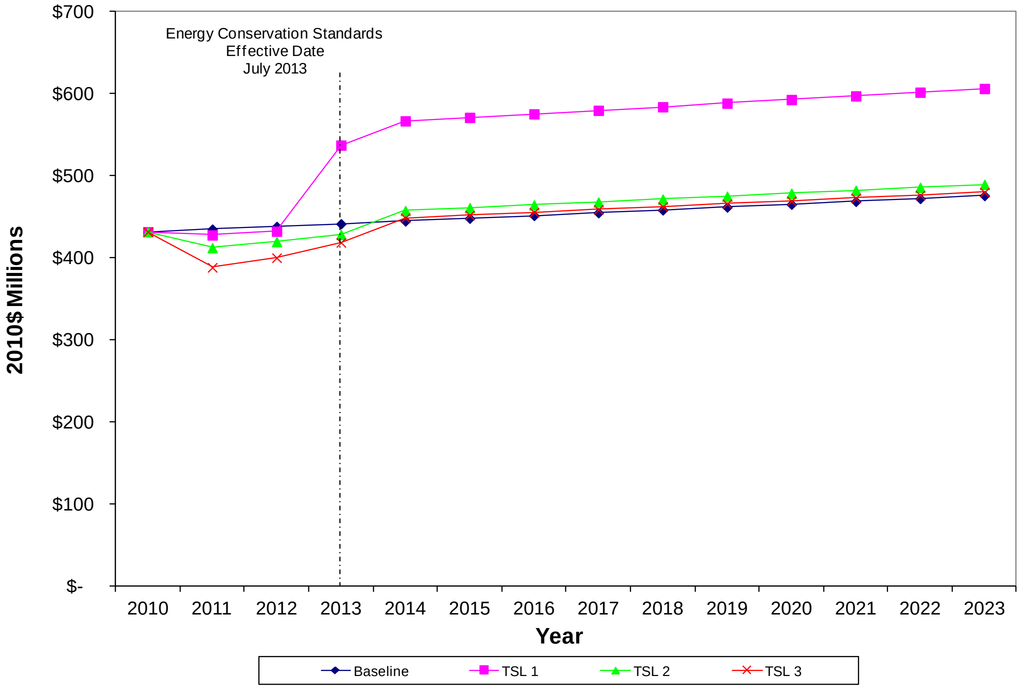


Figure 12.5.19 Annual Industry Net Cash Flows for Product Class 8 BCs (Constant Price Markup Scenario)

12.5.2.7 Product Class 10 BC Industry Financial Impacts

Table 12.5.60 through Table 12.5.62 provide the INPV estimates for the product class 10 & 6 BCs. Figure 12.5.20 through Figure 12.5.22 present the annual net cash flows for BCs for each of the different markup scenarios.

Table 12.5.60 Changes in Product Class 10 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	614	614	612	609
Change in INPV	*(2010$ millions)*	-	(0)	(2)	(5)
	(%)	-	-0.1%	-0.4%	-0.9%

Table 12.5.61 Changes in Product Class 10 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	614	593	586	577
Change in INPV	*(2010$ millions)*	-	(21)	(28)	(37)
	(%)	-	-3.5%	-4.5%	-5.9%

Table 12.5.62 Changes in Product Class 10 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*(2010$ millions)*	612	532	512	487
Change in INPV	*(2010$ millions)*	-	(81)	(100)	(126)
	(%)	-	-13.2%	-16.4%	-20.5%

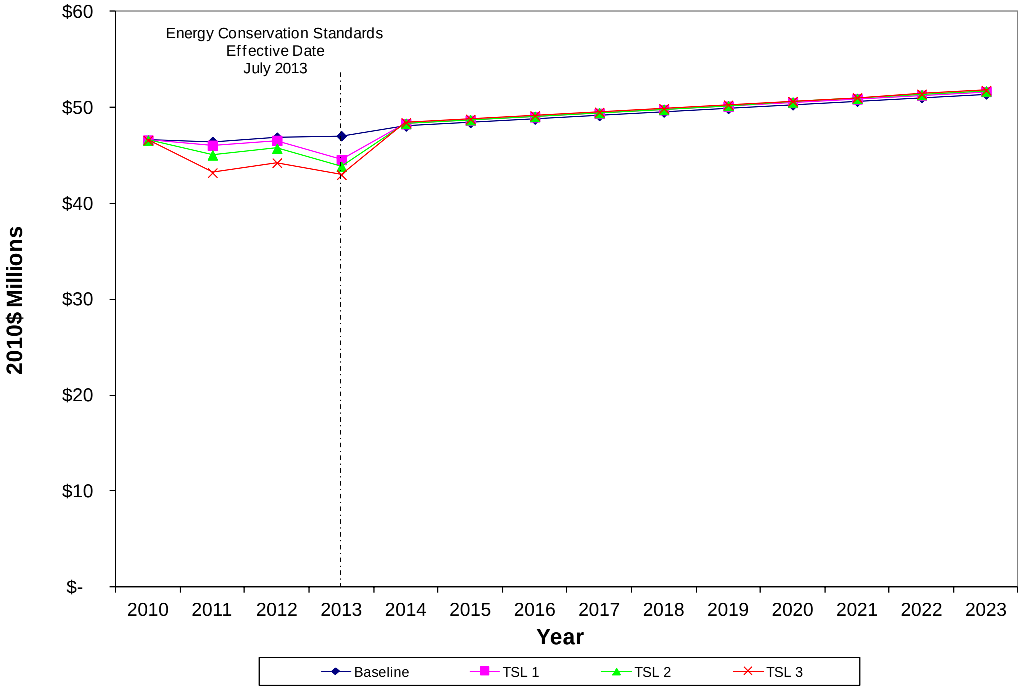


Figure 12.5.20 Annual Industry Net Cash Flows for Product Class 10 BCs (Flat Markup Scenario)

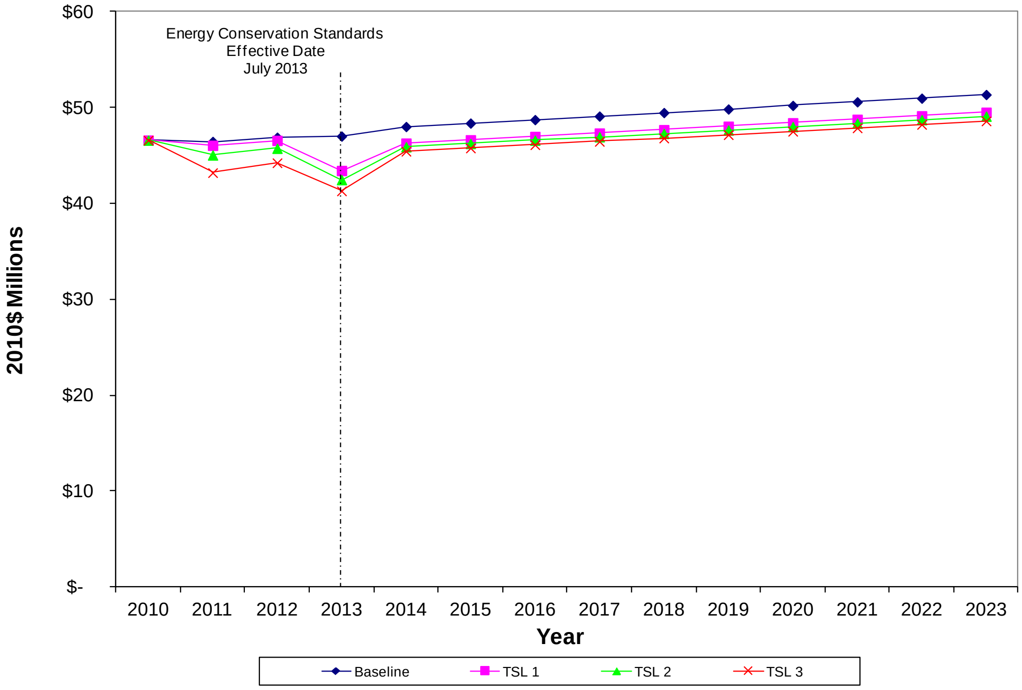


Figure 12.5.21 Annual Industry Net Cash Flows for Product Class 10 BCs (Pass Through Markup Scenario)

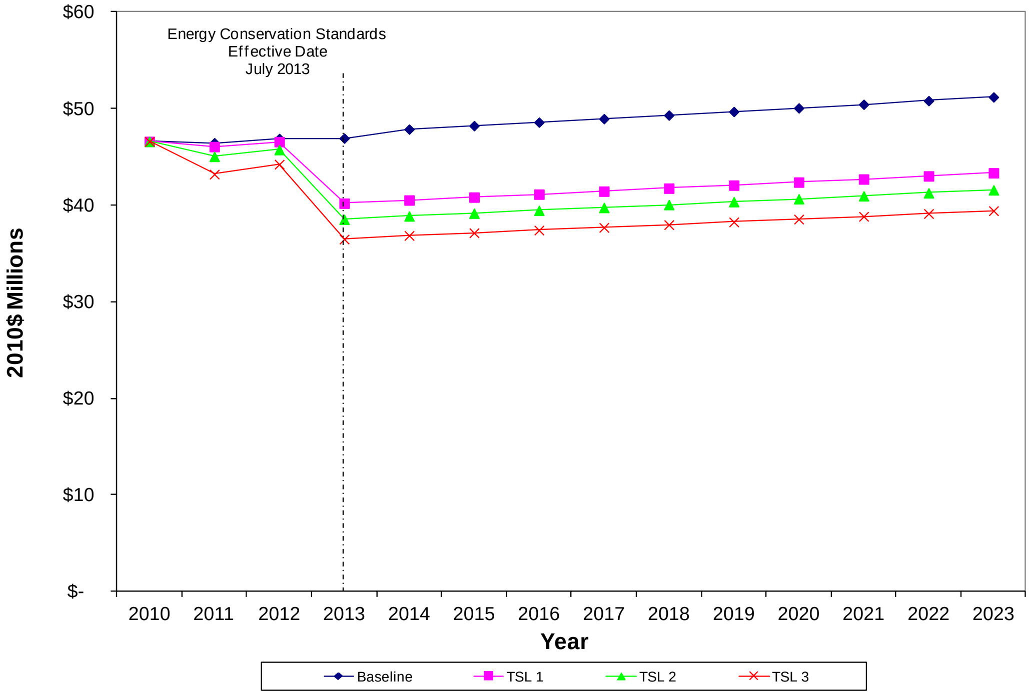


Figure 12.5.22 Annual Industry Net Cash Flows for Product Class 10 BCs (Constant Price Markup Scenario)

12.5.3 BC Impacts on Small Manufacturers

To estimate the number of companies that could be small business manufacturers of products covered by this rulemaking, DOE conducted a market survey using all available public information to identify potential small manufacturers. DOE's research involved industry trade association membership directories, product databases, individual company websites, and the SBA's Small Business Database to create a list of every company that could potentially manufacture products covered by this rulemaking. DOE also asked stakeholders and industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at previous DOE public meetings. DOE contacted companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer of covered BCs and EPSs. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a "small business," or are foreign-owned and operated.

Based on this screening, DOE identified 30 companies that could potentially manufacture EPSs or BCs. DOE eliminated most of these companies from consideration as small business manufacturers based on a review of product literature and Web sites, and when that proved inconclusive, contact with the companies themselves. DOE identified one small business that appears to produce covered BCs domestically.

12.5.4 BC Other Impacts

12.5.4.1 BC Employment

DOE's research revealed that very few companies have BC production in the United States. Therefore, changes in U.S. production employment, if any, due to new BC energy conservation standards would likely occur in the high energy application market because high energy BCs are more likely to use technologies produced domestically. Most likely because of the relative infrequency of their domestic production, DOE did not find sufficient information to quantify the number of employees currently employed in the production of BCs and the applications that incorporate them.

12.5.4.2 BC Production Capacity

DOE does not anticipate that the standards proposed in today's rule would adversely impact manufacturer capacity. Most BC applications have similar design cycles. While there is no statutory compliance date for BCs, DOE believes the compliance date proposed in the NOPR provides sufficient time for manufacturers to ramp up capacity to meet the proposed standards for BCs.

12.5.5 BC Conclusions

12.5.5.1 Product Class 1

Product class 1 has only two applications: rechargeable toothbrushes and water jets. Rechargeable toothbrushes represent 99.9 percent of the product class 1 shipments. DOE found the majority of these models include nickel-cadmium (Ni-Cd) battery chemistries, although products with NiMH and Li-ion chemistries exist in the market. More than three quarters of market shipments are at the baseline CSL. However, the efficiency distribution is not necessarily indicative of the distribution of retail price points. During interviews, manufacturers indicated that energy efficiency was not a primary selling point in this market. As a consequence, manufacturers expect that stringent standards would likely impact the low-end of the market, where price competition is most fierce and retail selling prices are lowest.

The incremental costs of meeting TSL 1 and TSL 2, which represent CSL 1 and CSL 2 for product class 1, respectively, are relatively minor compared to the average application MSP of $58.36. While most applications will have to be altered at these TSLs, the relatively small increase in BC costs do not greatly impact industry cash flow even if none of these incremental costs can be passed on to retailers. At max-tech, however, the BC is 3.3 times more expensive than the baseline charger. The baseline level is set at the CSL at which the majority of the market currently ships. Therefore, in addition to the R&D efforts necessary to prepare all product lines to incorporate the max-tech levels, the inability to pass those much higher BC costs down the distribution chain drive the negative impacts at max-tech in the worst-case constant price scenario.

12.5.5.2 Product Class 2, 3, and 4

TSL 1 would require BCs in product class 2, 3 and 4 to each meet CSL 1. Impacts on INPV are relatively moderate at TSL 1 because a majority of application shipments in these product classes already meet CSL 1. However, those shipments already meeting CSL 1 are heavily weighted toward the consumer electronics sector. In most cases, CSL 1 could be met with incremental circuit design improvements and higher efficiency components. Satisfying this level would not require a full topology redesign or a move to Li-ion chemistry, although manufacturers of some applications indicated in interviews that they may elect such a design path.

TSL 2 has the same efficiency requirements for product class 3 and 4 as TSL 1 (CSL 1). Product class 2 would have to meet CSL 2 at TSL 2. CSL 2 would likely require BC design changes (e.g., moving to switched-mode and Li-ion chemistries) that would likely cause application manufacturers to incur significant R&D expenditures relative to what is normally budgeted for BCs. However, the financial impact of this investment effect would be minor compared to the base case industry value, which is largely driven by consumer electronics applications.

Industry impacts would become more acute at TSL 3 and TSL 4, as best-in-market or max-tech designs would be required for all BCs. The cost of a BC in product class 3 and 4 rises sharply at CSL 2 (best in market) and further at CSL 3 (max-tech). For relatively inexpensive applications, the inability to fully pass on these substantially higher costs (as assumed in the pass through and, to a greater extent, the constant price scenario) leads to significant margin compression, working capital drains, and, ultimately, reductions in INPV at the max-tech TSL.

12.5.5.3 Product Class 5 and 6

TSL 1, TSL 2, and TSL 3 represent CSL 1, CSL 2, and CSL 3 for both product class 5 and product class 6, respectively. The BC cost associated with each CSL is the same for product classes 5 and 6. The industry impacts at TSL 1 are minor because a large percentage of the market already meets the CSLs represented in that TSL and because the incremental BC product costs are minor relative to the average application manufacturer selling price of $220. At TSL 2, the BC cost declines compared to the baseline because of the technology shift from a line-frequency power supply to a switch-mode power supply, and impacts are projected to remain moderate. The constant price scenario yields positive impacts at TSL 2 because the higher average operating margin (due to the lower product costs) outweighs the one-time conversion costs. At TSL 3, however, the impacts on INPV are severe because the required max-tech BCs would cost nearly seven times the baseline charger.

Under the flat markup scenario, which assumes manufacturers could full mark up the product to recover this additional cost, such an increase generates substantially greater cash flow and industry value. However, as noted earlier, the greater the increase in product costs, the less likely DOE believes that manufacturers will be able to fully markup the substantially higher production costs (the flat markup scenario). DOE believes manufacturers would be forced to absorb much of this dramatic cost increase at max-tech, yielding the substantially negative industry impacts, as shown by the lower-bound results.

12.5.5.4 Product Class 7

Golf cars are the only application in product class 7. A little under half the market incorporates baseline BC technology -- the other half employing technology that meets the efficiency requirements at CSL 1. The cost of a BC in product class 7, though higher relative to other product classes, remains a small portion of the overall selling price of a golf car. As such, large percentage increases in the cost of the BC, as in the case of max-tech, do not yield severe impacts on golf car OEMs, even in the constant price scenario. Note, however, this analysis focuses on the application manufacturer, or the OEM. DOE did identify a U.S. small business manufacturer of the golf car BC itself (as opposed to the application). DOE evaluates the impacts on standards on such manufacturers in the Regulatory Flexibility Analysis (see section VI.B of the NOPR for the results of that analysis.)

12.5.5.5 Product Class 8

Product class 8 includes 14 applications, mostly consumer electronics. MP3 players and mobile phones make up the vast majority of product class 8 shipments (58 percent and 31 percent, respectively). Approximately 50 percent of MP3 players and mobile phones meet CSL 1 or higher. For all other applications in this product class, approximately half of the incorporated BCs already meet or exceed CSL 1. Furthermore, because the manufacturer selling prices of these dominant applications dwarf the incremental product costs associated with increasing the efficiency—even at max-tech—the overall industry impacts are projected to be minor for all TSLs for product class 8.

12.5.5.6 Product Class 10

Product class 10 has only one application: uninterruptible power supplies. The vast majority of models on the market have sealed lead-acid battery chemistries. The efficiency distribution for product class 10 assumes all shipments are at the baseline CSL. Compared to the average application MSP of approximately $289, the incremental costs of meeting the higher CSLs remain relatively low, despite increasing substantially on a percentage basis. Therefore, even in the constant price scenario INPV impacts are projected to be limited.

12.6 CUMULATIVE REGULATORY BURDEN

While any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. For the cumulative regulatory burden analysis, DOE describes other significant product-specific regulations that could affect BC and EPS manufacturers that will take effect 3 years before or after the compliance date of new and amended energy conservation standards for these products.[d] In addition to the new and amended energy conservation regulations on BCs and EPSs, several other Federal regulations and pending regulations apply to these products and other equipment produced by the same manufacturers. While, the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, DOE also has described a number of other

---

[d] The expected compliance date for BCs and EPSs is July, 2013.

regulations in section 12.6.3 through section 12.6.8 because it recognizes that these regulations also impact the products covered by this rulemaking.

Companies that produce a wide range of regulated products may be faced with more capital and product development expenditures than competitors with a narrower scope of products. Regulatory burdens can prompt companies to exit the market or reduce their product offerings, potentially reducing competition. Smaller companies in particular can be affected by regulatory costs since these companies have lower sales volumes over which they can amortize the costs of meeting new regulations. A proposed standard is not economically justified if it contributes to an unacceptable level of cumulative regulatory burden.

12.6.1 Federal DOE Regulations for Other Products Produced by BC and EPS Manufacturers

In addition to the amended energy conservation standards on BCs and EPSs, several other Federal regulations and pending regulations apply to other products produced by the same manufacturers. DOE recognizes that each regulation can significantly affect a manufacturer's financial operations. Multiple regulations affecting the same manufacturer can quickly strain manufacturers' profits and possibly cause an exit from the market. Table 12.6.1 list the Federal regulations that could also affect EPSs manufacturers in the three years leading up to and after the compliance date of amended energy conservation standards for these products. The amount of cumulative burden on any particular firm is extremely variable since the product scope of each company is different.

Table 12.6.1 Other DOE and Federal Actions Affecting the EPS Industry

Regulation	Approximate Publication Date	Approximate Compliance Date
Microwave	December, 2011	December, 2014
TV	January, 2013	January, 2016

12.6.2 Other Federal Regulations

12.6.2.1 Energy Independence and Security Act of 2007

The Energy Independence and Security Act (EISA) of 2007, Pub. L. 110-14, made numerous amendments to the Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, (42 U.S.C. 6291–6309), which established an energy conservation program for major household appliances and industrial and commercial equipment. Sections 301, 309, and 310 of EISA 2007 made several changes to EPCA related to BCs and EPSs.

Section 301 of EISA 2007 amended section 321 of EPCA by modifying definitions concerning EPSs. EPACT 2005 had amended EPCA to define an EPS as "an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product." (42 U.S.C. 6291(36)(A)) Section 301 of EISA 2007 further amended this definition by creating a subset of EPSs called Class A EPSs. EISA 2007 defined this subset as those EPSs that, in addition to meeting several other requirements common to all EPSs, are "able to convert to only 1 AC or DC output voltage at a time" and have "nameplate output power that is less than or equal to 250 watts." (42 U.S.C. 6291(36)(C)(i))

Section 301 also amended EPCA to establish minimum standards for Class A EPSs, shown below in Table 12.6.2. The Standard became effective on July 1, 2008 (42 U.S.C. 6295(u)(3)(A)).

Table 12.6.2 EISA 2007 Efficiency Standards for Class A EPSs

Nameplate Output	Active Mode Required Efficiency (decimal equivalent of a percentage)
<1 Watt	0.5 times the nameplate output
1 to not more than 51 Watts	The sum of 0.09 times the natural logarithm of the nameplate output and 0.5
>51 Watts	0.85
Nameplate Output	Maximum Consumption
Not more than 250 Watts	0.5 watts

Section 301 also directed DOE to publish a final rule by July 1, 2011, to determine whether to amend the aforementioned standards. (42 U.S.C. 6295(u)(3)(D)). Finally, Section 301 further directed DOE to issue a final rule that prescribes energy conservation standards for BCs or determine that no "standard is technically feasible or economically justified." (42 U.S.C. 6295(u)(1)(E)(i)(II)).

Because the EPS market is global, the EISA 2007 Standard on Class A EPSs led to improvements in the efficiency of EPSs sold worldwide. Furthermore, the standard, while intended to regulate only Class A EPSs, is likely having a spillover effect on the efficiency of BCs and non-Class A EPSs. The standard for Class A EPSs has increased the demand for, and lowered the cost of, some of the more efficient components and has stimulated the adoption of improved designs. Because some of the same techniques and components are used to manufacture both Class A EPSs and other BCs and EPSs, DOE assumes that some of these components and designs are being carried over into the design and manufacture of BCs and non-Class A EPSs.

12.6.2.2 Food and Drug Administration Regulation On Medical Devices

Manufacturers noted a regulatory burden caused by Food and Drug Administration (FDA) regulations on medical devices. Specifically, manufacturers were concerned that because the regulatory approval cycle for medical devices is longer than for consumer grade products, they would be faced with increased delays in time to market products.

The Code of Federal Regulation, Title 21, Volume 8: Food and Drug Chapter I (21CFR807), houses provisions on regulatory approval processes for medical devices intended to be commercialized in the US market. Section 807.81, numeral 3 establishes that a premarket notification submission is required when the device that is commercially distributed or being reintroduced into commercial distribution has been significantly changed or modified in design, components, methods of manufacturing, or intended use. The norm further specifies what constitutes a significant change or modification as follows:

> "(i) A change or modification in the device that could significantly affect the safety or effectiveness of the device, e.g., a significant change or modification in design, material, chemical composition, energy source, or manufacturing process"[e](21CFR807)

DOE acknowledges that medical products do have additional compliance requirements compared to more common, higher volume BCs and EPSs. However, DOE does not believe the time period between the announcement of the standard and compliance date should be extended for medical products.

12.6.3 State and Local Regulations

While, the cumulative regulatory burden focuses on the impacts on manufacturers of other Federal requirements, below DOE describes a number of State and local regulations in sections. These regulations impact the products covered by this rulemaking.

12.6.3.1 State Energy Conservation Standards

Since 2007, the state of California has established minimum performance standards for EPSs. California's Code of Regulations, Title 20, Sections 1605.3, houses the current provisions establishing requirements for EPSs. As shown in Table 12.6.3 since 2007, California's Energy Commission has set standards for EPSs used with laptop computers, mobile phones, printers, print servers, scanners, personal digital assistants and digital cameras.

Table 12.6.3 California Standards on EPSs used with Wireline Telephones and All Other Applications

Nameplate Output	**Active Mode Required Efficiency (decimal equivalent of a percentage)**
0 to <1 Watt	0.49 times the nameplate output
1 to not more than 51 Watts	The sum of 0.09 times the natural logarithm of the nameplate output and 0.49
>51 Watts	0.84
Nameplate Output	Maximum Consumption in No-Load Mode
<10 Watt	0.5 watts
10 to not more than 250 Watts	0.75 watts

More recently, California has regulated EPSs in a general fashion. These standards have been in effect since July 1st, 2008. As shown in Table 12.6.4 except for the difference in

---

[e] Section 807.81 Numeral 3. Code of Federal Regulations, Title 21, Volume 8. Subpart E- Premarket Notification Procedures. Available online at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=807&showFR=1&subpartNode=21:8.0.1.1.5.5

nameplate output requirement set for the No-Load Mode, these standards on EPSs are exactly the same as the federal standards on EPSs Class A.

Table 12.6.4 California Standards on EPSs

Nameplate Output	Active Mode Required Efficiency (decimal equivalent of a percentage)
<1 Watt	0.5 times the nameplate output
1 to not more than 51 Watts	The sum of 0.09 times the natural logarithm of the nameplate output and 0.5
>51 Watts	0.85
Nameplate Output	Maximum Consumption in No-Load Mode
Any Output	0.5 watts

As for BCs, the California Energy Commission issued Appliance Efficiency Standards for Battery Chargers. Docket No 11-AAER-2 houses the different proceedings, documents and announcements for this rulemaking.[f] As part of the cumulative regulatory burden, DOE quantitatively assessed the impact of the CEC BC standard on manufacturers. Table 12.6.5 presents the range of impacts on all BC product classes due to the CEC standards.

Table 12.6.5 – Base Case Manufacturer Impact Analysis for All BC Product Classes Due to the CEC Standard

	Units	No California Standards	With California Standards*		
			Flat Markup	Pass Through Markup	Constant Price Markup
INPV	2010$ Millions	53,780	53,918	53,660	53,205
Change in INPV	2010$ Millions	-	137	-120	-575
	(%)	-	0.3	(0.2)	(1.1)
Product Conversion Costs	2010$ Millions	-	12.6	12.6	12.6
Capital Conversion Costs	2010$ Millions	-	3.8	3.8	3.8
Total Investment Required	2010$ Millions	-	16.4	16.4	16.4

* The reason the base case INPV value varies for BCs is because of the uncertainty of how manufacturers will markup their products sold in California due to the CEC standards. The markup scenario used in each column is applied to those products sold in California. Therefore in the "Constant Price" column a constant price markup is applied to all products sold in California after the CEC standards go into effect.

These standards affect applications using a BC that are sold in California beginning in 2013. DOE estimated the impacts on manufacturers to range from $137 million to -$575 million, or a change in INPV of 0.3 percent to -1.1 percent. This range depends on manufacturers' ability to pass on the incremental price increases caused by the CEC standard to consumers in the California markets. DOE also estimated manufacturers will have to invest $12.6 million in product conversion costs and $3.8 million in capital conversion costs in order to have all BCs sold in California meet the CEC standard by 2013.

---

[f] This Docket can be visit at: http://www.energy.ca.gov/appliances/battery_chargers/index.html

Additionally, the state of California has passed laws on the Restriction on the use of certain Hazardous Substances (RoHS). California's RoHS law took effect January 1, 2007 and was modeled after the EU's2002/95/EC directive, which bans certain hazardous substances from electrical and electronic equipment.

12.6.4 International Energy Conservation Standards

DOE also describes a number of international energy conservation standards that also impact the products covered by this rulemaking. Because of the global nature of the BC and EPS markets, the international standards described below have and will continue to impact the US market.

12.6.4.1 Australia/New Zealand - Minimum Energy Performance Standards

Since December 2008 in Australia and December 2009 in New Zealand, most EPSs manufactured or imported for sale in Australia or New Zealand have been required to meet Minimum Energy Performance Standards. Products covered by this regulation include EPS units with a nominal 230 V AC supply input and a single output at extra low voltage (either AC or DC), and a maximum output of 250 W or 250 VA.[g]

12.6.4.2 Canada - Minimum Energy Performance Standards

The Natural Resources Canada's Office of Energy Efficiency (OEE) proposed to amend Canada's Energy Efficiency Regulations by adding minimum energy performance standards for EPSs. The Standard went in effect on July 1, 2010.[h]

12.6.4.3 China - Minimum Energy Performance Standards

China National Institute of Standardization (CNIS) has established minimum allowable values of energy efficiency and evaluating values of energy conservation for single voltage external AC-DC and AC-AC power supplies. Products covered by this regulation include EPSs with rated output power no larger than 250W. The Standard does not apply to DC-DC transformer. This standard has been in effect since 2007.[i]

12.6.4.4 European Union - Energy Using Products Standard

Recently, the European Union Commission enacted Directive 2009/125/EC for "energy-related products" (ErP), which amended EU Directive 2005/32/EC for "energy-using products" (EuP). Commission Regulation (EU) No 278 implements Directive 2009/125/EC and established ecodesign requirements for EPSs. The European Union standard is equivalent to the current Federal standard for Class A EPSs.[j]

---

[g] For more information on this topic see: http://www.energyrating.gov.au/library/pubs/2008-factsheet-eps.pdf.

[h] For more information on this topic see: http://oee.nrcan.gc.ca/regulations/bulletin/ext-power-supplies-june-2010.cfm

[i] For more information on this topic see: http://www.apec-esis.org/programinfo.php?no=10086

[j] For more information on this topic see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:en:PDF

The European Union Commissions also recently enacted Directive 2008/1275/EC which sets "requirements for standby and off-mode electric power consumption of electrical and electronic household equipment." This directive also amended EU Directive 2005/32/EC. The regulation sets the maximum power consumption for most BCs and EPSs in standby or off-mode at 1.00W in January 2010 and 0.50W in January 2013.[k]

12.6.4.5 Korea - Minimum Energy Performance Standards

The Korean Energy Management Corporation has established Minimum Energy Performance Standards for EPSs, effective January 1st, 2009. The regulation contemplates adapters with a rated power of less than 150W and chargers of input 20W with Li-Ion Battery as a single voltage EPSs for use in electronic devices.[l]

12.6.5 Restriction of Hazardous Substances (RoHS)

The Restriction of Hazardous Substances (RoHS) Directive (2002/95/EC), implemented as of July 2006, prohibits electronics and electrical equipment (EEE) containing more than agreed levels of certain hazardous materials from being put on the market in the EU market.[m] This directive was created in an attempt to address concerns regarding the global issue of consumer electronics waste and the long term effects of low-level chemical exposure related to these products.

While RoHS-like legislation has not been implemented on the federal level in the United States, the global effects of the RoHS Directive in the E.U. and similar legislation around the world have not gone unnoticed in the U.S. market. Companies based in the United States that partially rely on international sales have been forced to manufacture RoHS compliant products to avoid losing their E.U. sales, and these same products are being sold in the United States.

The RoHS Regulations apply to EEE which are dependent on electric currents or electromagnetic fields in order to function properly, are designed for use with a voltage rating no greater than 1,000 V for alternating current and 1,500 V for direct current, and fall into one of ten categories listed in Schedule 1 to the RoHS Regulations. Several of the categories are directly relevant to BCEPS, including telecommunications equipment and consumer electronics.

As noted above, California has passed legislation that limits the amount of hazards substances included in the RoHS directive that can be sold in California.

12.6.6 Waste Electrical and Electronic Equipment (WEEE)

On January 27, 2003, The European Union enacted Directive 2002/96/EC of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE). The

---

[k] For more information on this topic see: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:en:PDF

[l] For more information on this topic see: http://www.kemco.or.kr/nd_file/kemco_eng/MKE%20Notice%202009-158.pdf

[m] RoHS denotes specific maximum allowable levels of six hazardous substances, including lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl and polybrominated diphenyl ether flame retardants.

objective of the WEEE Directive is primarily to prevent the waste electrical and electronic equipment, and in addition, the reuse, recycling and other forms of recovery of such wastes with the aim to reduce the disposal of waste.

Importantly, this directive seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, including producers, distributors and consumers. More specifically, the directive imposes the financial responsibility for the disposal of electrical and electronic equipment waste on the manufacturer of such equipment. BCs and EPSs are among the electronic products covered by this regulation and therefore impacted by it. Since the BC and EPS market is global, the practical effect of this regulation is shared throughout the world, including the United States.

Currently, the European Union Parliament is studying a Proposal that revises Directive 2002/96/EC to improve its effectiveness and implementation, and to reduce administrative costs related to its application. The final vote on the Proposal is pending of approval and will probably take place in early 2011.

12.6.7 Electromagnetic Compatibility (EMC)

BCs and EPSs are subject to Electromagnetic Compatibility (EMC) current regulations in the European Union.

On December 15, 2004, the European Union adopted Directive 2004/108/EC of the European Parliament and of the Council related to EMC. The Directive applies to all electronic or electrical products liable to cause or be disturbed by electromagnetic interference (EMI) and requires that all equipment produced, imported into and commercialized in the European market comply with basic protection aiming to ensure that:

- “The electromagnetic disturbance generated by equipment does not affect the correct functioning of other apparatus as well as radio and telecommunications equipment, related equipment and electricity distribution networks.
- Equipment has an adequate level of intrinsic immunity to electromagnetic disturbances to enable them to operate as intended.”[n]

EMC European regulations have been noted as a regulatory burden for US manufacturer of BC and EPS equipment since compliance with such regulations is required to access the European market.

---

[n] European Guide for the EMC Directive2004/108/EC, May 21, 2007. P 9. Available online at: 2004/108/EChttp://ec.europa.eu/enterprise/sectors/electrical/files/emcguide_may2007_en.pdf

12.6.8 Product Certification Regulations

12.6.8.1 UL 60601-1 Medical Electrical Equipment Safety

UL/IEC 60601-1 Part 1General Requirements for Safety" (1st ed.) is the harmonized standard for medical electrical equipment. In addition to safety requirements, the standard includes particular standards requirements for functional safety, software, lasers and EMC.

UL/IEC 60601-1 sets design standards for EPSs for use in medical devices. Manufactures noted that compliance this standard could potentially impose a cumulative burden on them should the new conservation standards on BCs and EPSs require changes that necessitate re-testing for compliance with UL/IEC 60601-1.

12.6.8.2 UL 2575

UL 2575 corresponds to the proposed first edition of the Standard for Lithium Ion Battery Systems for use in Electric Power Tool and Motor Operated, Heating and Lighting Appliances.

The Proposed Standard was published on March, 2010 and it seeks to harmonize IEC 60745 and IEC 60335 to UL 2575. This Standard is expected to become effective in 2011.

When UL 2575 comes into effect every motor-operating stand alone appliance, including BCs and EPSs but excluding laptops, will have to comply with the safety functions delineated in it. Manufacturers will be faced with the financial burden of testing to an additional standard as well as the challenge of dealing with reduced testing laboratory space.

12.6.8.3 ITE/ EN 60950-1

ITE/EN 60950-1 Information Technology Equipment - Safety - Part 1: General Requirements sets a standard applicable to mains-powered or battery-powered information technology equipment, including electrical business equipment and associated equipment. ITE/EN 60950-1 in its current Edition specifies requirements intended to reduce risks of fire, electric shock or injury with respect to installed equipment, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the equipment in the manner prescribed by the manufacturer.

The second edition of ITE standard, EN 60950-1 will become effective beginning December 2010. BC and EPS manufacturer noted compliance with the 2nd Edition, which contains more than 50 revised or new clauses, will pose a regulatory burden on them as they may have to cover the cost of re-testing in order to remain compliant and maintain access to the European markets.

REFERENCES

---

1 Securities and Exchange Commission, Annual 10-K Reports, Various Years, Washington DC. <www.sec.gov>.

2 Standard and Poors Financial Services LLC, Company Credit Ratings, Various Companies, New York, NY. < www2.standardandpoors.com>.

3 McKinsey & Company, Inc. *Valuation: Measuring and Managing the Value of Companies*, 3rd Edition, Copeland, Koller, Murrin. New York: John Wiley & Sons, 2000.

4 McKinsey & Company, Inc. *Valuation: Measuring and Managing the Value of Companies*, 3rd Edition, Copeland, Koller, Murrin. New York: John Wiley & Sons, 2000.

CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 13. EMPLOYMENT IMPACT ANALYSIS

13.1 INTRODUCTION

DOE's employment impact analysis is designed to estimate indirect national job creation or elimination resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating external power supplies and battery chargers. Job increases or decreases reported in this chapter are separate from the direct external power supply and battery charger sector employment impacts reported in the manufacturer impact analysis (Chapter 12), and reflect the employment impact of efficiency standards on all other sectors of the economy.

13.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (i.e., they may remain "saved"). The standards may increase the purchase price of products, including the retail price plus sales tax, and increase installation costs.

Using an input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see Chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore include a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

13.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 3.1.1[2] (Impact of Sector Energy Technologies) as a successor to ImBuild[3], a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationship of different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity and so changes in the level of spending (e.g., due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (e.g., changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and wage income.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient products. The increased cost of products leads to higher employment in the product manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, electric utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, electric utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the external power supply and battery charger manufacturing sector estimated in Chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

13.4 SHORT-TERM RESULTS

The results in this section refer to impacts of external power supply and battery charger standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. DOE anticipates no change in operations and maintenance costs for external power supplies and battery chargers. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the external power supply and battery charger production sector, the energy generation sector, and the general consumer good sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule increases the purchase price of external power supplies and battery chargers; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on electricity. The reduction in electricity demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on external power supplies and battery chargers and reduced expenditures on electricity, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (as more workers are hired they consume more goods, which generates more employment, the converse is true for workers laid off).

In certain years of the analysis, external power supplies and battery chargers purchased under standards are projected to have a lower purchase price than in a baseline situation without standards. In these cases, the employment impact due to the change in purchase price will be opposite to that described above, with decreased employment in the external power supply and battery charger production sector and increased employment in other sectors of the economy.

Table 13.4.1 – 13.4.2 present the modeled net employment impact from the rule in 2015. Nearly 100% of external power supplies and battery chargers are imported, with less than 1% produced domestically. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported external power supplies and battery chargers. The two scenarios bounding the ranges presented in Table 13.4.1 – 13.4.2. represent situations in which none of the money spent on imported external power supplies and battery chargers returns to the U.S. economy and all of the money spent on imported external power supplies and battery chargers returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50% and 75% of the money spent on imported external power supplies and battery chargers is likely to return, with employment impacts falling within the ranges presented below.

Table 13.4.1 External Power Supply Net National Short-term Change in Employment (1000 jobs)

Product Class	Trial Standard Level	2015	2020
B	TSL 1	-0.4 to 0.5	-0.1 to 0.7
	TSL 2	-1.1 to 0.5	-0.8 to 1.0
	TSL 3	-5.1 to 0.4	-4.4 to 1.2
X	TSL 1	0.0 to 0.1	0.1
	TSL 2	0.0 to 0.1	0.1
	TSL 3	-0.7 to 0.0	-0.6 to 0.1
H	TSL 1	0.0	0.0
	TSL 2	0.0	0.0
	TSL 3	0.0	0.0
B,C,D,E	TSL 1	-0.6 to 0.4	-0.2 to 0.9
	TSL 2	-1.4 to 0.6	-0.9 to 1.2
	TSL 3	-5.6 to 0.5	-4.8 to 1.6

Table 13.4.2 Battery Charger Net National Short-term Change in Employment (1000 jobs)

Product Class	Trial Standard Level	2015	2020
1	TSL 1	-0.1 to 0.0	0.0
	TSL 2	-0.3 to -0.2	-0.2 to -0.1
	TSL 3	-3.3 to -2.4	-3.2 to -2.3
2, 3, 4	TSL 1	-2.1 to -1.7	-1.9 to -1.5
	TSL 2	-20.2 to -17.7	-20.4 to -17.9
	TSL 3	-99.3 to -87.5	-101.9 to -89.6
	TSL 4	-167.1 to -143.8	-172.4 to -148.1
5, 6	TSL 1	0.1 to 0.2	0.3 to 0.4
	TSL 2	0.9 to 1.2	1.4 to 1.7
	TSL 3	-12.9 to -5.4	-12.8 to -5.1
7	TSL 1	0.1	0.1
	TSL 2	-1.1 to -0.8	-1.1 to -0.8
8	TSL 1	3.6 to 4.8	3.8 to 5.0
	TSL 2	-3.3 to -2.4	-3.4 to -2.5
	TSL 3	-3.9 to -2.9	-4.1 to -3.0
10	TSL 1	0.1 to 0.2	0.4 to 0.5
	TSL 2	0.0 to 0.1	0.3 to 0.5
	TSL 3	0.0 to 0.2	0.4 to 0.6

For context, the Office of Management of Budget currently assumes that the unemployment rate may decline to 6.9% in 2014 and drop further to 5.3% in 2017.[5] The unemployment rate in 2017 is projected to be close to "full employment." When an economy is at full employment any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

13.5 LONG-TERM RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for electricity to decline over time and demand for other goods to increase. Since the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will in general be negligible over time due to the small magnitude of the short-term effects presented in Table 13.4.1 – 13.4.2 for most product classes and TSLs. The ImSET model projections, assuming no price or wage effects until 2020, are included in the second column of Table 13.4.1 – 13.4.2.

REFERENCES

1. Scott, M., JM Roop, RW Schultz, DM Anderson, KA Cort, The Impact of DOE Building Technology Energy Efficiency Programs on U.S. Employment, Income, and Investment. *Energy Economics*, 2008. 30(5): pp. 2283-2301

2. Roop, J. M., M. J. Scott, and R. W. Schultz, *ImSET: Impact of Sector Energy Technologies*, 2005. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL- 15273.

3. Scott, M. J., D. J. Hostick, and D. B. Belzer, *ImBuild: Impact of Building Energy Efficiency Programs*, April, 1998. Pacific Northwest National Laboratory. Richland, WA. Report No. PNNL-11884. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

4. Minnesota IMPLAN Group Inc., *IMPLAN Professional: User's Guide, Analysis Guide, Data Guide*, 1997. Stillwater, MN.

5. Office of Management and Budget, *Fiscal Year 2012 Mid-Session Review: Budget of the U.S. Government*, Washington, DC. <http://www.whitehouse.gov/sites/default/files/omb/budget/fy2012/assets/12msr.pdf>

CHAPTER 14. UTILITY IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 14. UTILITY IMPACT ANALYSIS

14.1 INTRODUCTION

DOE analyzed the effects of battery charger (BC) and external power supply (EPS) standard levels on the electric utility industry using a variant of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *Annual Energy Outlook (AEO)*. The *AEO* for 2010 *(AEO2010)* forecasts energy supply and demand through 2035.[1] DOE used a variant of this model, referred to here as NEMS-BT,[b] to account for the impacts of battery charger and external power supply energy conservation standards. DOE's utility impact analysis consists of a comparison between model results for the *AEO2010* Reference Case and for cases in which standards are in place, and applies the same basic set of assumptions as the *AEO2010*. The *AEO2010* reference case corresponds to medium economic growth.

The utility impact analysis reports the changes in electric installed capacity and generation that result for each trial standard level (TSL) by plant type, as well as changes in residential electricity consumption.

NEMS-BT has several advantages that have led to its adoption as the forecasting tool in the analysis of energy conservation standards. NEMS-BT uses a set of assumptions that are well known and fairly transparent, due to the exposure and scrutiny each *AEO* receives. In addition, the comprehensiveness of NEMS-BT permits the modeling of interactions among the various energy supply and demand sectors, producing a complete picture of the effects of energy conservation standards. Perhaps most importantly, NEMS-BT can be used to estimate marginal effects, which yield a better estimate of the actual impact of energy conservation standards than considering only average effects.

14.2 METHOD

The utility impact analysis uses the assumptions of the *AEO2010* and treats BCs and EPSs conservation standards as variations in policy. The effects of the policy are calculated as the difference between the *AEO2010* Reference Case and each proposed standard case, which is described as a trial standard level (TSL).

---

[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March, 2003.

[b] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

DOE used the site energy savings developed in the national impact analysis (chapter 10) for each TSL as input to NEMS-BT. The magnitude of the energy decrement that would be required for NEMS-BT to produce stable results out of the range of numerical noise is larger than the highest efficiency standard under consideration. Therefore, DOE estimated results corresponding to each TSL using interpolation. DOE ran higher energy use reduction levels in NEMS-BT, representing multipliers of each TSL, and used these outputs to linearly interpolate the results to estimate actual changes in generation and capacity due to the standard.

Policy runs are executed by reducing electricity consumption in the NEMS-BT Residential Demand Module and in the Commercial Demand Module. Energy use reductions are applied to the refrigeration end use.

Although the current time horizon of NEMS-BT is 2035, other parts of the energy conservation standards analysis extend to the year 2043. It is not feasible to extend the forecast period of NEMS-BT for the purposes of this analysis, nor does DOE/EIA have an approved method for extrapolation of many outputs beyond 2035. While it might seem reasonable to make simple linear extrapolations of results, in practice this is not advisable because outputs could be contradictory. An analysis of various trends sufficiently detailed to guarantee consistency is beyond the scope of this work, and, in any case, would involve a great deal of uncertainty. Therefore, all extrapolations beyond 2035 are simple replications of year 2035 results. To emphasize the extrapolated results wherever they appear, they are shaded in gray to distinguish them from actual NEMS-BT results.

14.3 RESULTS

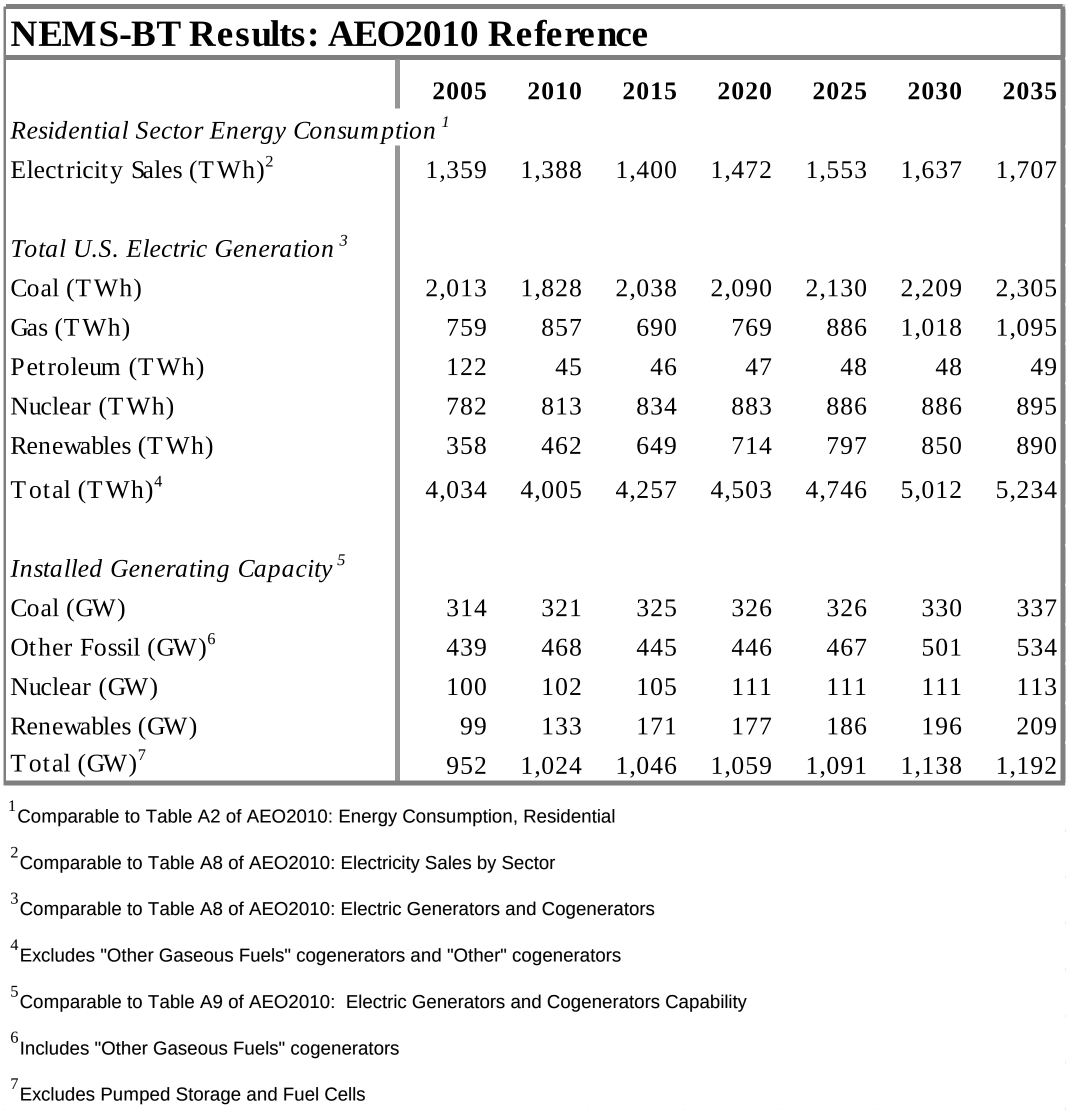
This utility impact analysis reports NEMS-BT forecasts for residential-sector electricity consumption, total electricity generation by fuel type, and installed electricity generation capacity by fuel type. Results are presented in five-year increments to year 2035. Beyond year 2035, an extrapolation through 2042 for each proposed TSL represents a simple replication of the year 2035 results.

The results from the *AEO2010* Reference Case are shown in Table 13.3.1.

A separate set of TSLs is modeled for each product class grouping within each product category: battery chargers, and external power supplies. The results for the external power supply TSLs are presented in Tables 13.3.2 through 13.3.13, and the results for battery charger TSLs are presented in Tables 13.3.14 through 13.3.31. Each table shows forecasts using interpolated results, as described in section 13.2, for total U.S. electricity generation and installed capacity.

The considered BC and EPS TSLs reduce only electricity consumption compared to the *AEO2010* Reference Case. The electricity savings predicted by the NIA Model for all external power supply products considered range from 0.00 to 0.31 percent of total residential electricity consumption in the year 2035. The electricity savings of considered battery charger products range from 0.00 to 0.39 percent of total residential electricity consumption in 2035.

Table 14.3.1 AEO2010 Reference Case Forecast



NEMS-BT Results: AEO2010 Reference

	2005	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption [1]							
Electricity Sales (TWh)[2]	1,359	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation [3]							
Coal (TWh)	2,013	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	759	857	690	769	886	1,018	1,095
Petroleum (TWh)	122	45	46	47	48	48	49
Nuclear (TWh)	782	813	834	883	886	886	895
Renewables (TWh)	358	462	649	714	797	850	890
Total (TWh)[4]	4,034	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity [5]							
Coal (GW)	314	321	325	326	326	330	337
Other Fossil (GW)[6]	439	468	445	446	467	501	534
Nuclear (GW)	100	102	105	111	111	111	113
Renewables (GW)	99	133	171	177	186	196	209
Total (GW)[7]	952	1,024	1,046	1,059	1,091	1,138	1,192

[1] Comparable to Table A2 of AEO2010: Energy Consumption, Residential

[2] Comparable to Table A8 of AEO2010: Electricity Sales by Sector

[3] Comparable to Table A8 of AEO2010: Electric Generators and Cogenerators

[4] Excludes "Other Gaseous Fuels" cogenerators and "Other" cogenerators

[5] Comparable to Table A9 of AEO2010: Electric Generators and Cogenerators Capability

[6] Includes "Other Gaseous Fuels" cogenerators

[7] Excludes Pumped Storage and Fuel Cells

Table 14.3.2 EPS Product Class B: Trial Standard Level 1 Forecast

NEMS-BT Results:						
	2010	**2015**	**2020**	**2025**	**2030**	**2035**
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,470	1,552	1,636	1,706
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	850	890
Total (TWh)	4,005	4,256	4,501	4,744	5,010	5,232
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case									
							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.93	-1.35	-1.41	-1.46	-1.52	-1.58	-1.59	-1.60
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.26	-0.44	-0.34	-0.46	-0.44	-0.44	-0.44	-0.44
Gas (TWh)	0.07	-0.30	-0.53	-0.73	-0.59	-0.50	-0.50	-0.50	-0.50
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.04	-0.04	-0.04	-0.04
Renewables (TWh)	-0.08	-0.42	-0.42	-0.49	-0.44	-0.48	-0.48	-0.48	-0.48
Total (TWh)	0.00	-0.99	-1.41	-1.57	-1.49	-1.47	-1.47	-1.47	-1.47
Installed Generating Capacity									
Coal (GW)	0.00	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04
Other Fossil (GW)	0.00	-0.04	-0.07	-0.11	-0.10	-0.10	-0.10	-0.10	-0.10
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.02	-0.12	-0.11	-0.10	-0.10	-0.11	-0.11	-0.11	-0.11
Total (GW)	-0.02	-0.18	-0.21	-0.24	-0.24	-0.26	-0.26	-0.26	-0.26

Table 14.3.3 EPS Product Class B: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,469	1,551	1,635	1,705
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	768	884	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	849	890
Total (TWh)	4,005	4,256	4,500	4,743	5,009	5,231
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-1.48	-2.14	-2.23	-2.32	-2.40	-2.50	-2.51	-2.53
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.41	-0.70	-0.54	-0.73	-0.70	-0.70	-0.70	-0.70
Gas (TWh)	0.12	-0.48	-0.84	-1.15	-0.93	-0.79	-0.79	-0.79	-0.79
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.07	-0.07	-0.07	-0.07
Renewables (TWh)	-0.12	-0.67	-0.67	-0.77	-0.69	-0.77	-0.77	-0.77	-0.77
Total (TWh)	0.00	-1.57	-2.23	-2.48	-2.36	-2.33	-2.33	-2.33	-2.33
Installed Generating Capacity									
Coal (GW)	0.00	-0.03	-0.05	-0.05	-0.06	-0.06	-0.06	-0.06	-0.06
Other Fossil (GW)	0.00	-0.07	-0.10	-0.17	-0.15	-0.15	-0.15	-0.15	-0.15
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.03	-0.19	-0.17	-0.16	-0.16	-0.18	-0.18	-0.18	-0.18
Total (GW)	-0.03	-0.28	-0.33	-0.38	-0.37	-0.40	-0.40	-0.40	-0.40

Table 14.3.4 EPS Product Class B: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,397	1,468	1,549	1,633	1,703
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,037	2,089	2,129	2,208	2,303
Gas (TWh)	857	689	768	883	1,016	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	647	713	796	849	889
Total (TWh)	4,005	4,254	4,499	4,741	5,007	5,230
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-2.73	-3.88	-4.05	-4.21	-4.37	-4.54	-4.57	-4.60
Total U.S. Electric Generation									
Coal (TWh)	0.02	-0.76	-1.27	-0.98	-1.32	-1.26	-1.26	-1.26	-1.26
Gas (TWh)	0.22	-0.88	-1.53	-2.10	-1.69	-1.43	-1.43	-1.43	-1.43
Petroleum (TWh)	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.12	-0.12	-0.12	-0.12
Renewables (TWh)	-0.23	-1.24	-1.22	-1.40	-1.26	-1.39	-1.39	-1.39	-1.39
Total (TWh)	0.01	-2.90	-4.05	-4.50	-4.29	-4.23	-4.23	-4.23	-4.23
Installed Generating Capacity									
Coal (GW)	0.00	-0.06	-0.09	-0.09	-0.11	-0.11	-0.11	-0.11	-0.11
Other Fossil (GW)	0.00	-0.12	-0.19	-0.30	-0.28	-0.28	-0.28	-0.28	-0.28
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (GW)	-0.06	-0.34	-0.32	-0.29	-0.29	-0.33	-0.33	-0.33	-0.33
Total (GW)	-0.06	-0.53	-0.59	-0.68	-0.68	-0.73	-0.73	-0.73	-0.73

Table 14.3.5 EPS Product Classes B, C, D, and E: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,470	1,552	1,635	1,705
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	768	885	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	850	890
Total (TWh)	4,005	4,256	4,501	4,744	5,010	5,232
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-1.12	-1.69	-1.80	-1.87	-1.94	-2.01	-2.03	-2.04
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.31	-0.55	-0.44	-0.59	-0.56	-0.56	-0.56	-0.56
Gas (TWh)	0.09	-0.36	-0.67	-0.93	-0.75	-0.63	-0.63	-0.63	-0.63
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05
Renewables (TWh)	-0.09	-0.51	-0.53	-0.62	-0.56	-0.62	-0.62	-0.62	-0.62
Total (TWh)	0.00	-1.19	-1.76	-2.00	-1.90	-1.88	-1.88	-1.88	-1.88
Installed Generating Capacity									
Coal (GW)	0.00	-0.02	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
Other Fossil (GW)	0.00	-0.05	-0.08	-0.13	-0.13	-0.12	-0.12	-0.12	-0.12
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.03	-0.14	-0.14	-0.13	-0.13	-0.14	-0.14	-0.14	-0.14
Total (GW)	-0.03	-0.22	-0.26	-0.30	-0.30	-0.33	-0.33	-0.33	-0.33

Table 14.3.6 EPS Product Classes B, C, D, and E: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,398	1,469	1,551	1,634	1,704
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,089	2,129	2,208	2,304
Gas (TWh)	857	690	768	884	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	849	889
Total (TWh)	4,005	4,255	4,500	4,743	5,009	5,231
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-1.77	-2.65	-2.82	-2.92	-3.03	-3.15	-3.17	-3.20
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.50	-0.87	-0.68	-0.92	-0.88	-0.88	-0.88	-0.88
Gas (TWh)	0.14	-0.57	-1.05	-1.46	-1.17	-0.99	-0.99	-0.99	-0.99
Petroleum (TWh)	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.08	-0.08	-0.08	-0.08
Renewables (TWh)	-0.15	-0.80	-0.83	-0.97	-0.87	-0.97	-0.97	-0.97	-0.97
Total (TWh)	0.01	-1.88	-2.76	-3.13	-2.98	-2.94	-2.94	-2.94	-2.94
Installed Generating Capacity									
Coal (GW)	0.00	-0.04	-0.06	-0.06	-0.08	-0.08	-0.08	-0.08	-0.08
Other Fossil (GW)	0.00	-0.08	-0.13	-0.21	-0.20	-0.20	-0.20	-0.20	-0.20
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.04	-0.22	-0.22	-0.20	-0.20	-0.23	-0.23	-0.23	-0.23
Total (GW)	-0.04	-0.34	-0.41	-0.47	-0.47	-0.51	-0.51	-0.51	-0.51

Table 14.3.7 EPS Product Classes B, C, D, and E: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,397	1,467	1,548	1,632	1,702
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,037	2,089	2,129	2,208	2,303
Gas (TWh)	857	689	767	883	1,016	1,093
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	647	712	795	849	889
Total (TWh)	4,005	4,254	4,498	4,740	5,007	5,229
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	533
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	195	209
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-3.14	-4.65	-4.93	-5.12	-5.32	-5.52	-5.56	-5.60
Total U.S. Electric Generation									
Coal (TWh)	0.02	-0.88	-1.52	-1.20	-1.61	-1.54	-1.54	-1.54	-1.54
Gas (TWh)	0.25	-1.01	-1.83	-2.55	-2.05	-1.74	-1.74	-1.74	-1.74
Petroleum (TWh)	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.15	-0.15	-0.15	-0.15
Renewables (TWh)	-0.26	-1.43	-1.46	-1.70	-1.53	-1.69	-1.69	-1.69	-1.69
Total (TWh)	0.01	-3.33	-4.84	-5.48	-5.22	-5.14	-5.14	-5.14	-5.14
Installed Generating Capacity									
Coal (GW)	0.00	-0.07	-0.11	-0.11	-0.14	-0.14	-0.14	-0.14	-0.14
Other Fossil (GW)	0.00	-0.14	-0.23	-0.37	-0.34	-0.34	-0.34	-0.34	-0.34
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (GW)	-0.07	-0.39	-0.38	-0.35	-0.35	-0.40	-0.40	-0.40	-0.40
Total (GW)	-0.07	-0.60	-0.71	-0.83	-0.83	-0.89	-0.89	-0.89	-0.89

Table 14.3.8 EPS Product Class X: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.11	-0.19	-0.19	-0.20	-0.21	-0.22	-0.22	-0.22
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.03	-0.06	-0.05	-0.06	-0.06	-0.06	-0.06	-0.06
Gas (TWh)	0.01	-0.03	-0.07	-0.10	-0.08	-0.07	-0.07	-0.07	-0.07
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (TWh)	-0.01	-0.05	-0.06	-0.07	-0.06	-0.07	-0.07	-0.07	-0.07
Total (TWh)	0.00	-0.11	-0.19	-0.21	-0.20	-0.20	-0.20	-0.20	-0.20
Installed Generating Capacity									
Coal (GW)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Other Fossil (GW)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	0.00	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
Total (GW)	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03

Table 14.3.9 EPS Product Class X: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.12	-0.21	-0.22	-0.23	-0.24	-0.25	-0.25	-0.25
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.03	-0.07	-0.05	-0.07	-0.07	-0.07	-0.07	-0.07
Gas (TWh)	0.01	-0.04	-0.08	-0.11	-0.09	-0.08	-0.08	-0.08	-0.08
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (TWh)	-0.01	-0.06	-0.07	-0.08	-0.07	-0.08	-0.08	-0.08	-0.08
Total (TWh)	0.00	-0.13	-0.22	-0.25	-0.23	-0.23	-0.23	-0.23	-0.23
Installed Generating Capacity									
Coal (GW)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Other Fossil (GW)	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Total (GW)	0.00	-0.02	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04

Table 14.3.10 EPS Product Class X: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.25	-0.44	-0.45	-0.47	-0.49	-0.51	-0.51	-0.51
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.07	-0.14	-0.11	-0.15	-0.14	-0.14	-0.14	-0.14
Gas (TWh)	0.02	-0.08	-0.17	-0.23	-0.19	-0.16	-0.16	-0.16	-0.16
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (TWh)	-0.02	-0.12	-0.14	-0.16	-0.14	-0.16	-0.16	-0.16	-0.16
Total (TWh)	0.00	-0.27	-0.45	-0.50	-0.48	-0.47	-0.47	-0.47	-0.47
Installed Generating Capacity									
Coal (GW)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Other Fossil (GW)	0.00	-0.01	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	-0.01	-0.03	-0.04	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04
Total (GW)	-0.01	-0.05	-0.07	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08

Table 14.3.11 EPS Product Class H: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	886	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.001	-0.003	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
Total U.S. Electric Generation									
Coal (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Gas (TWh)	0.000	0.000	-0.001	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total (TWh)	0.000	-0.001	-0.003	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
Installed Generating Capacity									
Coal (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Fossil (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total (GW)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001

Table 14.3.12 EPS Product Class H: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	886	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.001	-0.003	-0.004	-0.004	-0.004	-0.005	-0.005	-0.005
Total U.S. Electric Generation									
Coal (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Gas (TWh)	0.000	0.000	-0.001	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (TWh)	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Total (TWh)	0.000	-0.001	-0.003	-0.005	-0.004	-0.004	-0.004	-0.004	-0.004
Installed Generating Capacity									
Coal (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Fossil (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total (GW)	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001

Table 14.3.13 EPS Product Class H: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	886	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.001	-0.004	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
Total U.S. Electric Generation									
Coal (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Gas (TWh)	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (TWh)	0.000	-0.001	-0.001	-0.002	-0.001	-0.002	-0.002	-0.002	-0.002
Total (TWh)	0.000	-0.001	-0.004	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
Installed Generating Capacity									
Coal (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Fossil (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total (GW)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001

Table 14.3.14 BC Product Class 1: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.10	-0.17	-0.17	-0.18	-0.18	-0.19	-0.19	-0.19
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.03	-0.05	-0.04	-0.06	-0.05	-0.05	-0.05	-0.05
Gas (TWh)	0.01	-0.03	-0.07	-0.09	-0.07	-0.06	-0.06	-0.06	-0.06
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (TWh)	-0.01	-0.04	-0.05	-0.06	-0.05	-0.06	-0.06	-0.06	-0.06
Total (TWh)	0.00	-0.10	-0.17	-0.19	-0.18	-0.18	-0.18	-0.18	-0.18
Installed Generating Capacity									
Coal (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Fossil (GW)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Total (GW)	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03

Table 14.3.15 BC Product Class 1: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.22	-0.38	-0.40	-0.41	-0.43	-0.45	-0.45	-0.45
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.06	-0.13	-0.10	-0.13	-0.12	-0.12	-0.12	-0.12
Gas (TWh)	0.02	-0.07	-0.15	-0.21	-0.17	-0.14	-0.14	-0.14	-0.14
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (TWh)	-0.02	-0.10	-0.12	-0.14	-0.12	-0.14	-0.14	-0.14	-0.14
Total (TWh)	0.00	-0.24	-0.40	-0.44	-0.42	-0.42	-0.42	-0.42	-0.42
Installed Generating Capacity									
Coal (GW)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Other Fossil (GW)	0.00	-0.01	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	-0.01	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Total (GW)	-0.01	-0.04	-0.06	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07

Table 14.3.16 BC Product Class 1: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,636	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.31	-0.53	-0.55	-0.57	-0.59	-0.61	-0.62	-0.62
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.09	-0.17	-0.13	-0.18	-0.17	-0.17	-0.17	-0.17
Gas (TWh)	0.02	-0.10	-0.21	-0.28	-0.23	-0.19	-0.19	-0.19	-0.19
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (TWh)	-0.03	-0.14	-0.17	-0.19	-0.17	-0.19	-0.19	-0.19	-0.19
Total (TWh)	0.00	-0.33	-0.55	-0.61	-0.58	-0.57	-0.57	-0.57	-0.57
Installed Generating Capacity									
Coal (GW)	0.00	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01
Other Fossil (GW)	0.00	-0.01	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	-0.01	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Total (GW)	-0.01	-0.06	-0.08	-0.09	-0.09	-0.10	-0.10	-0.10	-0.10

Table 14.3.17 BC Product Classes 2,3,4: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,636	1,706
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,256	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.67	-0.91	-0.95	-0.99	-1.03	-1.06	-1.07	-1.08
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.19	-0.30	-0.23	-0.31	-0.30	-0.30	-0.30	-0.30
Gas (TWh)	0.05	-0.22	-0.36	-0.49	-0.40	-0.34	-0.34	-0.34	-0.34
Petroleum (TWh)	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.03	-0.03	-0.03	-0.03
Renewables (TWh)	-0.06	-0.31	-0.29	-0.33	-0.30	-0.33	-0.33	-0.33	-0.33
Total (TWh)	0.00	-0.72	-0.95	-1.06	-1.01	-0.99	-0.99	-0.99	-0.99
Installed Generating Capacity									
Coal (GW)	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
Other Fossil (GW)	0.00	-0.03	-0.04	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	-0.02	-0.08	-0.07	-0.07	-0.07	-0.08	-0.08	-0.08	-0.08
Total (GW)	-0.02	-0.13	-0.14	-0.16	-0.16	-0.172	-0.17	-0.17	-0.17

Table 14.3.18 BC Product Classes 2,3,4: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,469	1,551	1,635	1,705
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,208	2,304
Gas (TWh)	857	690	768	884	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	849	889
Total (TWh)	4,005	4,255	4,500	4,743	5,009	5,231
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-1.60	-2.23	-2.34	-2.43	-2.52	-2.61	-2.63	-2.65
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.45	-0.73	-0.57	-0.76	-0.73	-0.73	-0.73	-0.73
Gas (TWh)	0.13	-0.51	-0.88	-1.21	-0.97	-0.82	-0.82	-0.82	-0.82
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.07	-0.07	-0.07	-0.07
Renewables (TWh)	-0.13	-0.73	-0.70	-0.80	-0.72	-0.80	-0.80	-0.80	-0.80
Total (TWh)	0.01	-1.70	-2.33	-2.59	-2.47	-2.44	-2.44	-2.44	-2.44
Installed Generating Capacity									
Coal (GW)	0.00	-0.03	-0.05	-0.05	-0.06	-0.06	-0.06	-0.06	-0.06
Other Fossil (GW)	0.00	-0.07	-0.11	-0.18	-0.16	-0.16	-0.16	-0.16	-0.16
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.04	-0.20	-0.18	-0.17	-0.17	-0.19	-0.19	-0.19	-0.19
Total (GW)	-0.04	-0.31	-0.34	-0.39	-0.39	-0.42	-0.42	-0.42	-0.42

Table 14.3.19 BC Product Classes 2,3,4: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,396	1,466	1,548	1,631	1,701
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,037	2,089	2,128	2,207	2,303
Gas (TWh)	858	689	767	883	1,016	1,093
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	647	712	795	848	888
Total (TWh)	4,005	4,253	4,497	4,740	5,006	5,228
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	533
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	195	209
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-3.79	-5.29	-5.53	-5.75	-5.96	-6.19	-6.24	-6.28
Total U.S. Electric Generation									
Coal (TWh)	0.03	-1.06	-1.73	-1.34	-1.80	-1.72	-1.72	-1.72	-1.72
Gas (TWh)	0.30	-1.22	-2.09	-2.86	-2.30	-1.95	-1.95	-1.95	-1.95
Petroleum (TWh)	0.00	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.16	-0.16	-0.16	-0.16
Renewables (TWh)	-0.32	-1.72	-1.66	-1.90	-1.72	-1.90	-1.90	-1.90	-1.90
Total (TWh)	0.01	-4.02	-5.51	-6.14	-5.86	-5.77	-5.77	-5.77	-5.77
Installed Generating Capacity									
Coal (GW)	0.00	-0.08	-0.12	-0.12	-0.15	-0.15	-0.15	-0.15	-0.15
Other Fossil (GW)	0.00	-0.17	-0.26	-0.41	-0.38	-0.38	-0.38	-0.38	-0.38
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (GW)	-0.09	-0.47	-0.43	-0.40	-0.39	-0.44	-0.44	-0.44	-0.44
Total (GW)	-0.09	-0.73	-0.81	-0.93	-0.93	-1.00	-1.00	-1.00	-1.00

Table 14.3.20 BC Product Classes 2,3,4: Trial Standard Level 4

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,396	1,466	1,547	1,631	1,701
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,037	2,088	2,128	2,207	2,303
Gas (TWh)	858	689	767	882	1,016	1,093
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	647	712	795	848	888
Total (TWh)	4,005	4,253	4,496	4,739	5,005	5,227
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	445	467	501	533
Nuclear (GW)	102	105	111	111	111	112
Renewables (GW)	133	171	176	186	195	209
Total (GW)	1,024	1,045	1,058	1,090	1,137	1,191

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-4.24	-5.88	-6.15	-6.38	-6.63	-6.88	-6.93	-6.98
Total U.S. Electric Generation									
Coal (TWh)	0.03	-1.19	-1.92	-1.49	-2.00	-1.92	-1.92	-1.92	-1.92
Gas (TWh)	0.34	-1.37	-2.32	-3.18	-2.56	-2.17	-2.17	-2.17	-2.17
Petroleum (TWh)	0.00	-0.02	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.18	-0.18	-0.18	-0.18
Renewables (TWh)	-0.36	-1.93	-1.85	-2.12	-1.91	-2.11	-2.11	-2.11	-2.11
Total (TWh)	0.01	-4.50	-6.12	-6.83	-6.51	-6.41	-6.41	-6.41	-6.41
Installed Generating Capacity									
Coal (GW)	0.00	-0.09	-0.13	-0.13	-0.17	-0.17	-0.17	-0.17	-0.17
Other Fossil (GW)	0.00	-0.19	-0.29	-0.46	-0.43	-0.43	-0.43	-0.43	-0.43
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (GW)	-0.10	-0.53	-0.48	-0.44	-0.44	-0.49	-0.49	-0.49	-0.49
Total (GW)	-0.10	-0.82	-0.90	-1.03	-1.03	-1.113	-1.11	-1.11	-1.11

Table 14.3.21 BC Product Classes 5,6: Trial Standard Level 1

NEMS-BT Results:						
	2010	**2015**	**2020**	**2025**	**2030**	**2035**
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,636	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case									
							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.45	-0.75	-0.82	-0.85	-0.89	-0.92	-0.93	-0.93
Total U.S. Electric Generation									
Coal (TWh)	0.00	-0.13	-0.24	-0.20	-0.27	-0.26	-0.26	-0.26	-0.26
Gas (TWh)	0.04	-0.14	-0.30	-0.43	-0.34	-0.29	-0.29	-0.29	-0.29
Petroleum (TWh)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Renewables (TWh)	-0.04	-0.20	-0.24	-0.28	-0.26	-0.28	-0.28	-0.28	-0.28
Total (TWh)	0.00	-0.48	-0.78	-0.91	-0.87	-0.86	-0.86	-0.86	-0.86
Installed Generating Capacity									
Coal (GW)	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Other Fossil (GW)	0.00	-0.02	-0.04	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Renewables (GW)	-0.01	-0.06	-0.06	-0.06	-0.06	-0.07	-0.07	-0.07	-0.07
Total (GW)	-0.01	-0.09	-0.11	-0.14	-0.14	-0.15	-0.15	-0.15	-0.15

Table 14.3.22 BC Product Classes 5,6: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,470	1,552	1,635	1,705
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	768	885	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	850	890
Total (TWh)	4,005	4,256	4,501	4,744	5,010	5,232
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.99	-1.66	-1.83	-1.90	-1.97	-2.05	-2.06	-2.08
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.28	-0.54	-0.44	-0.60	-0.57	-0.57	-0.57	-0.57
Gas (TWh)	0.08	-0.32	-0.66	-0.95	-0.76	-0.64	-0.64	-0.64	-0.64
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.05	-0.05	-0.05	-0.05
Renewables (TWh)	-0.08	-0.45	-0.52	-0.63	-0.57	-0.63	-0.63	-0.63	-0.63
Total (TWh)	0.00	-1.05	-1.73	-2.03	-1.93	-1.91	-1.91	-1.91	-1.91
Installed Generating Capacity									
Coal (GW)	0.00	-0.02	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
Other Fossil (GW)	0.00	-0.04	-0.08	-0.14	-0.13	-0.13	-0.13	-0.13	-0.13
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.02	-0.12	-0.14	-0.13	-0.13	-0.15	-0.15	-0.15	-0.15
Total (GW)	-0.02	-0.19	-0.25	-0.31	-0.31	-0.33	-0.33	-0.33	-0.33

Table 14.3.23 BC Product Classes 5,6: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,399	1,469	1,551	1,635	1,705
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,208	2,304
Gas (TWh)	857	690	768	884	1,017	1,094
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	713	796	849	889
Total (TWh)	4,005	4,256	4,500	4,743	5,009	5,231
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	176	186	196	209
Total (GW)	1,024	1,046	1,059	1,090	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-1.28	-2.17	-2.39	-2.48	-2.58	-2.68	-2.70	-2.72
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.36	-0.71	-0.58	-0.78	-0.75	-0.75	-0.75	-0.75
Gas (TWh)	0.10	-0.41	-0.86	-1.24	-0.99	-0.84	-0.84	-0.84	-0.84
Petroleum (TWh)	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02
Nuclear (TWh)	0.00	0.00	0.00	0.00	0.00	-0.07	-0.07	-0.07	-0.07
Renewables (TWh)	-0.11	-0.58	-0.68	-0.82	-0.74	-0.82	-0.82	-0.82	-0.82
Total (TWh)	0.00	-1.36	-2.26	-2.66	-2.53	-2.49	-2.49	-2.49	-2.49
Installed Generating Capacity									
Coal (GW)	0.00	-0.03	-0.05	-0.05	-0.07	-0.07	-0.07	-0.07	-0.07
Other Fossil (GW)	0.00	-0.06	-0.11	-0.18	-0.17	-0.17	-0.17	-0.17	-0.17
Nuclear (GW)	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.03	-0.16	-0.18	-0.17	-0.17	-0.19	-0.19	-0.19	-0.19
Total (GW)	-0.03	-0.25	-0.33	-0.40	-0.40	-0.43	-0.43	-0.43	-0.43

Table 14.3.24 BC Product Class 7: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	886	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.017	-0.020	-0.021	-0.021	-0.022	-0.023	-0.023	-0.023
Total U.S. Electric Generation									
Coal (TWh)	0.000	-0.006	-0.007	-0.006	-0.008	-0.008	-0.008	-0.008	-0.008
Gas (TWh)	0.001	-0.006	-0.007	-0.009	-0.007	-0.006	-0.006	-0.006	-0.006
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001
Renewables (TWh)	-0.001	-0.006	-0.006	-0.007	-0.006	-0.007	-0.007	-0.007	-0.007
Total (TWh)	0.000	-0.018	-0.020	-0.022	-0.021	-0.021	-0.021	-0.021	-0.021
Installed Generating Capacity									
Coal (GW)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Other Fossil (GW)	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	0.000	-0.002	-0.002	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002
Total (GW)	0.000	-0.002	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003

Table 14.3.25 BC Product Class 7: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.054	-0.062	-0.065	-0.067	-0.070	-0.072	-0.073	-0.073
Total U.S. Electric Generation									
Coal (TWh)	0.000	-0.019	-0.022	-0.018	-0.024	-0.024	-0.024	-0.024	-0.024
Gas (TWh)	0.003	-0.018	-0.021	-0.028	-0.022	-0.018	-0.018	-0.018	-0.018
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.003	-0.003	-0.003	-0.003
Renewables (TWh)	-0.003	-0.017	-0.017	-0.022	-0.020	-0.021	-0.021	-0.021	-0.021
Total (TWh)	0.000	-0.055	-0.062	-0.069	-0.066	-0.066	-0.066	-0.066	-0.066
Installed Generating Capacity									
Coal (GW)	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Other Fossil (GW)	0.000	-0.002	-0.003	-0.004	-0.003	-0.002	-0.002	-0.002	-0.002
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	-0.001	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
Total (GW)	-0.001	-0.008	-0.010	-0.011	-0.010	-0.010	-0.010	-0.010	-0.010

Table 14.3.26 BC Product Class 8: Trial Standard Level 1 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,472	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	886	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	649	714	797	850	890
Total (TWh)	4,005	4,257	4,503	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.021	-0.028	-0.030	-0.031	-0.032	-0.033	-0.033	-0.034
Total U.S. Electric Generation									
Coal (TWh)	0.000	-0.006	-0.009	-0.007	-0.010	-0.009	-0.009	-0.009	-0.009
Gas (TWh)	0.002	-0.007	-0.011	-0.015	-0.012	-0.010	-0.010	-0.010	-0.010
Petroleum (TWh)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001
Renewables (TWh)	-0.002	-0.009	-0.009	-0.010	-0.009	-0.010	-0.010	-0.010	-0.010
Total (TWh)	0.000	-0.022	-0.030	-0.033	-0.031	-0.031	-0.031	-0.031	-0.031
Installed Generating Capacity									
Coal (GW)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Other Fossil (GW)	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	0.000	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Total (GW)	0.000	-0.004	-0.004	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005

Table 14.3.27 BC Product Class 8: Trial Standard Level 2 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.088	-0.121	-0.126	-0.131	-0.136	-0.141	-0.142	-0.143
Total U.S. Electric Generation									
Coal (TWh)	0.001	-0.025	-0.040	-0.031	-0.041	-0.039	-0.039	-0.039	-0.039
Gas (TWh)	0.007	-0.028	-0.048	-0.065	-0.052	-0.044	-0.044	-0.044	-0.044
Petroleum (TWh)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.004	-0.004	-0.004	-0.004
Renewables (TWh)	-0.007	-0.040	-0.038	-0.043	-0.039	-0.043	-0.043	-0.043	-0.043
Total (TWh)	0.000	-0.094	-0.126	-0.140	-0.133	-0.131	-0.131	-0.131	-0.131
Installed Generating Capacity									
Coal (GW)	0.000	-0.002	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
Other Fossil (GW)	0.000	-0.004	-0.006	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Renewables (GW)	-0.002	-0.011	-0.010	-0.009	-0.009	-0.010	-0.010	-0.010	-0.010
Total (GW)	-0.002	-0.017	-0.019	-0.021	-0.021	-0.023	-0.023	-0.023	-0.023

Table 14.3.28 BC Product Class 8: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,637	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,305
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,746	5,012	5,234
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	337
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	2015	2020	2025	2030	2035	2040	2041	2042
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.000	-0.098	-0.135	-0.140	-0.145	-0.150	-0.156	-0.157	-0.159
Total U.S. Electric Generation									
Coal (TWh)	0.001	-0.027	-0.044	-0.034	-0.045	-0.043	-0.043	-0.043	-0.043
Gas (TWh)	0.008	-0.031	-0.053	-0.072	-0.058	-0.049	-0.049	-0.049	-0.049
Petroleum (TWh)	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Nuclear (TWh)	0.000	0.000	0.000	0.000	0.000	-0.004	-0.004	-0.004	-0.004
Renewables (TWh)	-0.008	-0.044	-0.042	-0.048	-0.043	-0.048	-0.048	-0.048	-0.048
Total (TWh)	0.000	-0.104	-0.140	-0.155	-0.148	-0.146	-0.146	-0.146	-0.146
Installed Generating Capacity									
Coal (GW)	0.000	-0.002	-0.003	-0.003	-0.004	-0.004	-0.004	-0.004	-0.004
Other Fossil (GW)	0.000	-0.004	-0.007	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010
Nuclear (GW)	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001
Renewables (GW)	-0.002	-0.012	-0.011	-0.010	-0.010	-0.011	-0.011	-0.011	-0.011
Total (GW)	-0.002	-0.019	-0.021	-0.023	-0.023	-0.025	-0.025	-0.025	-0.025

Table 14.3.29 BC Product Class 10: Trial Standard Level 1 Forecast

NEMS-BT Results:						
	2010	**2015**	**2020**	**2025**	**2030**	**2035**
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,636	1,707
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,130	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case									
							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.28	-0.68	-0.71	-0.73	-0.76	-0.79	-0.80	-0.80
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.07	-0.24	-0.20	-0.24	-0.25	-0.25	-0.25	-0.25
Gas (TWh)	0.02	-0.08	-0.27	-0.31	-0.27	-0.23	-0.23	-0.23	-0.23
Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	0.00	0.00	-0.02	-0.07	-0.07	-0.08	-0.08	-0.08	-0.08
Renewables (TWh)	-0.02	-0.14	-0.16	-0.18	-0.16	-0.18	-0.18	-0.18	-0.18
Total (TWh)	0.00	-0.29	-0.69	-0.76	-0.75	-0.74	-0.74	-0.74	-0.74
Installed Generating Capacity									
Coal (GW)	0.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03
Other Fossil (GW)	0.00	-0.01	-0.02	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
Nuclear (GW)	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.01	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Total (GW)	-0.01	-0.07	-0.08	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11

Table 14.3.30 BC Product Class 10: Trial Standard Level 2 Forecast

NEMS-BT Results:							**Difference from AEO2010 Reference Case**									
														Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**		**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption							*Residential Sector Energy Consumption*									
Electricity Sales (TWh)	1,388	1,400	1,471	1,553	1,636	1,707	Electricity Sales (TWh)	0.00	-0.33	-0.79	-0.82	-0.85	-0.88	-0.92	-0.92	-0.93
Total U.S. Electric Generation							*Total U.S. Electric Generation*									
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304	Coal (TWh)	0.01	-0.08	-0.27	-0.23	-0.28	-0.29	-0.29	-0.29	-0.29
Gas (TWh)	857	690	769	885	1,018	1,095	Gas (TWh)	0.02	-0.09	-0.31	-0.36	-0.32	-0.26	-0.26	-0.26	-0.26
Petroleum (TWh)	45	46	47	48	48	49	Petroleum (TWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nuclear (TWh)	813	834	883	886	886	895	Nuclear (TWh)	0.00	0.00	-0.03	-0.08	-0.08	-0.10	-0.10	-0.10	-0.10
Renewables (TWh)	462	648	714	797	850	890	Renewables (TWh)	-0.03	-0.17	-0.18	-0.21	-0.19	-0.21	-0.21	-0.21	-0.21
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233	Total (TWh)	0.00	-0.34	-0.80	-0.88	-0.88	-0.86	-0.86	-0.86	-0.86
Installed Generating Capacity							*Installed Generating Capacity*									
Coal (GW)	321	325	326	326	330	336	Coal (GW)	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
Other Fossil (GW)	468	445	446	467	501	534	Other Fossil (GW)	0.00	-0.02	-0.03	-0.05	-0.04	-0.03	-0.03	-0.03	-0.03
Nuclear (GW)	102	105	111	111	111	113	Nuclear (GW)	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	133	171	177	186	196	209	Renewables (GW)	-0.01	-0.05	-0.04	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192	Total (GW)	-0.01	-0.08	-0.10	-0.12	-0.13	-0.123	-0.12	-0.12	-0.12

Table 14.3.31 BC Product Class 10: Trial Standard Level 3 Forecast

NEMS-BT Results:

	2010	2015	2020	2025	2030	2035
Residential Sector Energy Consumption						
Electricity Sales (TWh)	1,388	1,400	1,471	1,552	1,636	1,706
Total U.S. Electric Generation						
Coal (TWh)	1,828	2,038	2,090	2,129	2,209	2,304
Gas (TWh)	857	690	769	885	1,018	1,095
Petroleum (TWh)	45	46	47	48	48	49
Nuclear (TWh)	813	834	883	886	886	895
Renewables (TWh)	462	648	714	797	850	890
Total (TWh)	4,005	4,257	4,502	4,745	5,011	5,233
Installed Generating Capacity						
Coal (GW)	321	325	326	326	330	336
Other Fossil (GW)	468	445	446	467	501	534
Nuclear (GW)	102	105	111	111	111	113
Renewables (GW)	133	171	177	186	196	209
Total (GW)	1,024	1,046	1,059	1,091	1,138	1,192

Difference from AEO2010 Reference Case

							Extrapolation		
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**
Residential Sector Energy Consumption									
Electricity Sales (TWh)	0.00	-0.39	-0.92	-0.95	-0.99	-1.03	-1.07	-1.08	-1.08
Total U.S. Electric Generation									
Coal (TWh)	0.01	-0.10	-0.32	-0.27	-0.33	-0.33	-0.33	-0.33	-0.33
Gas (TWh)	0.03	-0.11	-0.36	-0.41	-0.37	-0.31	-0.31	-0.31	-0.31
Petroleum (TWh)	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Nuclear (TWh)	0.00	0.00	-0.03	-0.09	-0.09	-0.11	-0.11	-0.11	-0.11
Renewables (TWh)	-0.03	-0.19	-0.21	-0.25	-0.22	-0.24	-0.24	-0.24	-0.24
Total (TWh)	0.00	-0.40	-0.93	-1.03	-1.02	-1.01	-1.01	-1.01	-1.01
Installed Generating Capacity									
Coal (GW)	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Other Fossil (GW)	0.00	-0.02	-0.03	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04
Nuclear (GW)	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Renewables (GW)	-0.01	-0.05	-0.05	-0.05	-0.05	-0.06	-0.06	-0.06	-0.06
Total (GW)	-0.01	-0.09	-0.11	-0.14	-0.15	-0.143	-0.14	-0.14	-0.14

14.4 SUMMARY OF UTILITY IMPACT ANALYSIS

The following tables present a summary of utility impact results for all BCs and EPSs TSLs in the final year of the analysis period, 2042. Table 13.4.1 and Table 13.4.2 present the reduction in total U.S. electricity generation in 2042. Table 13.4.3 and Table 13.4.4 present the reduction in total U.S. electric generating capacity in 2042.

Table 14.4.1 Reduction in Total U.S. Electricity Generation in 2042 Under External Power Supply Product TSLs

	TSL 1	TSL 2	TSL 3
	TWh		
Product Class B	1.47	2.33	4.23
Product Classes B, C, D, E	1.88	2.94	5.14
Product Class X	0.200	0.230	0.471
Product Class H	0.004	0.004	0.005

Table 14.4.2 Reduction in Total U.S. Electricity Generation in 2042 Under Battery Charger Product TSLs

	TSL 1	TSL 2	TSL 3	TSL 4
	TWh			
Product Class 1	0.18	0.42	0.57	n.a.
Product Classes 2, 3, 4	0.99	2.44	5.77	6.41
Product Classes 5, 6	0.86	1.91	2.49	n.a.
Product Class 7	0.021	0.066	n.a.	n.a.
Product Class 8	0.031	0.131	0.146	n.a.
Product Class 10	0.74	0.86	1.01	n.a.

Table 14.4.3 Reduction in Electric Generating Capacity in 2042 Under External Power Supply Product TSLs

	TSL 1	TSL 2	TSL 3
	Gigawatts		
Product Class B	0.255	0.404	0.734
Product Classes B, C, D, E	0.326	0.510	0.893
Product Class X	0.035	0.040	0.082
Product Class H	0.001	0.001	0.001

Table 14.4.4 Reduction in Electric Generating Capacity in 2042 Under Battery Charger Product TSLs

	TSL 1	TSL 2	TSL 3	TSL 4
	Gigawatts			
Product Class 1	0.031	0.072	0.099	n.a.
Product Classes 2, 3, 4	0.17	0.42	1.00	1.11
Product Classes 5, 6	0.15	0.33	0.43	n.a.
Product Class 7	0.003	0.010	n.a.	n.a.
Product Class 8	0.005	0.023	0.025	n.a.
Product Class 10	0.11	0.12	0.14	n.a.

14.5 IMPACT OF STANDARDS ON ELECTRICITY PRICES AND ASSOCIATED BENEFITS FOR CONSUMERS

Using the framework of the utility impact analysis, DOE analyzed the potential impact on electricity prices resulting from the proposed standards on BCs and EPSs. Associated benefits for all electricity users in all sectors of the economy are then derived from these price impacts.

DOE's analysis of energy price impacts used NEMS-BT in a similar manner as described in section 13.2. Like other widely-used energy-economic models, NEMS uses elasticities to estimate the energy price change that would result from a change (increase or decrease) in energy demand. The elasticity of price to a decrease in demand is the "inverse price elasticity." The calculated inverse price elasticity based on NEMS-BT simulations differs throughout the forecast period in response to the dynamics of supply and demand for electricity.

14.5.1 Impact on Electricity Prices

DOE separately analyzed the electricity price effect of all EPSs, and the electricity price effect of all BCs. The results for the proposed TSL for each of the three EPS product class groupings were summed together to produce combined energy savings.[c] Results for the proposed TSL for each of the six BC product class groupings were summed together to produce combined energy savings.[d] This allows for two regressions that represents the total impact of all EPS and all BC. After generating results using higher decrements to electricity consumption, a regressed interpolation toward the origin derived the price effects associated with the combined energy savings of the proposed TSLs.

Figure 13.5.1 shows the annual change in U.S. electricity consumption for the proposed standards, relative to the base case which involves no new standards.

---

[c] The proposed standards consist of TSL 2 for EPS B, C, D, and E, TSL 2 for EPS X, and TSL 2 for EPS H.

[d] The proposed standards consist of TSL 2 for BC 1, TSL 1 for BC 2,3,4, TSL 2 for BC 5, 6, TSL 1 for BC 7 , TSL 1 for BC 8, and TSL 3 for BC 10.

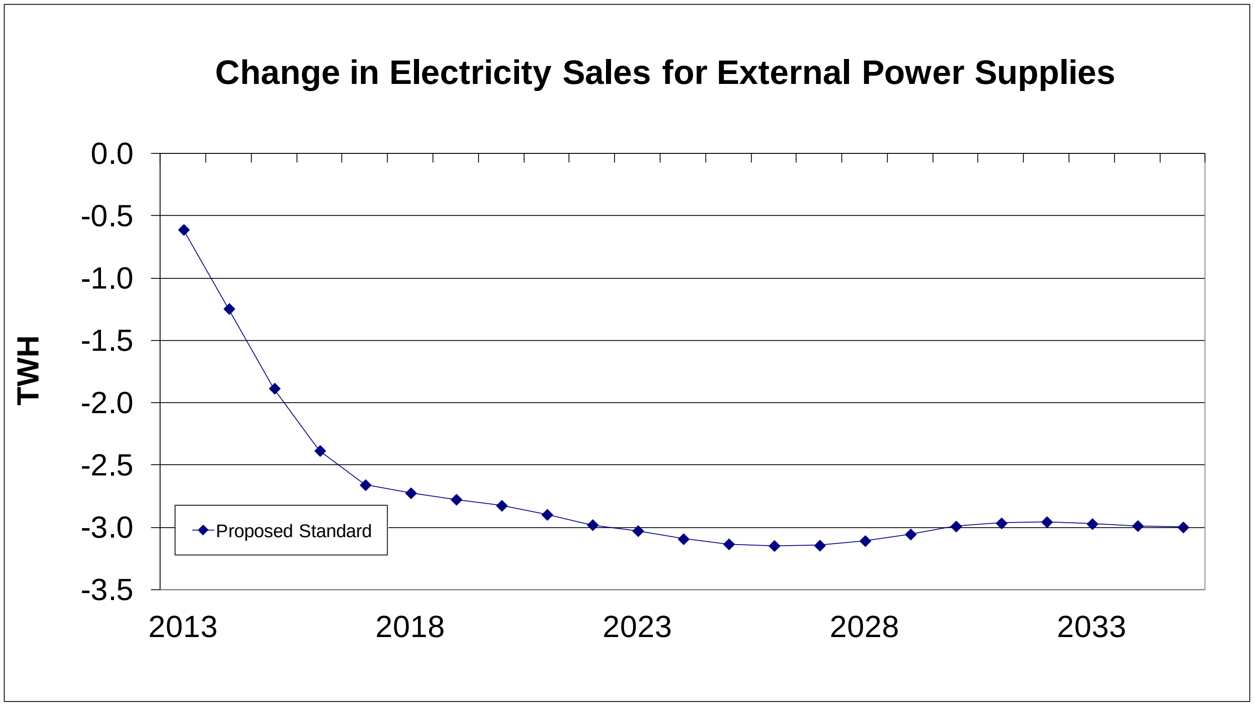


Figure 14.5.1 **Change in U.S. Electricity Sales Associated with Proposed External Power Supply Energy Conservation Standards**

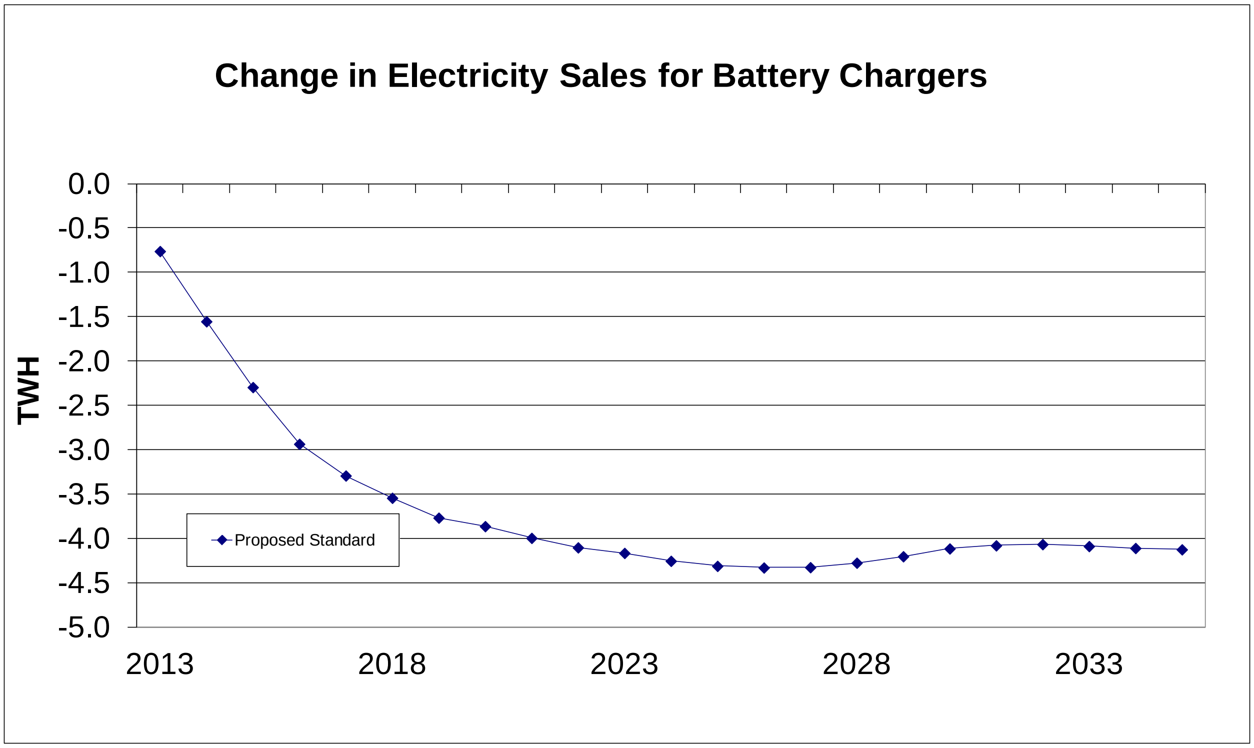


Figure 14.5.2 **Change in U.S. Electricity Sales Associated with Proposed Battery Charger Energy Conservation Standards**

Figure 13.5.3 shows the annual change in average U.S. price for electricity, relative to the Reference case, projected to result from the proposed EPS standards. The price reduction averages 0.001 cents per kWh (in 2010$). This average price reduction equals 0.01 percent.

Figure 13.5.4 shows the annual change in average U.S. price for electricity, relative to the Reference case, projected to result from the proposed BC standards. The price reduction averages 0.002 cents per kWh (in 2010$). This average price reduction equals 0.02 percent.

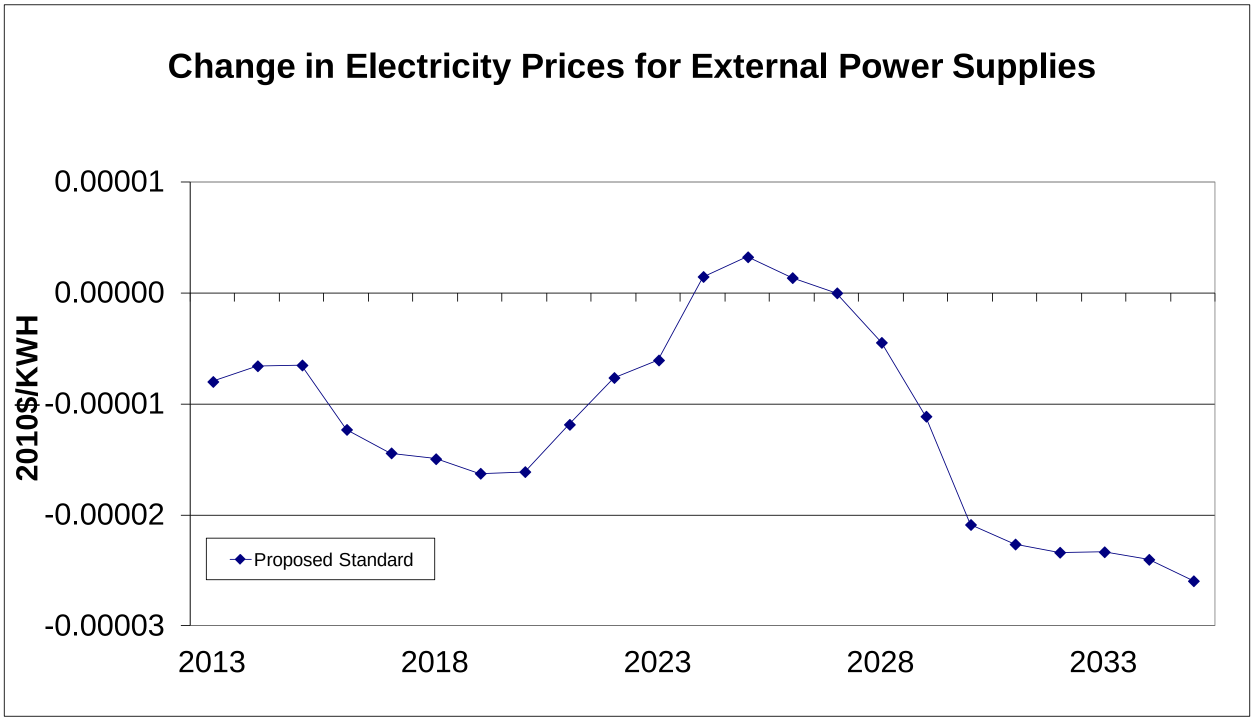


Figure 14.5.3 **Effect of Proposed External Power Supply Energy Conservation Standards on Average U.S. Electricity Price (All Users)**

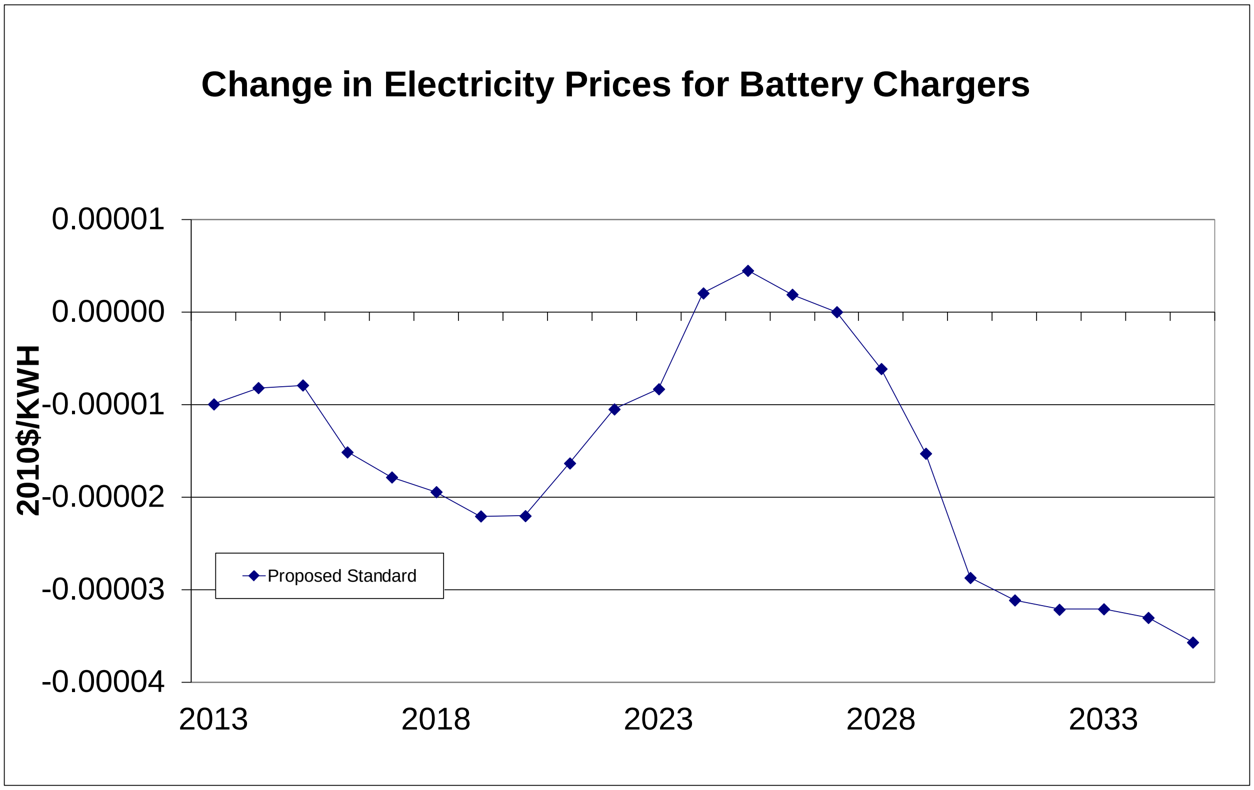


Figure 14.5.4 **Effect of Proposed Battery Charger Energy Conservation Standards on Average U.S. Electricity Price (All Users)**

14.5.2 Impact of Changes in Electricity Price on Electricity Users

Using the estimated electricity price impacts, DOE calculated the nominal savings in total electricity expenditures in each year by multiplying the annual change in the average-user price for electricity by the total annual U.S. electricity sales forecast by NEMS, adjusted for the impact of the standards. The amended standards would continue to reduce demand for electricity after 2035 (which is the last year in the NEMS forecast). DOE's estimate for 2036–2042 (the period used to estimate the NPV of the national consumer benefits from amended standards) multiplied the average electricity price reduction in 2015–2035 by estimated total annual electricity consumption in 2036–2042.[e] DOE then discounted the stream of reduced expenditures to calculate a NPV.

Table 13.5.1 shows the calculated NPV of the economy-wide savings in electricity expenditures for each considered TSL at 3-percent and 7-percent discount rates. The need to

---

[e] The estimation of electricity consumption after 2035 uses the average annual growth rate in 2031-2035 of total U.S. electricity consumption forecasted by NEMS. This forecast includes the impact of the standards.

extrapolate price effects and electricity consumption beyond 2035 suggests that one should interpret the post-2035 results as a rough indication of the benefits to electricity users in the post-2035 period.

Table 14.5.1 Cumulative NPV of the Economy-Wide Savings in Electricity Expenditures Due to the Projected Decline in Electricity Prices Resulting from the Proposed Standards for External Power Supplies*

Discount Rate	*billion $2009*
3 percent	0.925
7 percent	0.520

* Impacts for units sold from 2012 to 2042

Table 14.5.2 Cumulative NPV of the Economy-Wide Savings in Electricity Expenditures Due to the Projected Decline in Electricity Prices Resulting from the Proposed Standards for Battery Chargers*

Discount Rate	*billion $2009*
3 percent	1.241
7 percent	0.691

* Impacts for units sold from 2012 to 2042

14.5.3 Discussion of Savings in Electricity Expenditures

Although the aggregate benefits for all electricity users are potentially large, there may be negative effects on the actors involved in electricity supply. The electric power industry is a complex mix of power plant providers, fuel suppliers, electricity generators, and electricity distributors. While the distribution of electricity is regulated everywhere, the institutional structure of the power sector varies, and has changed over time. For these reasons, an assessment of impacts on the actors involved in electricity supply from reduction in electricity demand associated with energy conservation standards is beyond the scope of this rulemaking.

In considering the potential benefits to electricity users, DOE takes under advisement the provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis (OMB Circular A-4 (Sept. 17, 2003), section E, “Identifying and Measuring Benefits and Costs”). Specifically, at page 38, Circular A-4 instructs that transfers should be excluded from the estimates of the benefits and costs of a regulation. DOE is continuing to investigate the extent to which change in electricity prices projected to result from standards represents a net gain to society.

REFERENCES

1. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

CHAPTER 15. EMISSIONS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 15. EMISSIONS ANALYSIS

15.1 INTRODUCTION

This chapter describes potential changes to emissions of carbon dioxide (CO_2) that may result from new and amended energy conservation standards for battery chargers (BCs) and external power supplies products (EPSs).

The impacts on air emissions are largely driven by changes in power plant types and quantities of electricity generated under each of the considered standard levels. Changes in electricity generation are described in the utility impact analysis in chapter 14.

15.2 AIR EMISSIONS DESCRIPTION AND REGULATION

This analysis considers three pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg). An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (i.e., anthropogenic) and may take the form of solid particles (i.e., particulates or particulate matter), liquid droplets, or gases.[a] DOE's analysis also considers carbon dioxide (CO_2).

Sulfur Dioxide. Sulfur dioxide, or SO_2, belongs to the family of sulfur oxide gases (SO_X). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SO_X gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment. [1]

Nitrogen Oxides. Nitrogen oxides**,** or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2), along with particles in the air can often be seen as a reddish-brown layer over many urban areas. NO_2 is the specific form of NO_X reported in this document. NO_X is one of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. It can contribute to the formation of acid rain, and can impair visibility in areas such as national parks. NO_X also contributes to the formation of fine particles that can impair human health. [2]

Nitrogen oxides form when fossil fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_X are motor vehicles, electric utilities, and other

---

[a] More information on air pollution characteristics and regulations is available on the U.S. Environment Protection Agent (EPA)'s website at www.epa.gov.

industrial, commercial, and residential sources that burn fossil fuels. NO_X can also be formed naturally. Electric utilities account for about 22 percent of NO_X emissions in the United States.[2]

Mercury. Coal-fired power plants emit mercury (Hg) found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.[3] U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.[4]

Carbon Dioxide. Carbon dioxide (CO_2) is not a criteria pollutant (see below), but it is of interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun’s radiation inside the Earth’s atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, CO_2, methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Human activities, however, add to the levels of most of these naturally occurring gases. For example, CO_2 is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, over 90 percent of anthropogenic (i.e., human-made) CO_2 emissions resulted from burning fossil fuels.[5]

Concentrations of CO_2 in the atmosphere are naturally regulated by numerous processes, collectively known as the “carbon cycle.” The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic CO_2 emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2007, CO_2 emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.[5]

Particulate Matter. Particulate matter (PM) also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM impacts are of concern due to human exposures that can impact health. Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease.

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant are in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_X. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_X, and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM comprised of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described below, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2 and NO_X in many States, since those pollutants are now largely regulated by cap and trade systems.

Air Quality Regulation. The Clean Air Act Amendments of 1990 list 188 toxic air pollutants that EPA is required to control. [6] EPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants), two of which are SO_2 and NO_X. Also, the Clean Air Act Amendments of 1990 gave EPA the authority to control acidification and to require operators of electric power plants to reduce emissions of SO_2 and NO_X. Title IV of the 1990 amendments established a cap-and-trade program for SO_2, in all 50 states and the District of Columbia (D.C.), intended to help control acid rain.[6] This cap-and-trade program serves as a model for more recent programs with similar features.

In 2005, EPA issued the Clean Air Interstate Rule (CAIR) under sections 110 and 111 of the Clean Air Act (40 CFR Parts 51, 96, and 97). [b] 70 FR 25162–25405 (May 12, 2005). CAIR limited emissions from 28 eastern States and D.C. by capping emissions and creating an allowance-based trading program. Although, CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), (see North Carolina v. EPA, 550 F.3d 1176 (D.C. Cir. 2008),) it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in North Carolina v. EPA, 531 F.3d 896 (D.C. Cir. 2008).

On July 6, 2011, EPA promulgated a replacement for CAIR, entitled "Federal Implementation Plans: Interstate Transport of Fine Particulate Matter and Ozone and Correction of SIP Approvals," but commonly referred to as the Cross-State Air Pollution Rule or the

---

[b] See http://www.epa.gov/cleanairinterstaterule/.

Transport Rule. 76 FR 48208 (Aug. 8, 2011). On December 30, 2011, however, the D.C. Circuit stayed the new rules while a panel of judges reviews them, and told EPA to continue enforcing CAIR (see *EME Homer City Generation v. EPA*, No. 11-1302, Order at *2 (D.C. Cir. Dec. 30, 2011)).

On December 21, 2011, EPA announced national emissions standards for hazardous air pollutants (NESHAPs) for mercury and certain other pollutants emitted from coal and oil-fired EGUs. (See http://epa.gov/mats/pdfs/20111216MATSfinal.pdf). The NESHAPs do not include a trading program and, as such, DOE's energy conservation standards would likely reduce Hg emissions.

15.3 GLOBAL CLIMATE CHANGE

Climate change has evolved into a matter of global concern because it is expected to have widespread, adverse effects on natural resources and systems. A growing body of evidence points to anthropogenic sources of greenhouse gases, such as carbon dioxide (CO_2), as major contributors to climate change. Because this Rule, if finalized, will likely decrease CO_2 emission rates from the fossil fuel sector in the United States, the Department here examines the impacts and causes of climate change and then the potential impact of the Rule on CO_2 emissions and global warming.

Impacts of Climate Change on the Environment. Climate is usually defined as the average weather, over a period ranging from months to many years. Climate change refers to a change in the state of the climate, which is identifiable through changes in the mean and/or the variability of its properties (e.g., temperature or precipitation) over an extended period, typically decades or longer.

The World Meteorological Organization and United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) to provide an objective source of information about climate change. According to the IPCC Fourth Assessment Report (IPCC Report), published in 2007, climate change is consistent with observed changes to the world's natural systems; the IPCC expects these changes to continue.[7]

Changes that are consistent with warming include warming of the world's oceans to a depth of 3000 meters; global average sea level rise at an average rate of 1.8 mm per year from 1961 to 2003; loss of annual average Arctic sea ice at a rate of 2.7 percent per decade, changes in wind patterns that affect extra-tropical storm tracks and temperature patterns, increases in intense precipitation in some parts of the world, as well as increased drought and more frequent heat waves in many locations worldwide, and numerous ecological changes. [8]

Looking forward, the IPCC describes continued global warming of about 0.2 °C per decade for the next two decades under a wide range of emission scenarios for carbon dioxide (CO_2), other greenhouse gases (GHGs), and aerosols. After that period, the rate of increase is less certain. The IPCC Report describes increases in average global temperatures of about 1.1 °C to 6.4 °C at the end of the century relative to today. These increases vary depending on the model and emissions scenarios. [8]

The IPCC Report describes incremental impacts associated with the rise in temperature. At ranges of incremental increases to the global average temperature, IPCC reports, with either high or very high confidence, that there is likely to be an increasing degree of impacts such as coral reef bleaching, loss of wildlife habitat, loss to specific ecosystems, and negative yield impacts for major cereal crops in the tropics, but also projects that there likely will be some beneficial impacts on crop yields in temperate regions.

Causes of Climate Change. The IPCC Report states that the world has warmed by about 0.74 °C in the last 100 years. The IPCC Report finds that most of the temperature increase since the mid-20th century is very likely due to the increase in anthropogenic concentrations of CO_2 and other long-lived greenhouse gases such as methane and nitrous oxide in the atmosphere, rather than from natural causes.

Increasing the CO_2 concentration partially blocks the earth's re-radiation of captured solar energy in the infrared band, inhibits the radiant cooling of the earth, and thereby alters the energy balance of the planet, which gradually increases its average temperature. The IPCC Report estimates that currently, CO_2 makes up about 77 percent of the total CO_2-equivalent[c] global warming potential in GHGs emitted from human activities, with the vast majority (74 percent) of the CO_2 attributable to fossil fuel use. [8] For the future, the IPCC Report describes a wide range of GHG emissions scenarios, but under each scenario CO_2 would continue to comprise above 70 percent of the total global warming potential.[9]

Stabilization of CO_2 Concentrations. Unlike many traditional air pollutants, CO_2 mixes thoroughly in the entire atmosphere and is long-lived. The residence time of CO_2 in the atmosphere is long compared to the emission processes. Therefore, the global cumulative emissions of CO_2 over long periods determine CO_2 concentrations because it takes hundreds of years for natural processes to remove the CO_2. Globally, 49 billion metric tons of CO_2 – equivalent of anthropogenic (man-made) greenhouse gases are emitted every year. [d] Of this annual total, fossil fuels contribute about 29 billion metric tons of CO_2. [9]

Researchers have focused on considering atmospheric CO_2 concentrations that likely will result in some level of global climate stabilization, and the emission rates associated with achieving the "stabilizing" concentrations by particular dates. They associate these stabilized CO_2 concentrations with temperature increases that plateau in a defined range. For example, at the low end, the IPCC Report scenarios target CO_2 stabilized concentrations range between 350

---

[c] GHGs differ in their warming influence (radiative forcing) on a global climate system due to their different radiative properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric based on the radiative forcing of CO_2, i.e., CO_2-equivalent. CO_2 equivalent emission is the amount of CO_2 emission that would cause the same- time integrated radiative forcing, over a given time horizon, as an emitted amount of other long- lived GHG or mixture of GHGs.

[d] Other non-fossil fuel contributors include CO_2 emissions from deforestation and decay from agriculture biomass; agricultural and industrial emissions of methane; and emissions of nitrous oxide and fluorocarbons.

ppm and 400 ppm (essentially today's value)—because of climate inertia, concentrations in this low-end range would still result in temperatures projected to increase 2.0 °C to 2.4 °C above pre-industrial levels[e] (about 1.3 °C to 1.7 °C above today's levels). To achieve concentrations between 350 ppm to 400 ppm, the IPCC scenarios present that there would have to be a rapid downward trend in total annual global emissions of greenhouse gases to levels that are 50 to 85 percent below today's annual emission rates by no later than 2050. Since it is assumed that there would continue to be growth in global population and substantial increases in economic production, the scenarios identify required reductions in greenhouse gas emissions intensity (emissions per unit of output) of more than 90 percent. However, even at these rates, the scenarios describe some warming and some climate change is projected due to already accumulated CO_2 and GHGs in the atmosphere. [10]

The Beneficial Impact of the Rule on CO_2 Emissions. It is anticipated that the Rule will reduce energy-related CO_2 emissions, particularly those associated with energy consumption in buildings. The U.S. Energy Information Administration (EIA) reports in its 2010 *Annual Energy Outlook* (*AEO2010*) [11] that U.S. annual energy-related emissions of CO_2 in 2007 were about 6.0 billion metric tons, of which 1.2 billion tons were attributed to the residential buildings sector (including related energy–using products such as residential furnaces and central air conditioner products). Most of the greenhouse gas emissions attributed to residential buildings are emitted from fossil fuel-fired power plants that generate electricity used in this sector. In the *AEO2010* Reference Case, EIA projected that annual energy-related CO_2 emissions would grow from 5.7 billion metric tons in 2015 to 6.3 billion metric tons in 2035, an increase of 10 percent (see *AEO2010*), while residential emissions would grow to from 1.2 billion metric tons to 1.3 billion metric tons, an increase of 12 percent.

The estimated cumulative CO_2 emission reductions from BC and EPS energy conservation standards (shown as a range of alternative TSLs) during the 30-year analysis period are indicated in and Table 15.2.1 and Table 15.2.2, respectively. Estimated CO_2 emission reductions in these tables come from power sector electricity generation. The estimated CO_2 emission reductions from electricity generation are calculated using the NEMS-BT model.

Table 15.3.1 Reduction in Cumulative Energy-Related Emissions of CO_2 from 2013 through 2042 from External Power Supply Standards

	Trial Standard Levels		
	TSL 1	**TSL 2**	**TSL 3**
	Million Metric Tons		
Product Class B	21.7	34.3	62.5
Product Classes B, C, D, E	27.5	43.0	75.4
Product Class X	2.95	3.38	6.92
Product Class H	0.054	0.058	0.065

---

[e] IPCC Working Group 3 Table TS 2

Table 15.3.2 Reduction in Cumulative Energy-Related Emissions of CO_2 from 2013 through 2042 from Battery Chargers Energy Conservation Standards

	Trial Standard Levels			
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**
	Million Metric Tons			
Product Class 1	2.62	6.11	8.36	n.a
Product Classes 2, 3, 4	14.7	35.9	85.1	94.6
Product Classes 5, 6	12.4	27.4	35.9	n.a
Product Class 7	0.312	0.975	n.a	n.a
Product Class 8	0.457	1.95	2.16	n.a
Product Class 10	10.3	11.9	13.9	n.a

The Incremental Impact of the Rule on Climate Change. It is difficult to correlate specific emission rates with atmospheric concentrations of CO_2 and specific atmospheric concentrations with future temperatures because the IPCC Report describes a clear lag in the climate system between any given concentration of CO_2 (even if maintained for long periods) and the subsequent average worldwide and regional temperature, precipitation, and extreme weather regimes. For example, a major determinant of climate response is "equilibrium climate sensitivity", a measure of the climate system response to sustained radioactive forcing. It is defined as the global average surface warming following a doubling of carbon dioxide concentrations. The IPCC Report describes its estimated, numeric value as about 3 °C, but the likely range of that value is 2 °C to 4.5 °C, with cloud feedbacks the largest source of uncertainty. Further, as illustrated above, the IPCC Report scenarios for stabilization rates are presented in terms of a range of concentrations, which then correlates to a range of temperature changes. Thus, climate sensitivity is a key uncertainty for CO_2 mitigation scenarios that aim to meet specific temperature levels.

Because of how complex global climate systems are, it is difficult to know to what extent and when particular CO_2 emissions reductions will impact global warming. However, as Table 15.2.1 and Table 15.2.2 indicate, the rule is expected to reduce CO_2 emissions associated with energy consumption in buildings.

15.4 ANALYTICAL METHODS FOR AIR EMISSIONS

For each of the considered TSLs, DOE calculated total power-sector emissions based on output from the NEMS-BT model (see chapter 14 for description of the model).

Coal-fired electric generation is the single largest source of electricity in the United States. Because the mix of coals used significantly affects the emissions produced, the model includes a detailed representation of coal supply. The model considers the rank of the coal as well as the sulfur contents of the fuel used when determining optimal dispatch.[14]

Within the NEMS-BT model, planning options for achieving emissions restrictions in the Clean Air Act Amendments include installing pollution control equipment on existing power plants and building new power plants with low emission rates. These methods for reducing emission are compared to dispatching options such as fuel switching and allowance trading. Environmental regulations also affect capacity expansion decisions. For instance, new plants are not allocated SO_2 emissions allowances according to the Clean Air Act Amendments. Consequently, the decision to build a particular capacity type must consider the cost (if any) of obtaining sufficient allowances. This could involve purchasing allowances or over complying at an existing unit.

For this analysis, DOE used the version of NEMS-BT based on *AEO 2010*, which assumes the implementation of CAIR. Thus, DOE's analysis assumes the presence of nationwide emission caps on SO_2 and caps on NO_X emissions in the 28 States covered by CAIR. DOE expects that the NEMS-BT based on *AEO 2012* will incorporate implementation of the Transport Rule.

SO_2 emissions from affected Electric Generating Units (EGUs) are subject to nationwide and regional emissions cap and trading programs, and DOE has determined that these programs create uncertainty about the standards' impact on SO_2 emissions. The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the imposition of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of efficiency standards on SO_2 emissions covered by the existing cap and trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2.[f]

The CAIR established a cap on NO_x emissions in 28 eastern states and the District of Columbia. All these States and D.C. have elected to reduce their NOx emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards for battery chargers and external power supplies may have little or no physical effect on these emissions in the 28 eastern States and the D.C. for the same reasons that they may have little or no physical effect on SO_2 emissions.

DOE estimated mercury emissions reductions using NEMS-BT based on *AEO2010*, which does not incorporate the NESHAPs. DOE expects that future versions of the NEMS-BT model will reflect the implementation of the NESHAPs.

---

[f] In contrast to the modeling forecasts of NEMS-BT that SO_2 emissions will remain at the cap, during the years 2007 and 2008, SO_2 emissions were below the trading cap. This raises the possibility that standards could cause some reduction in SO_2 emissions. However, because DOE does not have a method to predict when emissions will be below the trading cap, it continues to reply on NEMS-BT and thus does not estimate SO_2 emissions reductions at this time.

As noted in chapter 14, NEMS-BT model forecasts end in year 2035. Emissions impacts beyond 2035 are assumed to be equal to the impacts in 2035.

15.5 EFFECTS ON POWER PLANT EMISSIONS

Table 15.2.3 shows *AEO2010* reference case power plant emissions in selected years. The Reference Case emissions are the emissions shown by the NEMS-BT model to result if none of the TSLs are promulgated (the base case). Values for CO_2 are given in metric tons, while values for NO_X and Hg are given in short tons.

Table 15.5.1 Power Sector Emissions Forecast from *AEO2010* Reference Case

NEMS-BT Results	2010	2015	2020	2025	2030	2035
CO_2 (million metric tons)	2,218	2,278	2,341	2,421	2,534	2,636
NO_X (million tons)	2.24	2.06	2.02	2.03	2.06	2.07
Hg (tons)	40.6	30.6	30.1	30.0	30.2	30.3

Tables 15.2.4 to Table 15.2.7 show the estimated changes in power plant emissions of CO_2, $NO_{X,}$ and Hg in selected years for each of the TSLs and each of the product class groupings. As in Table 15.2.1, values for CO_2 are given in metric tons, while values for NO_X and Hg are given in short tons. “Mt” refers to “million metric tons.”

Table 15.5.2 Power Sector Emissions Impacts Forecasts for External Power Supply Product Classes B and B,C,D,E TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case									
							Extrapolation			Total
	2010	2015	2020	2025	2030	2035	2040	2041	2042	2013-2042
EPS B TSL 1										
CO_2 (Mt/yr)	0.07	-0.46	-0.79	-0.85	-0.82	-0.72	-0.72	-0.72	-0.72	**-21.7**
NOx (1,000 tons/yr)	0.07	-0.42	-0.68	-0.72	-0.66	-0.57	-0.57	-0.57	-0.57	**-17.9**
Hg (ton/yr)	0.001	-0.003	-0.005	-0.003	-0.005	-0.003	-0.003	-0.003	-0.003	**-0.115**
EPS B TSL 2										
CO_2 (Mt/yr)	0.10	-0.74	-1.25	-1.35	-1.29	-1.14	-1.14	-1.14	-1.14	**-34.3**
NOx (kt/yr)	0.11	-0.67	-1.08	-1.14	-1.05	-0.90	-0.90	-0.90	-0.90	**-28.4**
Hg (ton/yr)	0.001	-0.006	-0.008	-0.005	-0.007	-0.005	-0.005	-0.005	-0.005	**-0.182**
EPS B TSL 3										
CO_2 (Mt/yr)	0.19	-1.36	-2.28	-2.45	-2.35	-2.08	-2.08	-2.08	-2.08	**-62.5**
NOx (1,000 tons/yr)	0.19	-1.23	-1.96	-2.06	-1.90	-1.63	-1.63	-1.63	-1.63	**-51.6**
Hg (ton/yr)	0.002	-0.010	-0.015	-0.010	-0.013	-0.009	-0.009	-0.009	-0.009	**-0.331**
EPS B,C,D,E TSL 1										
CO_2 (Mt/yr)	0.08	-0.56	-0.99	-1.09	-1.04	-0.92	-0.92	-0.92	-0.92	**-27.5**
NOx (1,000 tons/yr)	0.08	-0.51	-0.86	-0.92	-0.85	-0.72	-0.72	-0.72	-0.72	**-22.7**
Hg (ton/yr)	0.001	-0.004	-0.007	-0.004	-0.006	-0.004	-0.004	-0.004	-0.004	**-0.145**
EPS B,C,D,E TSL 2										
CO_2 (Mt/yr)	0.13	-0.88	-1.55	-1.70	-1.63	-1.44	-1.44	-1.44	-1.44	**-43.0**
NOx (1,000 tons/yr)	0.13	-0.80	-1.34	-1.43	-1.32	-1.13	-1.13	-1.13	-1.13	**-35.5**
Hg (ton/yr)	0.001	-0.007	-0.011	-0.007	-0.009	-0.007	-0.007	-0.007	-0.007	**-0.227**
EPS B,C,D,E TSL 3										
CO_2 (Mt/yr)	0.22	-1.56	-2.72	-2.99	-2.85	-2.53	-2.53	-2.53	-2.53	**-75.4**
NOx (1,000 tons/yr)	0.22	-1.41	-2.35	-2.51	-2.32	-1.98	-1.98	-1.98	-1.98	**-62.3**
Hg (ton/yr)	0.002	-0.012	-0.018	-0.012	-0.016	-0.012	-0.012	-0.012	-0.012	**-0.398**

*CO_2 results are in metric tons, NO_X and Hg results are in short tons.

Table 15.5.3 Power Sector Emissions Impacts Forecasts for External Power Supply Product Classes H and X TSLs

NEMS-BT Results*	Difference from AEO2010 Reference Case									
							Extrapolation			Total
	2010	2015	2020	2025	2030	2035	2040	2041	2042	2013-2042
EPS H TSL 1										
CO_2 (Mt/yr)	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	**-0.054**
NOx (1,000 tons/yr)	0.000	0.000	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	**-0.045**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
EPS H TSL 2										
CO_2 (Mt/yr)	0.000	-0.001	-0.002	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002	**-0.058**
NOx (kt/yr)	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	**-0.048**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
EPS H TSL 3										
CO_2 (Mt/yr)	0.000	-0.001	-0.002	-0.003	-0.003	-0.002	-0.002	-0.002	-0.002	**-0.065**
NOx (1,000 tons/yr)	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	**-0.053**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
EPS X TSL 1										
CO_2 (Mt/yr)	0.008	-0.054	-0.109	-0.116	-0.111	-0.098	-0.098	-0.098	-0.098	**-2.95**
NOx (1,000 tons/yr)	0.008	-0.049	-0.094	-0.098	-0.090	-0.077	-0.077	-0.077	-0.077	**-2.43**
Hg (ton/yr)	0.000	0.000	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	**-0.015**
EPS X TSL 2										
CO_2 (Mt/yr)	0.009	-0.062	-0.125	-0.134	-0.128	-0.113	-0.113	-0.113	-0.113	**-3.38**
NOx (1,000 tons/yr)	0.009	-0.056	-0.107	-0.112	-0.104	-0.089	-0.089	-0.089	-0.089	**-2.79**
Hg (ton/yr)	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.018**
EPS X TSL 3										
CO_2 (Mt/yr)	0.018	-0.126	-0.255	-0.274	-0.262	-0.232	-0.232	-0.232	-0.232	**-6.92**
NOx (1,000 tons/yr)	0.018	-0.114	-0.220	-0.230	-0.212	-0.181	-0.181	-0.181	-0.181	**-5.71**
Hg (ton/yr)	0.000	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.036**

*CO_2 results are in metric tons, NO_X and Hg results are in short tons.

Table 15.5.4 Power Sector Emissions Impacts Forecasts for Battery Chargers Product Classes 1 through 6 TSLs

NEMS-BT Results*	**Difference from AEO2010 Reference Case**									
							Extrapolation			**Total**
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**	**2013-2043**
BC PC1 TSL1										
CO2 (Mt/yr)	0.01	-0.05	-0.10	-0.10	-0.10	-0.09	-0.09	-0.09	-0.09	**-2.62**
NOx (1,000 tons/yr)	0.01	-0.04	-0.08	-0.09	-0.08	-0.07	-0.07	-0.07	-0.07	**-2.17**
Hg (ton/yr)	0.000	0.000	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	**-0.014**
BC PC1 TSL2										
CO2 (Mt/yr)	0.02	-0.11	-0.23	-0.24	-0.23	-0.20	-0.20	-0.20	-0.20	**-6.11**
NOx (1,000 tons/yr)	0.02	-0.10	-0.19	-0.20	-0.19	-0.16	-0.16	-0.16	-0.16	**-5.05**
Hg (ton/yr)	0.000	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	**-0.032**
BC PC1 TSL3										
CO2 (Mt/yr)	0.02	-0.15	-0.31	-0.33	-0.32	-0.28	-0.28	-0.28	-0.28	**-8.36**
NOx (1,000 tons/yr)	0.02	-0.14	-0.27	-0.28	-0.26	-0.22	-0.22	-0.22	-0.22	**-6.90**
Hg (ton/yr)	0.000	-0.001	-0.002	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	**-0.044**
BC PC 2,3,4 TSL 1										
CO2 (Mt/yr)	0.05	-0.34	-0.53	-0.58	-0.55	-0.49	-0.49	-0.49	-0.49	**-14.7**
NOx (kt/yr)	0.05	-0.30	-0.46	-0.48	-0.45	-0.38	-0.38	-0.38	-0.38	**-12.1**
Hg (ton/yr)	0.001	-0.003	-0.004	-0.002	-0.003	-0.002	-0.002	-0.002	-0.002	**-0.078**
BC PC 2,3,4 TSL 2										
CO2 (Mt/yr)	0.11	-0.80	-1.31	-1.41	-1.35	-1.20	-1.20	-1.20	-1.20	**-35.9**
NOx (1,000 tons/yr)	0.11	-0.72	-1.13	-1.19	-1.10	-0.94	-0.94	-0.94	-0.94	**-29.7**
Hg (ton/yr)	0.001	-0.006	-0.009	-0.006	-0.008	-0.005	-0.005	-0.005	-0.005	**-0.191**
BC PC 2,3,4 TSL 3										
CO2 (Mt/yr)	0.27	-1.89	-3.10	-3.35	-3.20	-2.83	-2.83	-2.83	-2.83	**-85.1**
NOx (1,000 tons/yr)	0.27	-1.71	-2.67	-2.82	-2.60	-2.22	-2.22	-2.22	-2.22	**-70.3**
Hg (ton/yr)	0.003	-0.014	-0.021	-0.013	-0.018	-0.013	-0.013	-0.013	-0.013	**-0.452**
BC PC 2,3,4 TSL 4										
CO2 (Mt/yr)	0.30	-2.12	-3.45	-3.72	-3.56	-3.15	-3.15	-3.15	-3.15	**-94.6**
NOx (1,000 tons/yr)	0.30	-1.91	-2.97	-3.13	-2.89	-2.47	-2.47	-2.47	-2.47	**-78.1**
Hg (ton/yr)	0.003	-0.016	-0.023	-0.015	-0.020	-0.014	-0.014	-0.014	-0.014	**-0.502**
BC PC 5,6 TSL 1										
CO2 (Mt/yr)	0.03	-0.22	-0.44	-0.50	-0.48	-0.42	-0.42	-0.42	-0.42	**-12.4**
NOx (1,000 tons/yr)	0.03	-0.20	-0.38	-0.42	-0.39	-0.33	-0.33	-0.33	-0.33	**-10.2**
Hg (ton/yr)	0.000	-0.002	-0.003	-0.002	-0.003	-0.002	-0.002	-0.002	-0.002	**-0.065**
BC PC 5,6 TSL 2										
CO2 (Mt/yr)	0.07	-0.49	-0.97	-1.11	-1.06	-0.94	-0.94	-0.94	-0.94	**-27.4**
NOx (1,000 tons/yr)	0.07	-0.44	-0.84	-0.93	-0.86	-0.73	-0.73	-0.73	-0.73	**-22.6**
Hg (ton/yr)	0.001	-0.004	-0.007	-0.004	-0.006	-0.004	-0.004	-0.004	-0.004	**-0.143**
BC PC 5,6 TSL 3										
CO2 (Mt/yr)	0.09	-0.64	-1.27	-1.45	-1.38	-1.23	-1.23	-1.23	-1.23	**-35.9**
NOx (1,000 tons/yr)	0.09	-0.58	-1.10	-1.22	-1.12	-0.96	-0.96	-0.96	-0.96	**-29.6**
Hg (ton/yr)	0.001	-0.005	-0.009	-0.006	-0.008	-0.006	-0.006	-0.006	-0.006	**-0.187**

*CO2 results are in metric tons, NOX and Hg results are in short tons.

Table 15.5.5 Power Sector Emissions Impacts Forecasts for Battery Chargers Product Classes 7,8, and 10 TSLs

NEMS-BT Results*	**Difference from AEO2010 Reference Case**									
							Extrapolation			**Total**
	2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2041**	**2042**	**2013-2043**
BC PC7 TSL 1										
CO2 (Mt/yr)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	**-0.312**
NOx (kt/yr)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	**-0.259**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**-0.002**
BC PC7 TSL 2										
CO2 (Mt/yr)	0.00	-0.03	-0.03	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	**-0.975**
NOx (1,000 tons/yr)	0.00	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	**-0.808**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**-0.006**
BC PC 8 TSL 1										
CO2 (Mt/yr)	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	**-0.457**
NOx (1,000 tons/yr)	0.00	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	**-0.378**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**-0.002**
BC PC 8 TSL 2										
CO2 (Mt/yr)	0.01	-0.04	-0.07	-0.08	-0.07	-0.06	-0.06	-0.06	-0.06	**-1.95**
NOx (1,000 tons/yr)	0.01	-0.04	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	**-1.61**
Hg (ton/yr)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**-0.010**
BC PC 8 TSL 3										
CO2 (Mt/yr)	0.01	-0.05	-0.08	-0.08	-0.08	-0.07	-0.07	-0.07	-0.07	**-2.16**
NOx (1,000 tons/yr)	0.01	-0.04	-0.07	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	**-1.78**
Hg (ton/yr)	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	**-0.011**
BC PC 10 TSL1										
CO2 (Mt/yr)	0.02	-0.12	-0.41	-0.40	-0.40	-0.37	-0.37	-0.37	-0.37	**-10.3**
NOx (1,000 tons/yr)	0.02	-0.11	-0.35	-0.34	-0.33	-0.29	-0.29	-0.29	-0.29	**-8.46**
Hg (ton/yr)	0.000	-0.001	-0.003	-0.002	-0.003	-0.002	-0.002	-0.002	-0.002	**-0.068**
BC PC 10 TSL2										
CO2 (Mt/yr)	0.02	-0.14	-0.47	-0.47	-0.47	-0.42	-0.42	-0.42	-0.42	**-11.9**
NOx (1,000 tons/yr)	0.02	-0.13	-0.41	-0.39	-0.38	-0.33	-0.33	-0.33	-0.33	**-9.81**
Hg (ton/yr)	0.000	-0.001	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	**-0.079**
BC PC 10 TSL3										
CO2 (Mt/yr)	0.03	-0.17	-0.55	-0.55	-0.55	-0.50	-0.50	-0.50	-0.50	**-13.9**
NOx (1,000 tons/yr)	0.03	-0.15	-0.48	-0.46	-0.44	-0.39	-0.39	-0.39	-0.39	**-11.5**
Hg (ton/yr)	0.000	-0.002	-0.004	-0.003	-0.004	-0.003	-0.003	-0.003	-0.003	**-0.092**

*CO2 results are in metric tons, NOX and Hg results are in short tons.

15.6 EFFECTS ON UPSTREAM FUEL-CYCLE EMISSIONS

Upstream fuel-cycle emissions refer to the emissions associated with the amount of energy used in the upstream production and downstream consumption of electricity, including energy used at the power plant. Upstream processes include the mining of coal or extraction of natural gas, physical preparatory and cleaning processes, and transportation to the power plant. The NEMS-BT does a thorough accounting of emissions at the power plant due to downstream energy consumption, but does not account for upstream emissions (i.e., emissions from energy losses during coal and natural gas production). Thus, this analysis reports only power plant emissions.

However, previous DOE environmental assessment documents have developed approximate estimates of effects on upstream fuel-cycle emissions. These emissions factors provide the reader with a sense of the possible magnitude of upstream effects. These upstream emissions would be in addition to emissions from direct combustion.

Relative to the entire fuel cycle, estimates based on the work of Dr. Mark DeLuchi, and reported in earlier DOE environmental assessment documents, find that an amount approximately equal to eight percent, by mass, of emissions (including SO_2) from coal production are due to mining, preparation that includes cleaning the coal, and transportation from the mine to the power plant. [12] Transportation emissions include emissions from the fuel used by the mode of transportation that moves the coal from the mine to the power plant. In addition, based on Dr. DeLuchi's work, DOE estimated that an amount equal to approximately 14 percent of emissions from natural gas production result from upstream processes.

Emission factor estimates and corresponding percentages of contributions of upstream emissions from coal and natural gas production, relative to power plant emissions, are shown in Table 15.2.5 for CO_2 and NO_X. The percentages provide a means to estimate upstream emission savings based on changes in emissions from power plants. This approach does not address Hg emissions.

Table 15.6.1 Estimated Upstream Emissions of Air Pollutants as a Percentage of Direct Power Plant Combustion Emissions

Pollutant	Percent of Coal Combustion Emissions	Percent of Natural Gas Combustion Emissions
CO_2	2.7	11.9
NO_X	5.8	40

15.7 SUMMARY OF EMISSIONS LEVELS

Table 15.7.1 and Table 15.7.2 summarize the estimated emissions impacts for each of the TSLs for EPSs and BCs, respectively. It shows cumulative changes in emissions for CO_2, NO_X, and Hg from 2013 through 2042 for each of the TSLs. Cumulative CO_2, NO_X, and Hg emissions are reduced compared to the Reference case for all TSLs. For comparison, the cumulative power sector emissions in the *AEO2010* Reference case, over the period 2013 through 2042, are 74,223 Mt for CO_2, 61,808 thousand tons for NO_X, and 929 tons for Hg.

Table 15.7.1 Cumulative Emissions Reductions Under EPS TSLs from 2013 through 2042*

	TSL 1	**TSL 2**	**TSL 3**
Product Class B			
CO_2 (Mt)	21.7	34.3	62.5
NO_X (kt)	17.9	28.4	51.6
Hg(t)	0.115	0.182	0.331
Product Classes B, C, D, and E			
CO_2 (Mt)	27.5	43.0	75.4
NO_X (kt)	22.7	35.5	62.3
Hg(t)	0.145	0.227	0.398
Product Class X			
CO_2 (Mt)	2.95	3.38	6.92
NO_X (kt)	2.43	2.79	5.71
Hg(t)	0.015	0.018	0.036
Product Class H			
CO_2 (Mt)	0.054	0.058	0.065
NO_X (kt)	0.045	0.048	0.053
Hg(t)	0.000	0.000	0.000

* CO_2 values are in metric tons, NO_x and Hg values are in short tons.

Table 15.7.2 Cumulative Emissions Reductions Under BC TSLs from 2013 through 2042*

	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**
Product Class 1				
CO_2 (Mt)	2.62	6.11	8.36	NA
NO_X (kt)	2.17	5.05	6.90	NA
Hg(t)	0.014	0.032	0.044	NA
Product Classes 2, 3, 4				
CO_2 (Mt)	14.7	35.9	85.1	94.6
NO_X (kt)	12.1	29.7	70.3	78.1
Hg(t)	0.078	0.191	0.452	0.502
Product Classes 5, 6				
CO_2 (Mt)	12.4	27.4	35.9	Na
NO_X (kt)	10.2	22.6	29.6	Na
Hg(t)	0.065	0.143	0.187	Na
Product Class 7				
CO_2 (Mt)	0.312	0.975	Na	Na
NO_X (kt)	0.259	0.808	Na	Na
Hg(t)	0.002	0.006	Na	Na
Product Class 8				
CO_2 (Mt)	0.46	1.95	2.16	Na
NO_X (kt)	0.38	1.61	1.78	Na
Hg(t)	0.002	0.010	0.011	Na
Product Class 10				
CO_2 (Mt)	10.3	11.9	13.9	Na
NO_X (kt)	8.46	9.81	11.5	Na
Hg(t)	0.068	0.079	0.092	Na

* CO_2 values are in metric tons, NO_x and Hg values are in short tons.

REFERENCES

[1] U.S. Environmental Protection Agency, Sulfur Dioxide, 2011. http://www.epa.gov/airquality/urbanair/

[2] U.S. Environmental Protection Agency, Nitrogen Dioxide, 2011. http://www.epa.gov/air/nitrogenoxides/

[3] U.S. Environmental Protection Agency, Mercury, 2011. http://www.epa.gov/mercury/

[4] Trasande, L., C. Schechter, K.A. Haynes, and P.J. Landrigan,, Applying Cost Analyses to Drive Policy That Protects Children : Mercury as a Case Study. Annals of the New York Academy of Sciences, 2006. 1076

[5] U.S. Environmental Protection Agency, 2009 U.S. Greenhouse Gas Inventory Report, 2009. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

[6] U.S. Environmental Protection Agency, Clean Air Act. 1990. http://www.epa.gov/air/caa/

[7] Intergovernmental Panel On Climate Change, IPCC WGI Fourth Assessment Report: Climate Change 2007: The Physical Science Basis, 2007. Geneva. http://ipcc-wg1.ucar.edu/wg1/docs/WG1AR4_SPM_PlenaryApproved.pdf

[8] Intergovernmental Panel On Climate Change, Climate Change 2007 – Impacts, Adaptation and Vulnerability. http://www.ipcc-wg2.gov

[9] Intergovernmental Panel On Climate Change, IPCC Special Report on Land Use, Land-Use Change And Forestry, 2000. http://www.grida.no/publications/other/ipcc_sr/?src=/Climate/ipcc/land_use/index.htm

[10] Intergovernmental Panel On Climate Change, IPCC Fourth Assessment Report Climate Change 2007: Working Group III Report "Mitigation of Climate Change", 2007. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-ts.pdf

[11] Energy Information Administration, Updated Annual Energy Outlook 2011. Report No. DOE/EIA-0383(2011). http://www.eia.gov/forecasts/aeo/

[12] DeLuchi, M. A., Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity, Volume 2: Appendixes A-S, November, 1993. Argonne National Laboratory. Argonne, IL. Report No. ANL/ESD/TM-22-Vol.2.

CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 16. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

16.1 INTRODUCTION

As part of its assessment of energy conservation standards for battery chargers and external power supplies, DOE estimated the monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2) and nitrogen oxides (NO_X) that are expected to result from each of the TSLs considered. In order to make this calculation similar to the calculation of the NPV of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of products shipped in the forecast period for each TSL. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

16.2 MONETIZING CARBON DIOXIDE EMISSIONS

16.2.1 Social Cost of Carbon

Under section 1(b) of Executive Order 12866, “Regulatory Planning and Review,” 58 FR 51735 (Oct. 4, 1993), agencies must, to the extent permitted by law, “assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.”

The purpose of the social cost of carbon (SCC) estimates presented here is to allow Federal agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small, or “marginal,” impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The social cost of carbon is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of carbon dioxide.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Research Council[a] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Consistent with the directive quoted above, the purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or “marginal,” impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions. DOE does not attempt to answer that question here.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, the interagency group will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

16.2.2 Social Cost of Carbon Values Used in Past Regulatory Analyses

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a “domestic” SCC value of

---

[a] National Research Council. Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. National Academies Press: Washington, DC. 2009.

$2 per ton of CO_2 and a “global” SCC value of $33 per ton of CO_2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year.[b] It also included a sensitivity analysis at $80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of $7 per ton of CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of $0-$14 for sensitivity analysis), also increasing at 2.4 percent per year.[c] A regulation for packaged terminal air conditioners and packaged terminal heat pumps finalized by DOE in October 2008 used a domestic SCC range of $0 to $20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). 73 FR 58772, 58814 (Oct. 7, 2008) In addition, EPA’s 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as “very preliminary” SCC estimates subject to revision.[d] EPA’s global mean values were $68 and $40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of $55, $33, $19, $10, and $5 per ton of CO_2.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules. See CAFE Rule for Passenger Cars and Light Trucks Draft EIS and Final EIS, cited above.

16.2.3 Current Approach and Key Assumptions

Since the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates, which were considered for this proposed rule.

---

[b] See Average Fuel Economy Standards Passenger Cars and Light Trucks Model Year 2011, 74 FR 14196 (March 30, 2009); Final Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015 at 3-90 (Oct. 2008) (Available at: http://www.nhtsa.gov/fuel-economy).

[c] See *Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015*, 73 FR 24352 (May 2, 2008); Draft Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015 at 3-58 (June 2008) (Available at: http://www.nhtsa.gov/fuel-economy).

[d] See *Regulating Greenhouse Gas Emissions Under the Clean Air Act*, 73 FR 44354 (July 30, 2008).

Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[e] These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in the SCC values that were developed.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: (1) climate sensitivity; (2) socio-economic and emissions trajectories; and (3) discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socio-economic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For emissions (or emission reductions) that occur in later years, these values grow in real terms over time, as depicted in Table 16-1. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects,[f] although preference is given to consideration of the global benefits of reducing CO_2 emissions.

---

[e] The models are described in appendix 16-A of the TSD.

[f] It is recognized that this calculation for domestic values is approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time.

Table 16-1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton)

	Discount Rate			
	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned above points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

DOE recognizes the uncertainties embedded in the estimates of the SCC used for cost-benefit analyses. As such, DOE and others in the U.S. Government intend to periodically review and reconsider those estimates to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance.

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the most recent SCC values identified by the interagency process, adjusted to 2010$ using the GDP price deflator. For each of the four cases specified, the values used for emissions in 2010 were $4.9, $22.3, $36.6, and $67.6 per metric ton avoided (values expressed in 2010$). To monetize the CO_2 emissions reductions expected to result from new and amended standards for battery chargers (BCs) and external power supplies (EPSs), DOE used the values identified in Table A1 of the "Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," which is reprinted in appendix 16-A of this TSD, appropriately escalated to 2010$.[g] To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SCC values in each case.

---

[g] Table A1 presents SCC values through 2050. For DOE's calculation, it derived values after 2050 using the 3-percent per year escalation rate used by the interagency group.

16.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefit of reduced NO_X emissions from the TSLs it considered. As noted in chapter 15, new or amended energy conservation standards would reduce NO_X emissions in those 22 States that are not affected by the CAIR, in addition to the reduction in site NO_X emissions nationwide. DOE estimated the monetized value of NO_X emissions reductions resulting from each of the TSLs considered based on environmental damage estimates from the literature. Available estimates suggest a very wide range of monetary values, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $450 to $4,623 per ton in 2010$).[h] In accordance with OMB guidance, DOE conducted two calculations of the monetary benefits using each of the above values used for NO_X, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[i]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

16.4 RESULTS

Table 16.2 to Table 16.5, and Table 16.6 to Table 16.11 present the global values of CO_2 emissions reductions at each energy efficiency TSL and for each product class grouping for external power supplies (EPSs) and battery chargers (BCs), respectively. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values, and these results are presented in Table 16.12 to Table 16.15 for EPSs. Table 16.16 to Table 16.21 present similar results for BCs. Results are shown separately for EPS product class B.

Table 16.2 External Power Supply Product Class B: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	91	448	752	1,369
2	145	710	1,190	2,166
3	263	1,289	2,162	3,936

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in

---

[h] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, ''2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities,'' Washington, DC.

[i] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.3 External Power Supply Product Classes B, C, D, and E: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	116	572	960	1,746
2	182	895	1,501	2,731
3	319	1,568	2,631	4,785

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.4 External Power Supply Product Class X: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	12	61	103	187
2	14	70	118	215
3	29	144	242	440

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.5 External Power Supply Product Class H: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	0	1	2	4
2	0	1	2	4
3	0	1	2	4

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.6 Battery Charger Product Class 1: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	11	55	92	167
2	26	127	213	388
3	35	174	292	531

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.7 Battery Chargers Product Classes 2, 3, 4: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	62	302	506	921
2	151	740	1,242	2,260
3	358	1,753	2,940	5,352
4	398	1,949	3,268	5,949

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.8 Battery Chargers Product Classes 5, 6: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	53	261	438	795
2	118	580	974	1,770
3	154	760	1,276	2,318

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.9 Battery Chargers Product Class 7: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	1	6	11	19
2	4	20	33	61

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.10 Battery Chargers Product Class 8: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	2	9	16	29
2	8	40	67	122
3	9	44	74	136

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.11 Battery Chargers Product Class 10: Estimates of Global Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	45	220	370	672
2	52	256	430	780
3	60	298	501	910

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.12 External Power Supply Product Class B: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	6 to 21	31 to 103	53 to 173	96 to 315
2	10 to 33	50 to 163	83 to 274	152 to 498
3	18 to 60	90 to 297	151 to 497	275 to 905

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.13 External Power Supply Product Classes B, C, D, E: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	8 to 27	40 to 132	67 to 221	122 to 402
2	13 to 42	63 to 206	105 to 345	191 to 628
3	22 to 73	110 to 361	184 to 605	335 to 1,101

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.14 External Power Supply Product Class X: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	3% discount rate, average*	2.5% discount rate, average*	3% discount rate, 95th percentile*
1	1 to 3	4 to 14	7 to 24	13 to 43
2	1 to 3	5 to 16	8 to 27	15 to 49
3	2 to 7	10 to 33	17 to 56	31 to 101

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.15 External Power Supply Product Class H: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	0.017 to 0.056	0.085 to 0.280	0.144 to 0.472	0.260 to 0.854
2	0.018 to 0.060	0.092 to 0.301	0.154 to 0.507	0.279 to 0.918
3	0.020 to 0.067	0.102 to 0.334	0.172 to 0.564	0.310 to 1.020

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.16 Battery Charger Product Class 1: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	1 to 3	4 to 13	6 to 21	12 to 38
2	2 to 6	9 to 29	15 to 49	27 to 89
3	2 to 8	12 to 40	20 to 67	37 to 122

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.17 Battery Charger Product Classes 2, 3, 4: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

	Million 2010$			
TSL	**5% discount rate, average***	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	4 to 14	21 to 69	35 to 116	64 to 212
2	11 to 35	52 to 170	87 to 286	158 to 520
3	25 to 82	123 to 403	206 to 676	375 to 1,231
4	28 to 91	136 to 448	229 to 752	416 to 1,368

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.18 Battery Charger Product Classes 5, 6: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	4 to 12	18 to 60	31 to 101	56 to 183
2	8 to 27	41 to 133	68 to 224	124 to 407
3	11 to 35	53 to 175	89 to 293	162 to 533

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.19 Battery Charger Product Class 7: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	0.091 to 0.300	0.446 to 1	1 to 2	1 to 4
2	0 to 1	1 to 5	2 to 8	4 to 14

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.20 Battery Charger Product Class 8: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	0.135 to 0.442	0.658 to 2	1 to 4	2 to 7
2	1 to 2	3 to 9	5 to 15	9 to 28
3	1 to 2	3 to 10	5 to 17	9 to 31

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.21 Battery Charger Product Class 10: Estimates of Domestic Present Value of Cumulative CO_2 Emissions Reduction Under TSLs

TSL	Million 2010$			
	5% discount rate, average*	**3% discount rate, average***	**2.5% discount rate, average***	**3% discount rate, 95th percentile***
1	3 to 10	15 to 51	26 to 85	47 to 155
2	4 to 12	18 to 59	30 to 99	55 to 179
3	4 to 14	21 to 69	35 to 115	64 to 209

* Columns are labeled by the discount rate used to calculate the SCC and whether it is an average value or drawn from a different part of the distribution. Values presented in the table are based on escalating the SCC values in 2007$ to 2010$ for consistency with other values presented in this notice, and incorporate the escalation of the SCC over time.

Table 16.22 and Table 16.23 present the cumulative monetary value of the economic benefits associated with NO_X emissions reductions for each TSL, calculated using seven-percent and three-percent discount rates.

Table 16.22 Estimates of Present Value of Cumulative NO_X Emissions Reduction Under External Power Supply TSLs

	TSL 1	**TSL 2**	**TSL 3**
	Million 2010$		
Product Class B			
3% discount rate	5 to 53	8 to 83	15 to 151
7% discount rate	3 to 29	5 to 47	8 to 85
Product Classes B, C, D, E			
3% discount rate	6 to 67	10 to 104	18 to 183
7% discount rate	4 to 37	6 to 58	10 to 102
Product Class X			
3% discount rate	1 to 7	1 to 8	2 to 17
7% discount rate	0 to 4	0 to 5	1 to 9
Product Class H			
3% discount rate	0.013 to 0.135	0.014 to 0.145	0.016 to 0.161
7% discount rate	0.007 to 0.069	0.007 to 0.074	0.008 to 0.082

Table 16.23 Estimates of Present Value of Cumulative NO_X Emissions Reduction Under Battery Charger TSLs

	TSL 1	TSL 2	TSL 3	TSL 4
	Million 2010$			
Product Class 1				
3% discount rate	1 to 6	1 to 15	2 to 20	n.a.
7% discount rate	0.344 to 4	1 to 8	1 to 11	n.a.
Product Classes 2, 3, 4				
3% discount rate	3 to 35	8 to 87	20 to 206	22 to 229
7% discount rate	2 to 20	5 to 49	11 to 116	13 to 129
Product Classes 5, 6				
3% discount rate	3 to 30	7 to 67	9 to 88	n.a.
7% discount rate	2 to 16	4 to 37	5 to 48	n.a.
Product Class 7				
3% discount rate	0.073 to 1	0.229 to 2	n.a.	n.a.
7% discount rate	0.042 to 0.431	0.131 to 1	n.a.	n.a.
Product Class 8				
3% discount rate	0.108 to 1	0.459 to 5	1 to 5	n.a
7% discount rate	0.061 to 1	0.260 to 3	0.288 to 3	n.a.
Product Class 10				
3% discount rate	2 to 25	3 to 29	3 to 34	n.a
7% discount rate	1 to 14	2 to 16	2 to 18	n.a.

CHAPTER 17. REGULATORY IMPACT ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 17. REGULATORY IMPACT ANALYSIS

17.1 INTRODUCTION

The U.S. Department of Energy (DOE) has determined that energy conservation standards for battery chargers (BCs) and external power supplies (EPSs) constitute an "economically significant regulatory action" under Executive Order (E.O.) 12866, Regulatory Planning and Review. 58 FR 51735, Volume 58, No. 190, page 51735. (October 4, 1993). Under 10 CFR part 430, subpart C, appendix A, section III.12, DOE committed to evaluating non-regulatory alternatives to proposed standards by performing a regulatory impact analysis (RIA). 61 FR 36981, Volume 61, No. 136, page 36978. (July 15, 1996). This RIA, which DOE has prepared pursuant to E.O. 12866, evaluates potential non-regulatory alternatives, comparing the costs and benefits of each to those of the proposed standards. 58 FR 51735, page 51741. As noted in E.O. 12866, this RIA is subject to review by the Office of Management and Budget's Office of Information and Regulatory Affairs. 58 FR 51735, page 51740.

For this Regulatory Impact Analysis, DOE used a revised version of its national impact analysis (NIA) model discussed in chapter 10. DOE studied the impacts of the non-regulatory policies on the product classes analyzed in the other downstream analyses for the NOPR. The savings reported in this chapter represent the savings for all the considered product classes.

DOE identified six non-regulatory policy alternatives that feasibly could provide incentives for the same energy efficiency levels as the proposed standards for the products that are the subject of this rulemaking:

- Consumer Rebates
- Consumer Tax Credits
- Manufacturer Tax Credits
- Voluntary Energy Efficiency Targets
- Early Replacement
- Bulk Government Purchases

DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the proposed standards. As is explained in section 17.3.5.3, results for the early replacement scenario were not quantified, as this policy was deemed unrealistic for the vast majority of BCs and EPSs. A scenario in which no new regulatory or non-regulatory action is taken was used as the base case and is referred to as the "No New Regulatory Action" scenario.

17.2 METHODOLOGY AND GENERAL ASSUMPTIONS

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the six non-regulatory policy alternatives for battery chargers (BCs) and external power supplies (EPSs). This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used a modification of the national impact analysis (NIA) spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) of consumer costs and benefits associated with each non-regulatory policy alternative. Chapter 10 of the technical support document (TSD) describes the NIA spreadsheet model. In this model, there is a selectable field through which the user can choose which scenario to quantify. The default is Federal energy efficiency standards, while the alternative options are the non-regulatory alternatives to standards, described in this chapter. Varying the selected scenario varies the efficiency distribution for each affected product class.

DOE quantified the effect of each alternative on the purchase of products that meet *target levels,* which are defined as the efficiency levels in the proposed standards. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA spreadsheet model. The primary model input revised were market shares of products meeting target efficiency levels. These are also referred to as market efficiency distributions. DOE assumed that the proposed standards would affect 100% of the shipments of products that did not meet target levels in the base case, whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy and assumed that shipments of the least efficient models in the market would increase to the target efficiency level (e.g., first models at CSL 0, then models at CSL 1, etc.).

Increasing the efficiency of a product often increases its average installed cost. On the other hand, operating costs generally decrease because energy consumption declines. DOE therefore calculated consumer NPV for each non-regulatory alternative in the same away it did for the proposed standards. In some scenarios, increases in total installed costs are mitigated by government rebates or tax credits. Because DOE assumed that consumers would re-pay credits and rebates in some way (such as through additional taxes), DOE did not include the value of rebates or tax credits themselves as consumer benefits when calculating national NPV and instead treated them as transfers. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease NPV.

The following are key measures for evaluating the impact of each alternative:

- National energy savings, given in quadrillion Btu (quads), is the cumulative national primary energy savings for products bought during the period from the effective date of the policy (2013) through the end of the analysis period (2042).

- Net present value represents the value in 2010$ (discounted to 2011) of energy cost savings less incremental product purchase costs for products bought during the period from the effective date of the policy (2013) through the end of the analysis period (2042).

NES and NPV are explained in detail in chapter 10 of the TSD.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain, because they depend on program implementation and marketing efforts and on consumers' responses to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will meet with full compliance. For each policy alternative DOE gathered information on past experience with programs of that type and sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affect the assumptions that underlie the modeling of each policy.

Each policy that DOE considered would improve the average efficiency of new BCs and EPSs relative to their base case efficiency scenarios (which involve no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same efficiency levels as required by the proposed standards (the target levels). As opposed to the standards case, however, the policy cases may not lead to 100% market penetration of units that meet target levels.

Table 17.1 and Table 17.2 show the trial standard levels (TSLs) proposed for EPSs and BCs, respectively, in this rulemaking. Chapter 5 discusses the underlying efficiency levels for these TSLs in greater detail. For all product classes, the target levels explored in each policy scenario are at levels equal to the TSLs listed in these tables.

Table 17.1 Proposed Standard Levels for External Power Supplies

	Output	**Class ID**	**Proposed Standard**
AC-DC	Basic Voltage	B: 2.5 W	TSL 2 *(CSL 3)*
		B: 18 W	TSL 2 *(CSL 3)*
		B: 60 W	TSL 2 *(CSL 3)*
		B: 120 W	TSL 2 *(CSL 3)*
	Low Voltage	C	TSL 2 *(CSL 3)*
AC-AC	Basic Voltage	D	TSL 2 *(CSL 3)*
	Low Voltage	E	TSL 2 *(CSL 3)*
Multiple-Voltage	<100 W	X	TSL 2 *(CSL 2)*
High Power	>250 W	H	TSL 2 *(CSL 3)*

Table 17.2 Proposed Standard Levels for Battery Chargers

	Battery Energy	Battery Voltage	Class ID	Proposed Standard
AC-DC	<100 Wh	Inductive Connection	1	TSL 2 *(CSL 2)*
		<4 V	2	TSL 1 *(CSL 1)*
		4–10 V	3	TSL 1 *(CSL 1)*
		>10 V	4	TSL 1 *(CSL 1)*
	100–3000 Wh	<20 V	5	TSL 2 *(CSL 2)*
		≥20 V	6	TSL 2 *(CSL 2)*
	>3000 Wh		7	TSL 1 *(CSL 1)*
DC-DC		<9 V	8	TSL 1 *(CSL 1)*
		≥9 V	9	N/A*
AC-AC		AC Output from Battery	10	TSL 3 *(CSL 3)*

*Proposed standards for product class 9 were not evaluated in the national impact analysis and thus were not included in the regulatory impact analysis.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as consumer rebates with voluntary efficiency standards. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are not additive. The combined effect of several or all policies cannot be inferred from summing their individual results.

17.3 NON-REGULATORY POLICIES

The following subsections describe DOE's analysis of the impacts of the six non-regulatory policy alternatives to proposed standards for BCs and EPSs. DOE developed estimates of the market penetration of high-efficiency products both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken constitutes the base case, as described in chapter 10 of the TSD. The base case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered a scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy efficient appliances. This policy provides a consumer rebate for purchasing BCs or EPSs that operate at (or above) the same efficiencies as stipulated in the proposed standards (target levels).

To inform its estimate of the market impacts of consumer rebates, DOE performed a thorough search for existing energy efficiency rebate programs nationwide. However, it was unable to identify any such programs for BCs or EPSs. Given the lack of utility or agency rebate programs for BCs and EPSs, DOE turned to rebate programs for other products regulated by DOE to analyze how rebate programs may affect the market penetration of an efficient product.

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. This study, performed by XENERGY, Inc.,[a] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized penetration curves that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies, including some developed after the referenced XENERGY report was published. These employed a variety of approaches, including: other economic parameters (e.g., payback period), expert surveys, or calibration of a model with specific program data rather than using generic penetration curves.[2, 3, 4] DOE ultimately decided that XENERGY's approach of employing penetration curves based on a product class's B/C ratio, which incorporates lifetime operating cost savings, was most appropriate for BCs and EPSs, given the nature of these products and the inputs to and outputs from the NIA and life-cycle cost analyses.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new products primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17-A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (also referred to as implementation) curves for a measure. XENERGY then calibrated the curves based on participation data from utility rebate programs. A rebate program reduces the upfront (installed) cost of an efficient product by lowering the incremental cost paid by the consumer. The benefits (reductions in operating costs) remain unchanged, so the B/C ratio increases. The curves illustrate the increased penetration (i.e., increased market share) of efficient products driven by consumer response to increases in the B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on the consumers' perceived barriers to purchasing

---

[a] XENERGY is now owned by KEMA, Inc. (www.kema.com)

high-efficiency products (from no barriers to extremely high barriers). The curves are depicted in Figure 17.1.

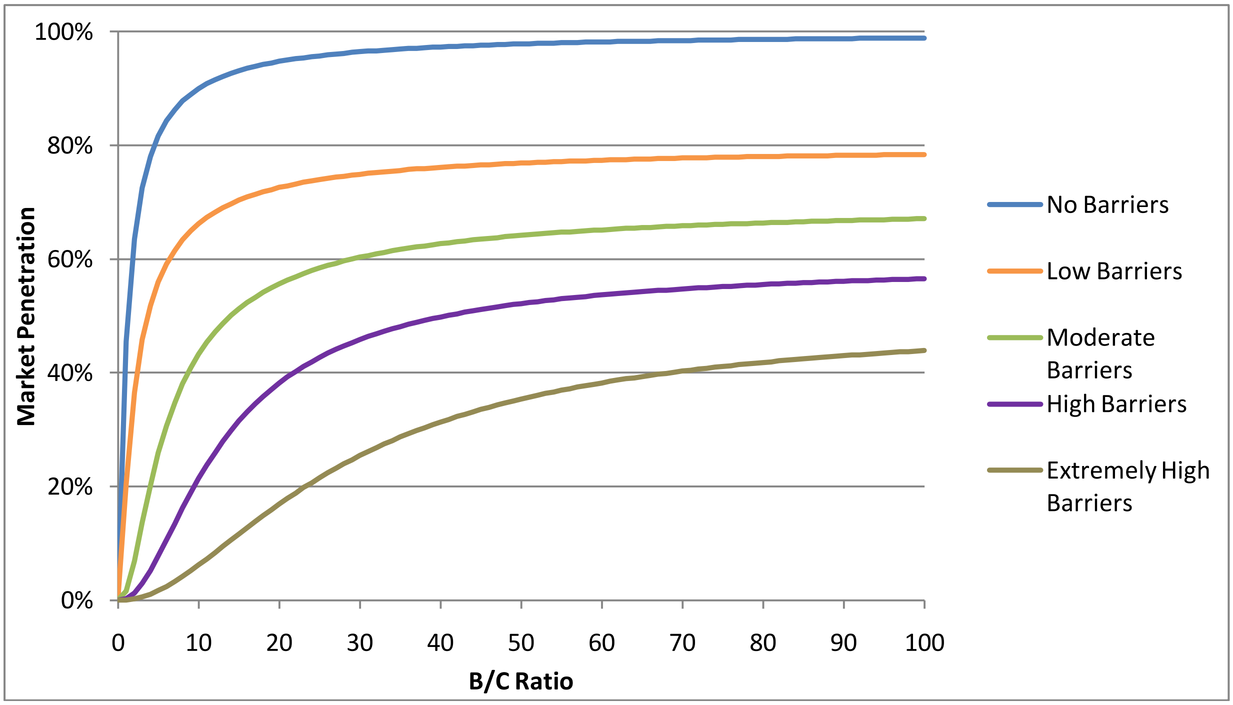


Figure 17.1 XENERGY Market Penetration Curves

In its Regulatory Impact Analysis for Refrigerator-Freezers, DOE adjusted XENERGY's penetration curves based on conversations with the authors of the XENERGY report.[5] DOE used these adjusted penetration curves in its analyses for BCs and EPSs as well. In adjusting XENERGY's methodology, DOE was able to derive interpolated market penetration curves specific to the barriers to market penetration faced by each BC and EPS product class. These adjustments are explained in detail in appendix 17-A.

DOE modeled the effects of a consumer rebate policy for BCs and EPSs by estimating the difference in market penetration in 2013 of products meeting the target efficiency levels relative to the no-standards base case. It did this using the interpolated penetration curves created for each product class based on the XENERGY methodology to best reflect the market barrier levels faced by each product class. Section 17.3.2.2 displays the interpolated penetration curves for each of the EPS product classes, while section 17.3.2.3 displays the interpolated penetration curves for each of the BC product classes.

17.3.2.1 Determining Rebate Levels for Battery Chargers and External Power Supplies

To estimate the changes in the B/C ratios that would result from a consumer rebate program for efficient BCs and EPSs, DOE first had to estimate the rebate levels that would be offered for these products. Despite an extensive search of utility websites and the DSIRE database,[6] DOE was unable to identify current or past utility or agency rebates for efficient BCs or EPSs. Given the lack of available data, DOE turned to previous rulemakings to estimate potential rebate levels.

In RIAs for previous rulemakings, DOE compiled rebate estimates for a variety of residential and commercial products, including small electric motors, water heaters, pool heaters, refrigerators, freezers, cooking products, and commercial clothes washers. DOE then determined the median rebate offered for each product. Appendix 17-A shows the median rebate and incremental cost for each of the products for which DOE gathered data.

For the BC and EPS rulemakings, DOE divided these average rebates for each product by the incremental cost (at the proposed standard levels) for that product to determine the share of incremental cost that a typical rebate offsets. By taking simple averages of these ratios for various products, DOE determined that the average rebate (across all products) represents 55.4% of those products' incremental costs. This value is only slightly higher for residential products (55.9%) and lower for commercial products (42.3%). The BCs and EPSs covered in this rulemaking are intended primarily for use with consumer applications, so DOE assumed that rebates would cover 55.9% of the products' incremental costs.

Product Classes with Negative Incremental Costs

DOE assumed that, all else equal, consumers will purchase products with lower upfront costs. Increasing a product's efficiency typically leads to an increase in the price at which the product is sold. This increase is referred to as an incremental cost. However, the incremental costs at the proposed standard level are negative in EPS product class H and BC product classes 5, 6, 7, and 8. In other words, the more efficient products in these product classes are less expensive than the baseline products.

Despite negative incremental costs, the markets for these products had not entirely shifted to the lower cost, higher efficiency models, indicating that factors other than price are leading some consumers to purchase the less efficient models. Since consumer rebates and tax credits are typically employed to offset the positive incremental cost that a consumer faces when purchasing an efficient product, and BCs and EPSs at the target levels for these product classes did not have positive incremental costs, DOE believes that price-based incentive programs such as rebates and tax credits are inappropriate policy tools to achieve increased market penetration at higher efficiency levels for these product classes. Thus, product classes H, 5, 6, 7, and 8 were not analyzed under the consumer rebate, consumer tax credit, and manufacturer tax credit scenarios.

17.3.2.2 Consumer Rebates for External Power Supplies

External Power Supplies, Product Class B

The majority of EPSs fall under product class B. For analysis purposes, DOE subdivided these EPSs into four segments by nameplate output power (in watts). These are displayed in Table 17.3.

Table 17.3 Basic Voltage AC-DC EPS Representative Units and Associated Output Power Ranges

Representative Unit	Nameplate Output Power	Nameplate Output Voltage	Range of Nameplate Output Powers
	[W]	[V]	[W]
1	2.5	5	0-10.25
2	18	12	10.26-39
3	60	15	40-90
4	120	19	91-250

DOE analyzed the effects of consumer rebates, consumer tax credits, and manufacturer tax credits separately for each of these subdivisions of product class B. The net effects on each of these subdivisions were then combined to yield the total projected NES and NPV for product class B.

As described in section 17.3.2.1, rebates for BCs and EPSs were determined based on the share of incremental costs offset by rebates for other commonly rebated products. These rebate amounts, on average, offset 55.9% of a product's incremental cost.

For EPSs in product class B, DOE first calculated B/C ratios without a rebate using the incremental costs of a product at the proposed standard level (cost) and the lifetime operating cost savings between the unit meeting the target level and the baseline unit (benefit). Using this B/C ratio and the no-standards case market penetration, along with the interpolated penetration curve methodology outlined in Appendix 17-A, DOE was able to identify the appropriate penetration curve for each representative unit. It found that the markets for efficient 2.5 W, 18 W, and 60 W EPSs in product class B faced moderate to high barriers and EPSs in the 120 W segment faced high to extremely high barriers. It then reduced the incremental cost for a product meeting the proposed standard level by 55.9% to account for a consumer rebate program and recalculated the B/C ratio for that representative unit. Table 17.4 displays this information for the four representative units in product class B.

Table 17.4 Benefits and Costs for EPSs in Product Class B, With and Without Consumer Rebates

Nameplate Output Power	2.5 W	18 W	60 W	120 W
Operating Cost Savings	$0.86	$2.84	$1.77	$2.01
Incremental Cost	$0.65	$0.90	$1.86	$0.63
B/C Ratio Without Rebate	1.3	3.2	1.0	3.2
Calculated Market Barrier Curve	Low – Moderate	Moderate – High	Moderate – High	High – Extremely High
Rebate Amount	$0.36	$0.50	$1.04	$0.35
Incremental Cost with Rebate	$0.29	$0.40	$0.82	$0.28
B/C Ratio With Rebate	3.0	7.2	2.2	7.2

Using the B/C ratio with consumer rebates and the appropriate penetration curve, DOE was then able to estimate the increase in market penetration that would be achieved through consumer rebates. The estimated increases in the market penetration of efficient product class B EPSs that would result from consumer rebates are graphically displayed in Figure 17.2 through Figure 17.5.

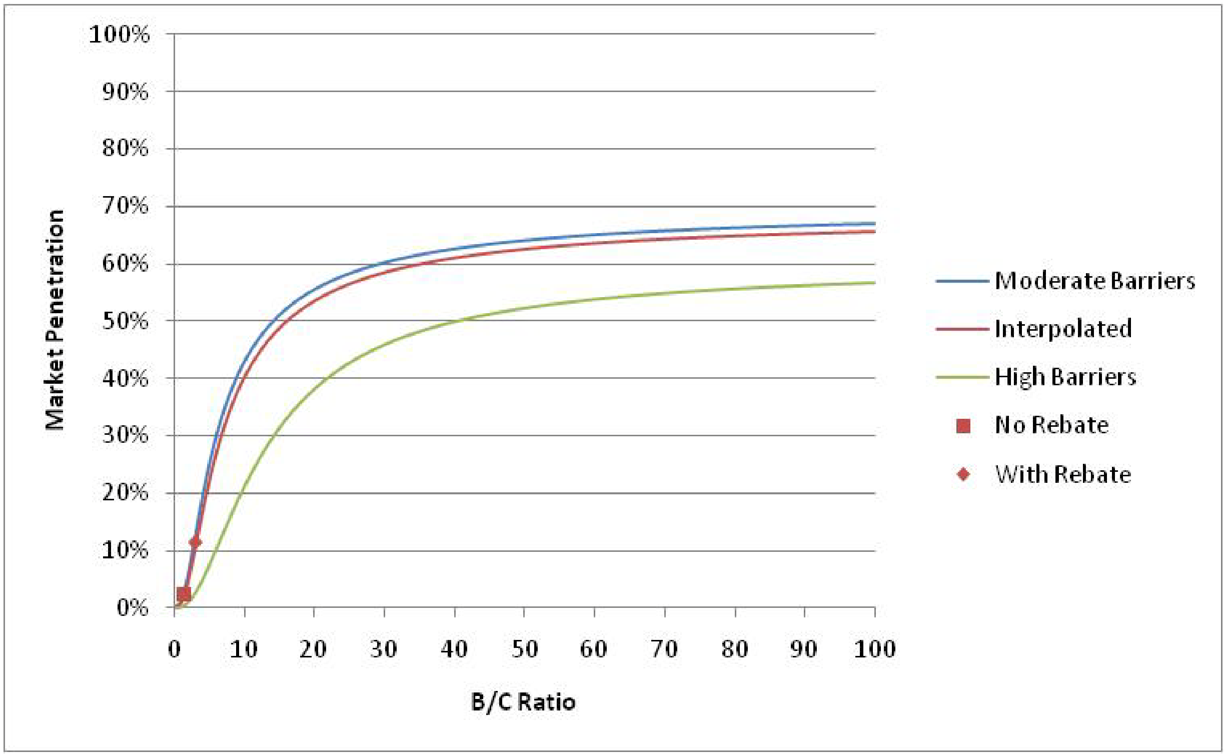


Figure 17.2 Market Penetration Curve for Product Class B, 2.5 W

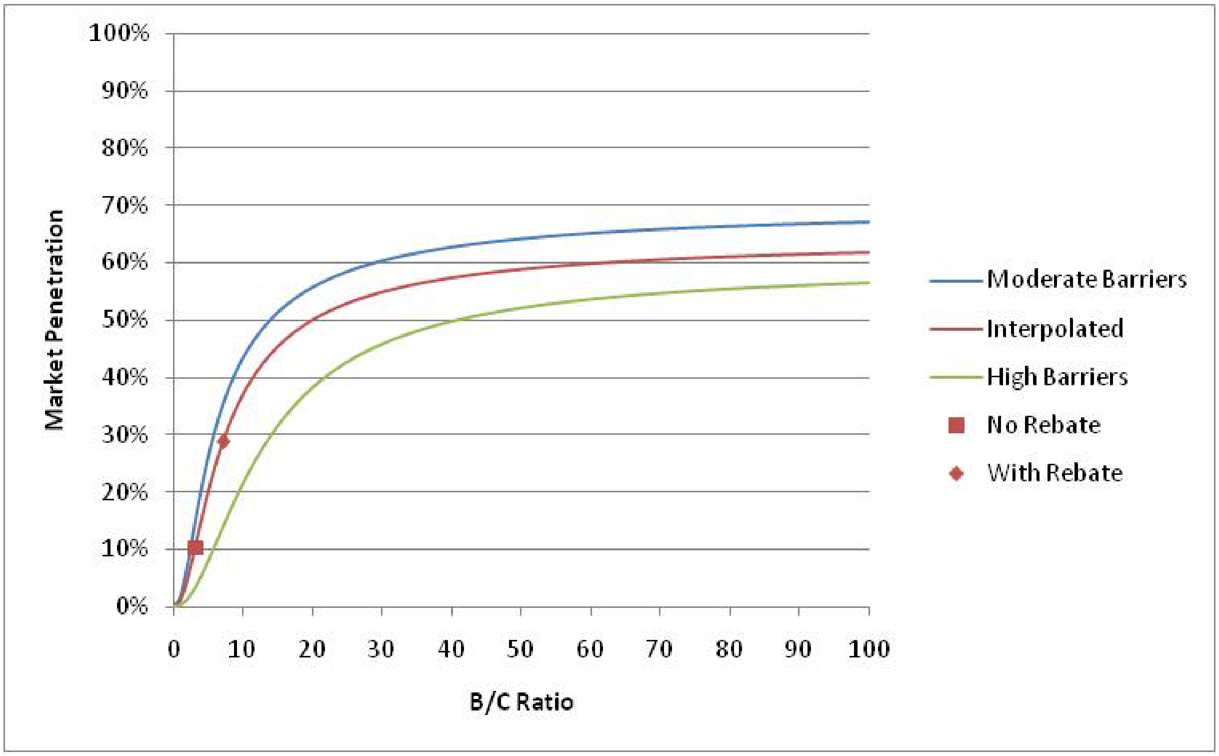


Figure 17.3 Market Penetration Curve for Product Class B, 18 W

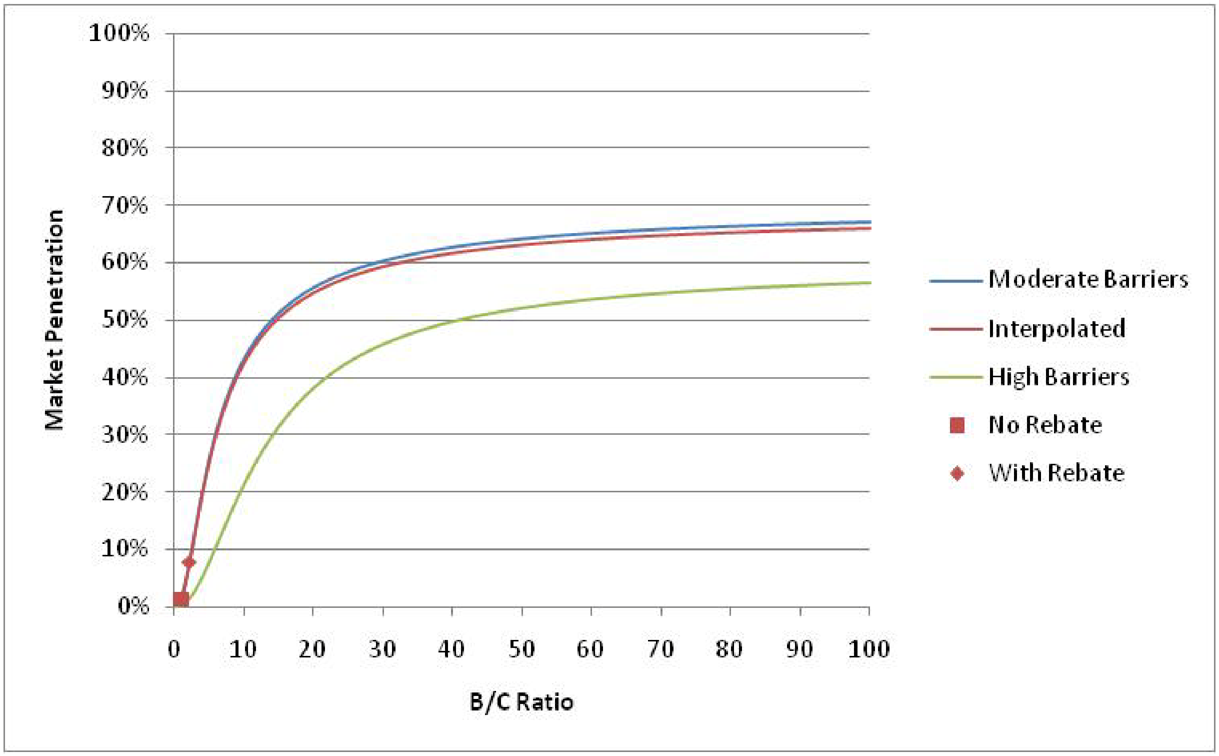


Figure 17.4 Market Penetration Curve for Product Class B, 60 W

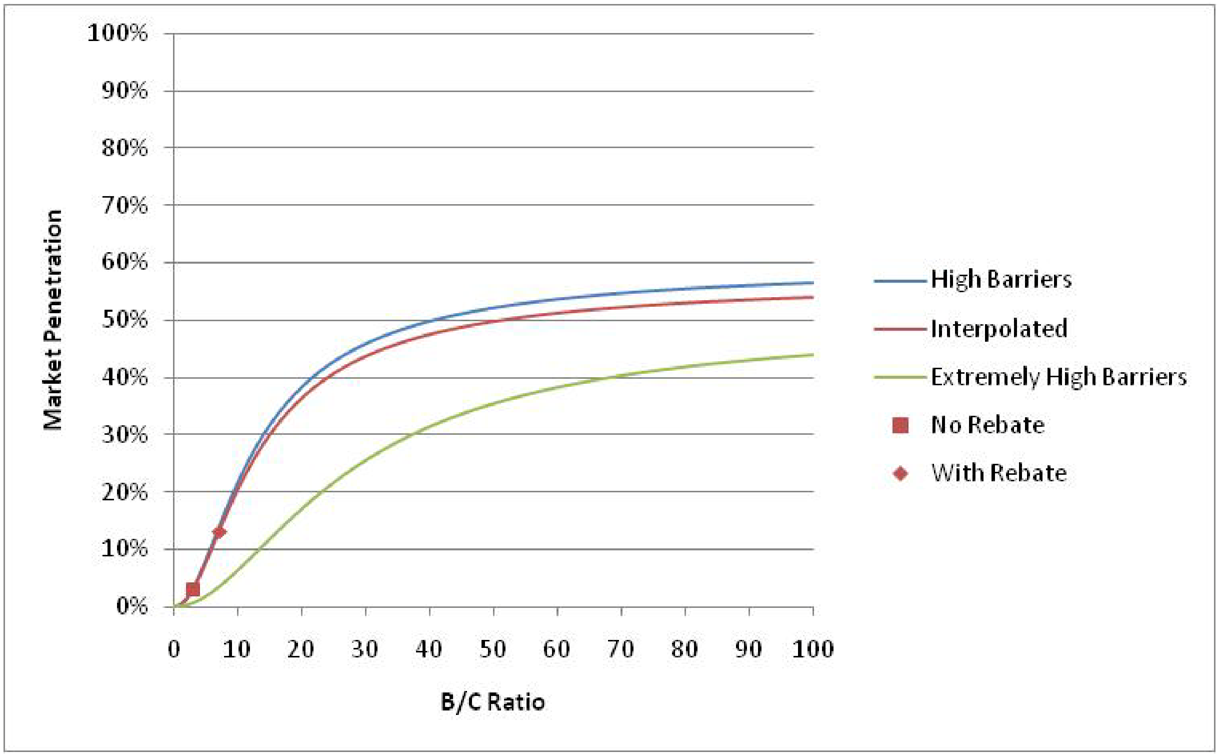


Figure 17.5 Market Penetration Curve for Product Class B, 120 W

DOE then estimated the percent increase in market penetration that would result from consumer rebates. DOE assumes that this is a one-time increase that would occur at the beginning of the analysis period (2013) and that the market efficiency distribution then would remain constant through the end of the analysis period (2042). Table 17.5 displays the 2013 base case and consumer rebate case efficiency distributions for the four segments of product class B. The target level is highlighted in yellow.

Table 17.5 EPS Product Class B Market Efficiency Distributions under the Consumer Rebate Scenario

Segment	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
2.5W Segment	No Regulatory Action	42	49	6	2	0
	Consumer Rebates	33	49	6	11	0
18W Segment	No Regulatory Action	19	52	18	10	0
	Consumer Rebates	1	52	18	29	0
60W Segment	No Regulatory Action	19	63	17	1	0
	Consumer Rebates	12	63	17	8	0
120W Segment	No Regulatory Action	26	53	18	3	0
	Consumer Rebates	16	53	18	13	0

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level for which a rebate would be offered.

External Power Supplies, Product Classes C, D, E, and X

As with EPSs in product class B, DOE assumed that consumer rebates for EPSs in product classes C, D, E, and X would offset 55.9% of the incremental costs of efficient EPSs. DOE also assumed that rebates would take effect at the beginning of the analysis period (2013) and remain unchanged through the end of the analysis period (2042), and that the resulting shift in market efficiency distributions would remain constant throughout this period.

As was discussed previously, the cost of EPSs in product class H at the proposed standard level was found to be less than the cost of baseline units (i.e., the incremental cost was found to be negative). As explained in section 17.3.2.1, DOE concluded that consumer rebates, consumer tax credits, and manufacturer tax credits would not be appropriate policy options for these product classes.

For EPSs in product classes C, D, E, and X, DOE first calculated B/C ratios without a rebate by dividing the lifetime operating cost savings by the incremental costs of a product at the proposed standard level. Using this B/C ratio and the no-standards case market penetration, along with the interpolated penetration curve methodology outlined in Appendix 17-A, DOE was able to derive the appropriate penetration curve for each product class. It then reduced the incremental cost for products meeting the target levels by 55.9% to account for consumer rebates and recalculated the B/C ratios. Table 17.6 displays this information for product classes C, D, E, and X.

Table 17.6 Benefits and Costs for EPSs in Product Classes C, D, E, and X, With and Without Consumer Rebates

	Product Class C	Product Class D	Product Class E	Product Class X
Operating Cost Savings	\$0.86	\$2.84	\$0.86	\$45.02
Incremental Cost	\$0.65	\$0.90	\$0.65	\$4.12
B/C Ratio Without Rebate	1.3	3.2	1.3	10.9
Calculated Market Barrier Curve	Moderate – High	High	Moderate	Extremely High
Rebate Amount	\$0.36	\$0.50	\$0.36	\$2.31
Incremental Cost with Rebate	\$0.29	\$0.40	\$0.29	\$1.82
B/C Ratio With Rebate	3.01	7.18	3.01	24.78

Based on the B/C ratios and market efficiency distributions for these product classes absent a rebate program, DOE found that EPSs in product class C faced moderate to high barriers, EPSs in product class D fell almost exactly on the high barriers curve, and those in product class E fell almost exactly on the moderate barriers curve.[b] Absent an incentive program or standards, no units in product class X were found at CSL 3 (the efficiency level at which DOE is proposing standards), so DOE assumed there to be extremely high barriers preventing sales at this level, and thus used the extremely high barriers curve to estimate the impacts of a consumer rebate program. The estimated increases in the market penetration of efficient EPSs in product classes C, D, E, and X that would result from consumer rebates are graphically displayed in Figure 17.6 through Figure 17.9.

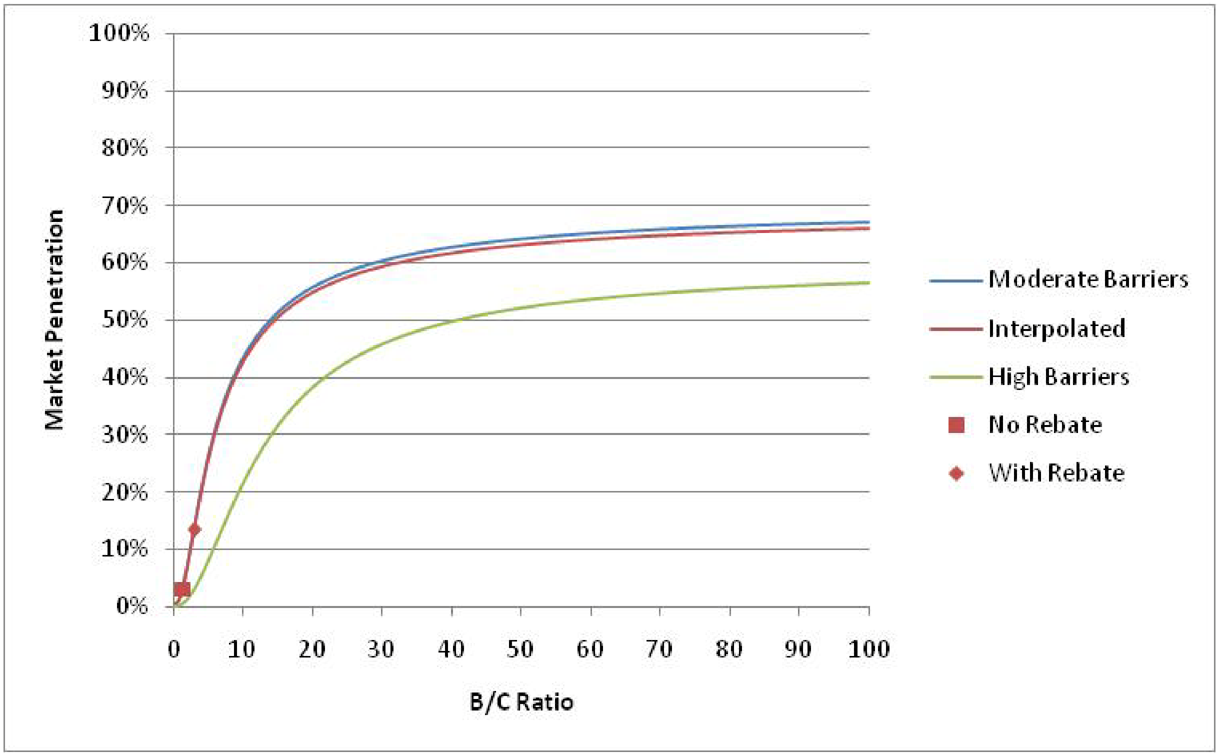


Figure 17.6 Market Penetration Curve for Product Class C

---

[b] Since product classes D and E fall almost exactly on the high and moderate barriers curves, respectively, DOE estimated the changes in market penetration based on these market barrier curves. Thus, interpolated market penetration curves are not displayed for these product classes.

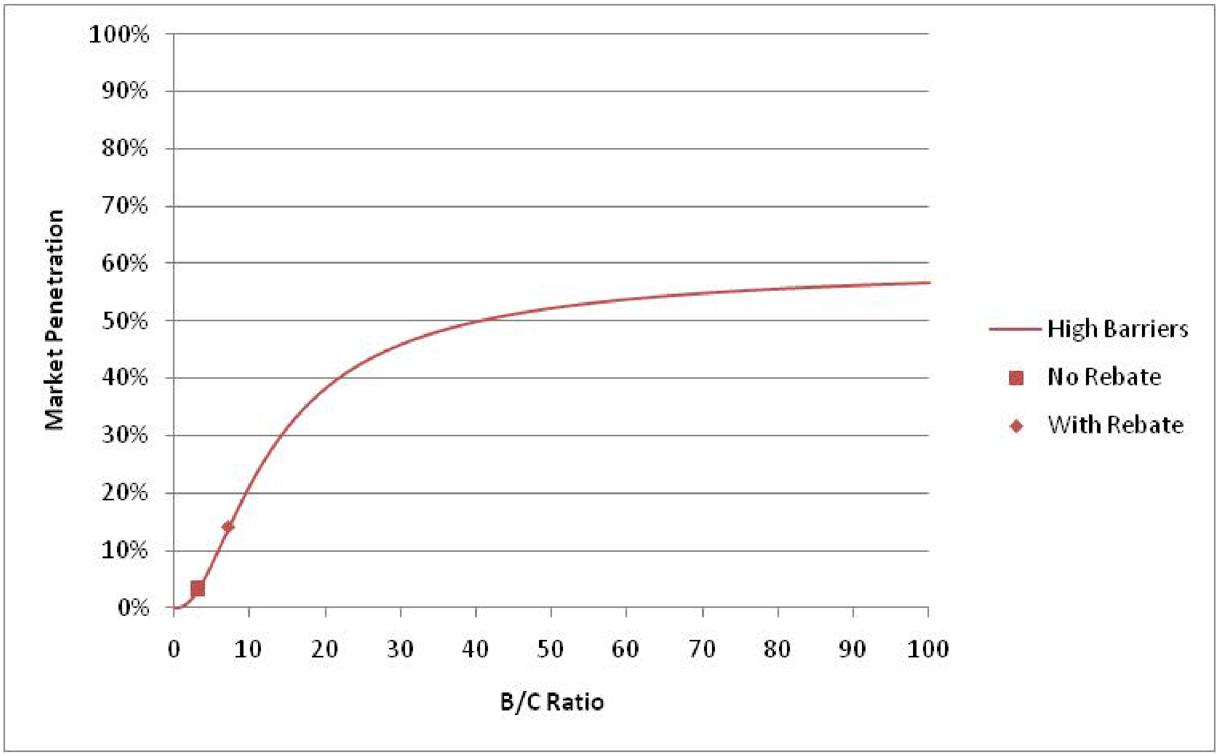


Figure 17.7 Market Penetration Curve for Product Class D

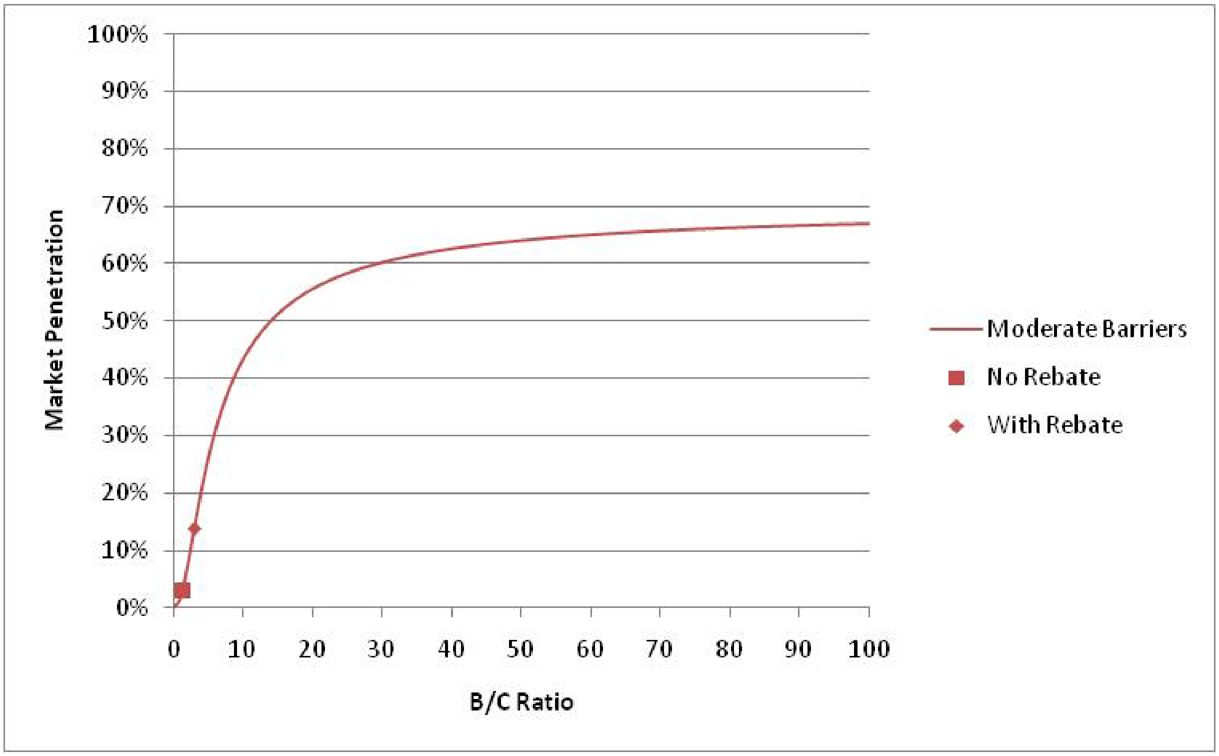


Figure 17.8 Market Penetration Curve for Product Class E

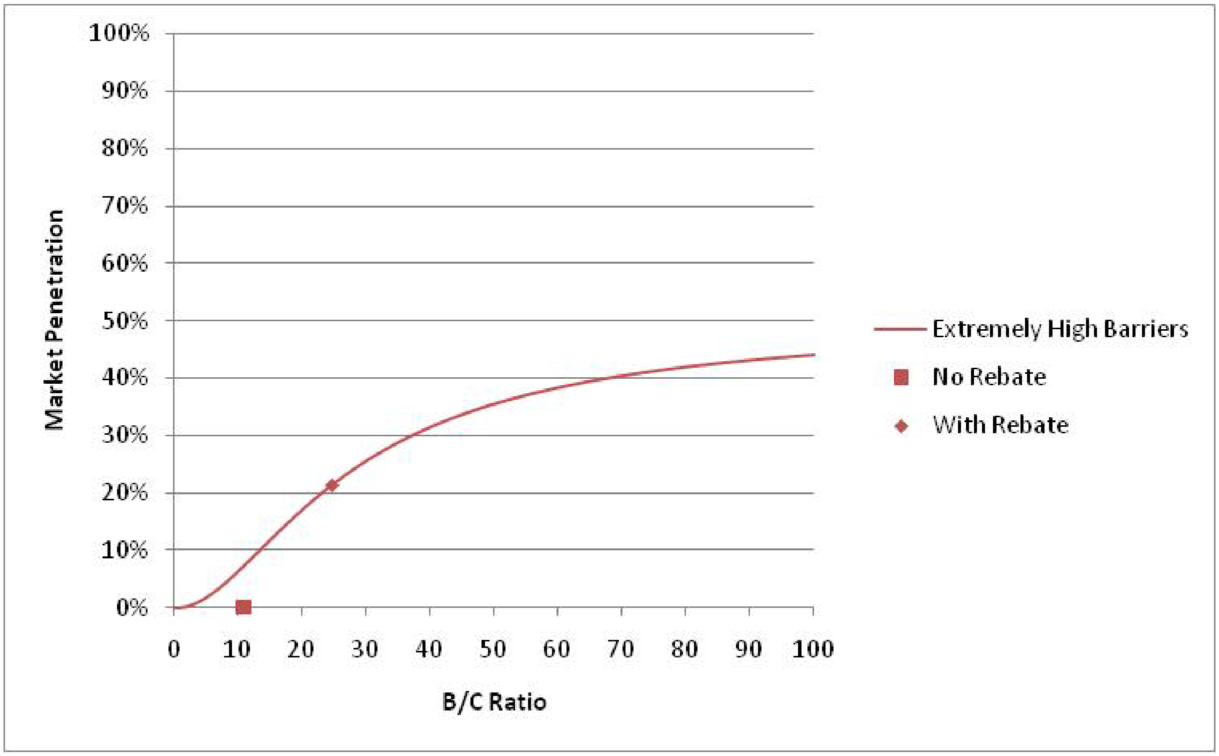


Figure 17.9 Market Penetration Curve for Product Class X

DOE then estimated the percent increase in market penetration that would result from consumer rebates based on these market penetration curves. Table 17.7 displays the 2013 base case and consumer rebate case market efficiency distributions for product classes C, D, E, and X. The efficiency level that would be rebated is highlighted in yellow.

Table 17.7 EPS Product Class C, D, E, and X Efficiency Distributions under the Consumer Rebate Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
C	No Regulatory Action	42	53	2	3	0
	Consumer Rebates	32	53	2	14	0
D	No Regulatory Action	24	55	17	4	0
	Consumer Rebates	14	55	17	14	0
E	No Regulatory Action	30	53	13	4	0
	Consumer Rebates	21	53	13	14	0
X	No Regulatory Action	5	95	0	0	-
	Consumer Rebates	0	79	21	0	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level for which a rebate would be offered.

17.3.2.3 Consumer Rebates for Battery Chargers

As with consumer rebates for EPSs, DOE assumed that consumer rebates for BCs would cover 55.9% of the incremental cost. DOE also assumed that rebates would take effect at the beginning of the analysis period (2013) and last through the end of the analysis period (2042), and that the resulting shift in market efficiency distributions would remain constant throughout this period.

As was discussed previously, the cost of BCs in product classes 5, 6, 7, and 8 at the proposed standard level was found to be less than the cost of baseline units (i.e., the incremental cost was found to be negative). As explained in section 17.3.2.1, DOE concluded that consumer rebates, consumer tax credits, and manufacturer tax credits would not be appropriate policy options for these product classes.

For BCs in product classes 1, 2, 3, 4, and 10, DOE first calculated B/C ratios without a rebate by dividing the lifetime operating cost savings by the incremental cost of a product at the proposed standard level. Using this B/C ratio and the no-standards case market penetration, along with the interpolated penetration curve methodology outlined in Appendix 17-A, DOE was able to identify the appropriate penetration curve for each product class. It then reduced the incremental cost for a product meeting the proposed standard level by 55.9% to account for consumer rebates and recalculated the B/C ratios. Table 17.6 displays this information for product classes 1, 2, 3, 4, and 10.

Table 17.8 Benefits and Costs for BCs, With and Without Consumer Rebates

	Product Class 1	**Product Class 2**	**Product Class 3**	**Product Class 4**	**Product Class 10**
Operating Cost Savings	$2.81	$0.76	$3.58	$10.30	$12.26
Incremental Cost	$0.99	$0.14	$1.73	$4.20	$2.71
B/C Ratio Without Rebate	2.9	5.6	2.1	2.5	4.5
Calculated Market Barrier Curve	Moderate – High	Moderate – High	No – Low	Low – Moderate	Moderate – High
Rebate Amount	$0.55	$0.08	$0.97	$2.35	$1.52
Incremental Cost with Rebate	$0.43	$0.06	$0.76	$1.85	$1.52
B/C Ratio With Rebate	6.5	12.7	4.7	5.6	8.1

Based on the B/C ratios and market efficiency distributions for these product classes absent a rebate program, DOE found that BCs in product classes 1, 2, and 10 faced moderate to high barriers, BCs in product class 3 faced no to low barriers, and BCs in product class 4 faced low to moderate barriers. The estimated increases in the market penetration of efficient BCs in product classes 1, 2, 3, 4, and 10 that would result from consumer rebates are graphically displayed in Figure 17.10 through Figure 17.14.

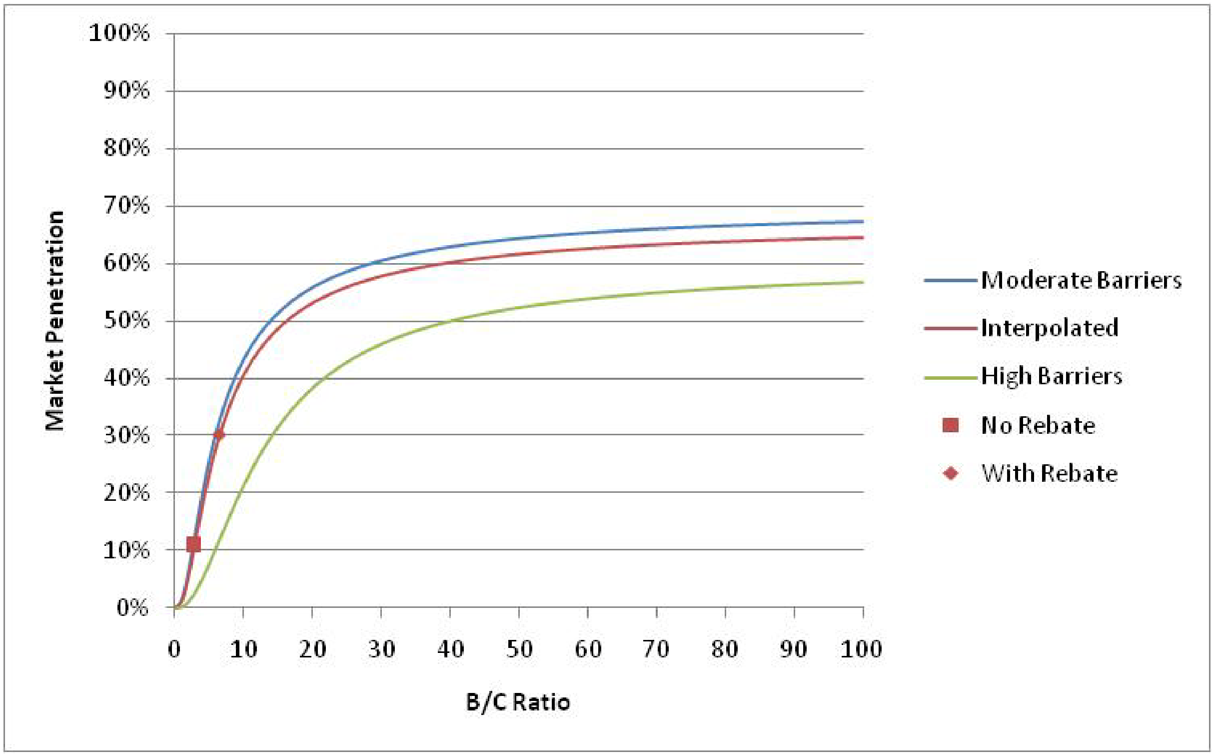


Figure 17.10 Market Penetration Curve for Product Class 1

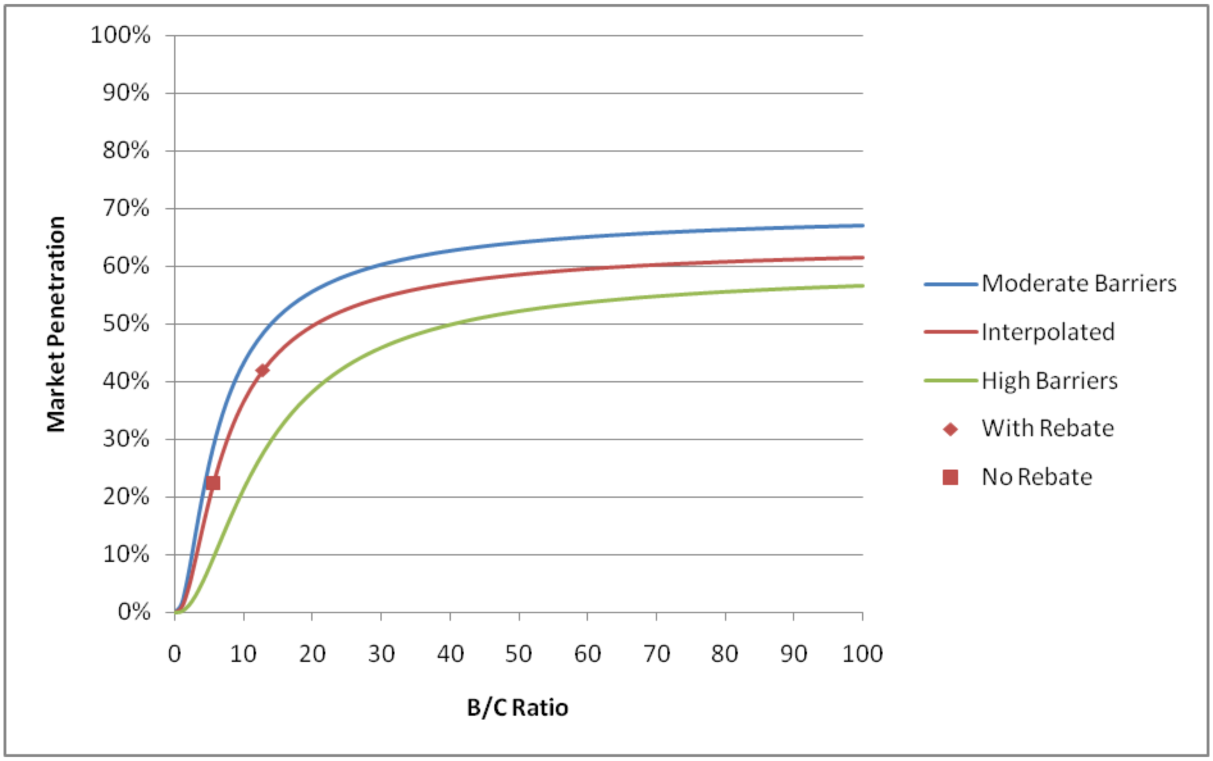


Figure 17.11 Market Penetration Curve for Product Class 2

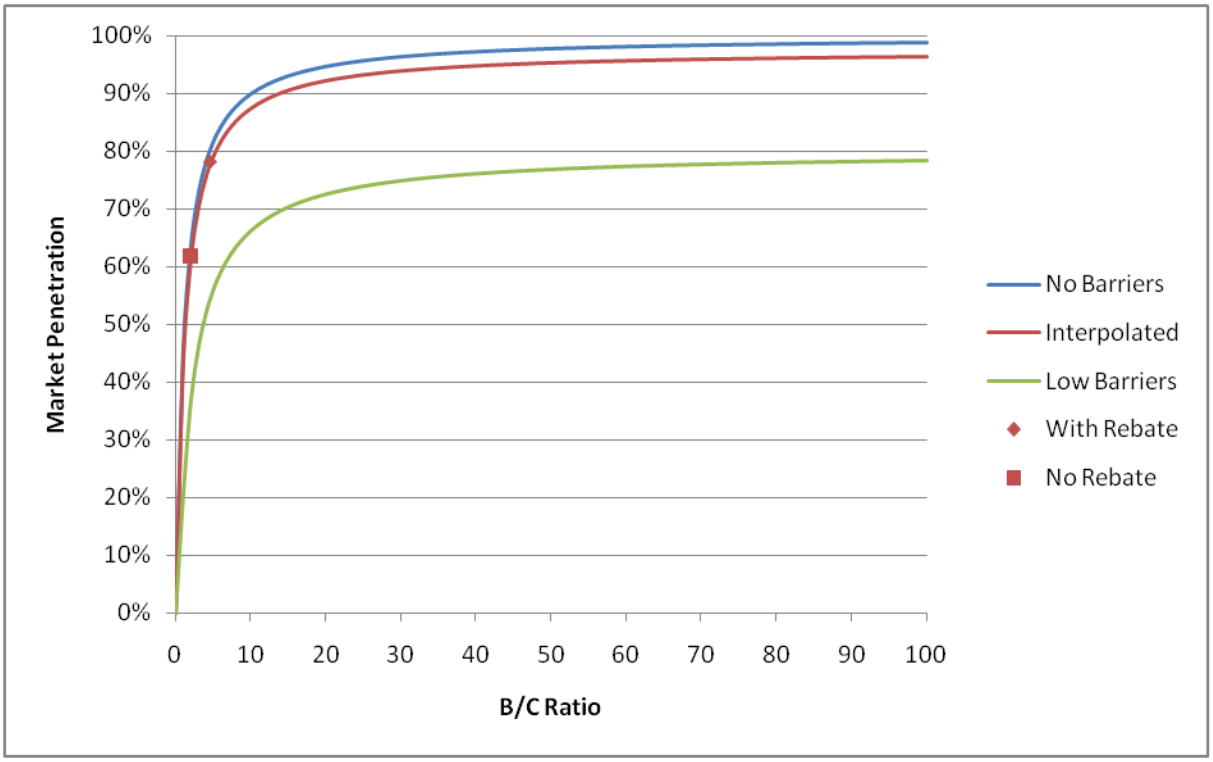


Figure 17.12 Market Penetration Curve for Product Class 3

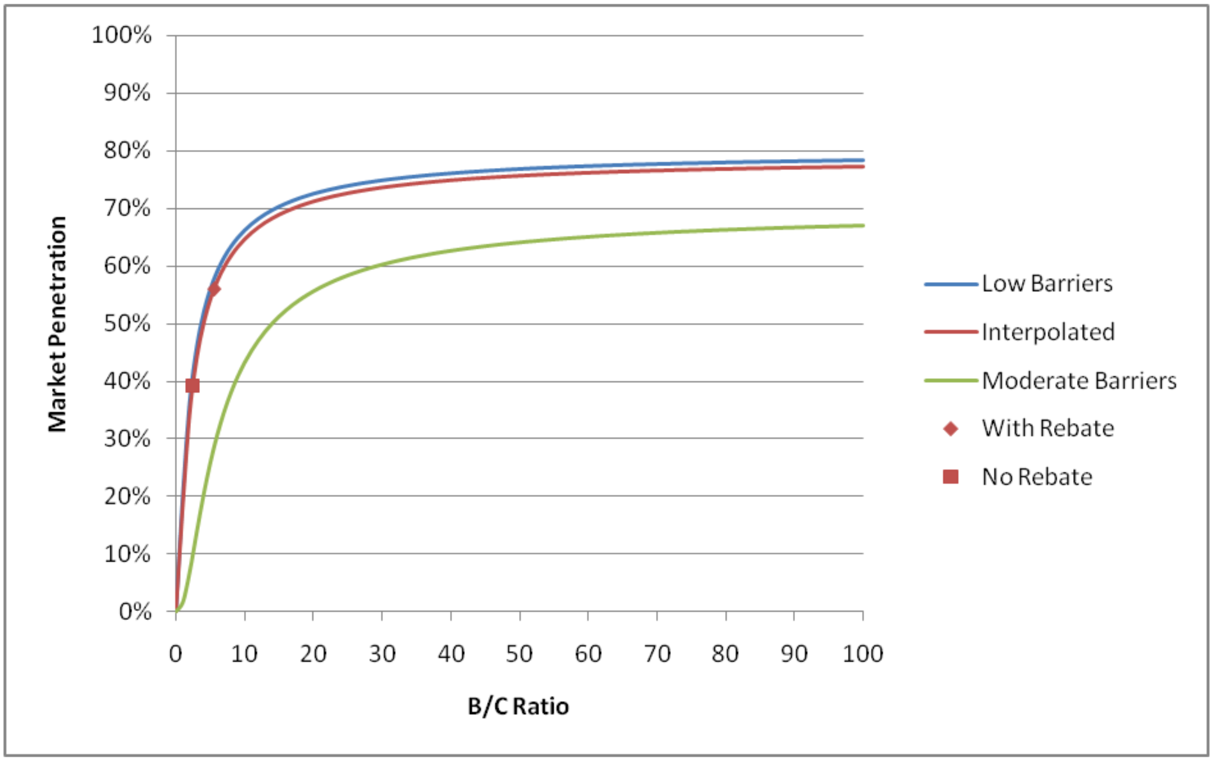


Figure 17.13 Market Penetration Curve for Product Class 4

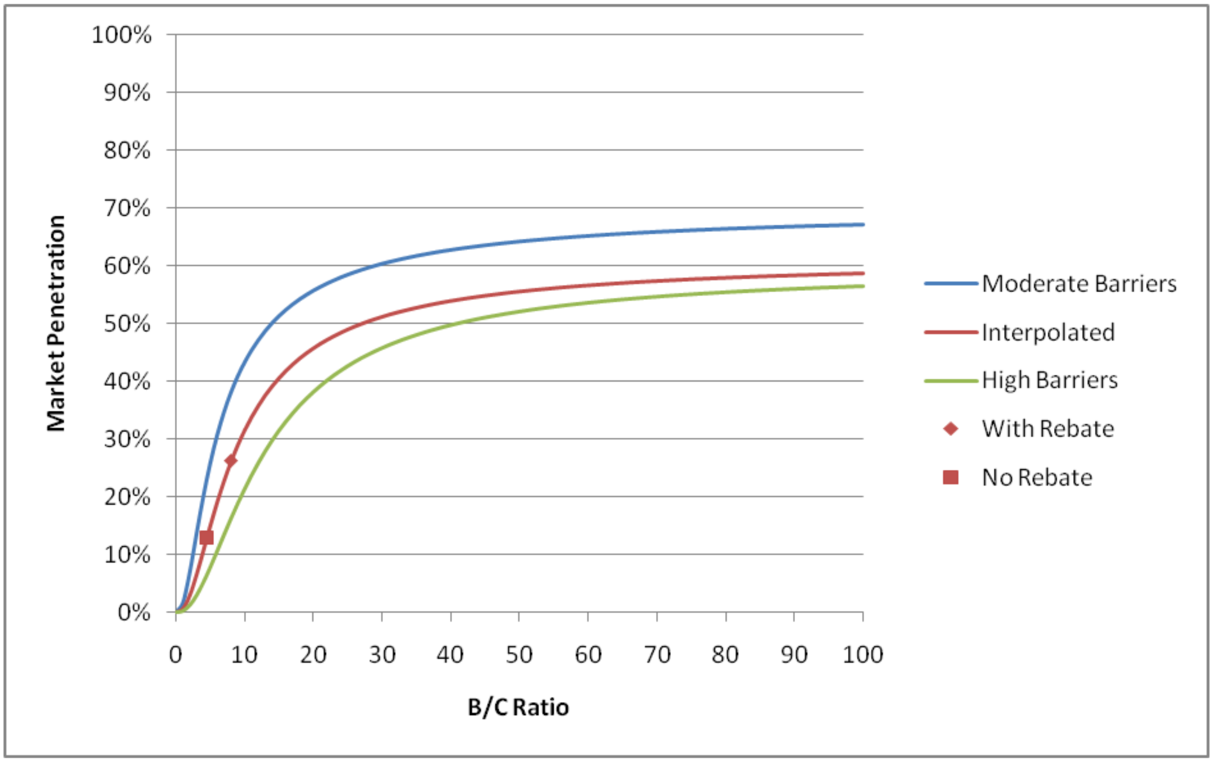


Figure 17.14 Market Penetration Curve for Product Class 10

Based on these interpolated curves, DOE estimated the percent increase in market penetration that would result from consumer rebates. Table 17.9 displays the 2013 base case and consumer rebate case market efficiency distributions for product classes 1, 2, 3, 4, and 10. The efficiency level that would be rebated is highlighted in yellow.

Table 17.9 BC Product Class 1, 2, 3, 4, and 10 Efficiency Distributions under the Consumer Rebate Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
1	No Regulatory Action	78	11	11	0	-
	Consumer Rebates	59	11	30	0	-
2	No Regulatory Action	17	22	57	3	0
	Consumer Rebates	0	40	57	3	0
3	No Regulatory Action	17	62	21	0	-
	Consumer Rebates	1	78	21	0	-
4	No Regulatory Action	13	41	46	0	-
	Consumer Rebates	0	48	52	0	-
10	No Regulatory Action	87	0	0	13	-
	Consumer Rebates	74	0	0	26	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level for which a rebate would be offered.

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its analyses of consumer participation in tax credits for previous rulemakings. DOE incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[7] The announcement effect derives from the credibility that an efficient technology receives from being included in an incentive program, as well as the additional marketing attention that it receives as part of an incentive program. DOE assumed that the consumer rebate and consumer tax credit policies would have both direct price effects and announcement effects, and that half the increase in market penetration resulting from either policy would be due to the direct price effect and the other half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credits for each product class would be the same as the corresponding rebate amounts discussed in section 17.3.2, i.e., 55.9% of the incremental cost.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on RIAs for previous rulemakings, DOE assumed that only 60 percent as many consumers would take advantage of a tax credit as would take advantage of a rebate.[8]

In preparing its assumptions, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

In a previous analysis performed for commercial clothes washers, DOE analyzed data from the Oregon Department of Energy on the number of tax credits claimed by Oregon taxpayers for efficient appliances.[9] In this analysis, DOE estimated that consumer tax credits were approximately 63 percent as effective as consumer rebates in encouraging consumers to purchase efficient clothes washers. This supports DOE's assumption that 60 percent of the number of consumers who would have purchased efficient BCs and EPSs due to consumer rebates would do so as a result of consumer tax credits.

The Energy Policy Act of 2005 (EPACT 2005) provided for Federal tax credits for consumers who purchase energy-efficient equipment, including water heaters, furnaces, and furnaces fans for new or existing homes.[10] Those tax credits were in effect in 2006 and 2007 and expired in 2008. They have since been reinstated for 2009-2011 by the American Recovery and Reinvestment Act of 2009 (ARRA)[11] and by the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010.[12] DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed these tax credits during tax years 2006 through 2008.[13] More recent data were not available from the IRS. DOE also reviewed data from state tax credit programs in Oregon, Hawaii, and elsewhere; however, DOE did not find data specific enough to BCs, EPSs, or similar products to warrant adjusting its analytical method for the

Consumer Tax Credits policy case. Appendix 17-A contains more information on Federal consumer tax credits.

In summary, DOE was not able to identify data on Federal or state consumer tax credits for BCs, EPSs, or similar products to directly use in estimating the impacts of consumer tax credits. As mentioned above, however, DOE used its previous analysis for refrigerators as well as a more recent analysis of Oregon data for residential clothes washers as support for its assumption that tax credits induce the participation of 60 percent as many consumers as do rebates. DOE used that percentage in its analysis of consumer tax credits for all BCs and EPSs.

DOE applied the assumed 60 percent participation described above to the penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the penetration curves selected for each product class. As with consumer rebates, DOE assumed that a consumer tax credit program would take effect at the beginning of the analysis period (2013) and its effects on BC and EPS market efficiency distributions would remain constant through the end of the analysis period (2042).

Table 17.10 through Table 17.12 contain DOE's assumed market efficiency distributions absent an incentive program as well as the market efficiency distributions that could be expected in the presence of a consumer tax credit program.

Table 17.10 EPS Product Class B Efficiency Distributions under the Consumer Tax Credit Scenario

Segment	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
2.5W Segment	No Regulatory Action	42	49	6	2	0
	Consumer Tax Credits	37	49	6	8	0
18W Segment	No Regulatory Action	19	52	18	10	0
	Consumer Tax Credits	8	52	18	21	0
60W Segment	No Regulatory Action	19	63	17	1	0
	Consumer Tax Credits	15	63	17	5	0
120W Segment	No Regulatory Action	26	53	18	3	0
	Consumer Tax Credits	20	53	18	9	0

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a consumer tax credit.

Table 17.11 EPS Product Class C, D, E, and X Efficiency Distributions under the Consumer Tax Credit Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
C	No Regulatory Action	42	53	2	3	0
	Consumer Tax Credits	36	53	2	9	0
D	No Regulatory Action	24	55	17	4	0
	Consumer Tax Credits	18	55	17	10	0
E	No Regulatory Action	30	53	13	4	0
	Consumer Tax Credits	25	53	13	10	0
X	No Regulatory Action	5	95	0	0	-
	Consumer Tax Credits	0	87	13	0	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a consumer tax credit.

Table 17.12 BC Product Class 1, 2, 3, 4, and 10 Efficiency Distributions under the Consumer Tax Credit Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
1	No Regulatory Action	78	11	11	0	-
	Consumer Tax Credits	66	11	23	0	-
2	No Regulatory Action	18	22	57	3	0
	Consumer Tax Credits	7	33	57	3	0
3	No Regulatory Action	17	62	21	0	-
	Consumer Tax Credits	7	72	21	0	-
4	No Regulatory Action	9	39	52	0	-
	Consumer Tax Credits	4	45	52	0	-
10	No Regulatory Action	87	0	0	13	-
	Consumer Tax Credits	79	0	0	21	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a consumer tax credit.

17.3.4 Manufacturer Tax Credits

The manufacturer tax credit scenario is a hypothetical policy in which tax credits are offered to manufacturers that produce BCs and EPSs that meet (or exceed) the target efficiency levels. DOE assumed that a manufacturer tax credit would lower the products' production costs an amount equivalent to that provided by the consumer rebates described in section 17.3.2. DOE further assumed that these cost reductions would be passed through the distribution channels to the consumers, causing a direct price effect. In other words, the manufacturer tax credit would ultimately offset 55.9 percent of the incremental cost to consumers for BCs and EPSs at the target efficiency levels.

DOE assumed that no announcement effect would occur, because most consumers would not be aware of the program.[c] Since the direct price effect is approximately equivalent in size to the announcement effect, DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. This assumed participation rate is therefore equal to 50 percent of the number of consumers who would participate under a consumer tax credit program, or 30 percent of the number of consumers who would participate in a rebate program.

DOE applied the assumption of 30 percent participation to the penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. As in consumer rebates, DOE assumed that these shifts to the market efficiency distributions would take effect in 2013 and remain constant through 2042. Table 17.13 through Table 17.15 display the market distributions absent tax credits as well as the shifted market efficiency distributions that would result from manufacturer tax credits.

Table 17.13 EPS Product Class B Efficiency Distributions under the Manufacturer Tax Credit Scenario

Segment	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
2.5W Segment	No Regulatory Action	42	49	6	2	0
	Manufacturer Tax Credits	40	49	6	5	0
18W Segment	No Regulatory Action	19	52	18	10	0
	Manufacturer Tax Credits	14	52	18	16	0
60W Segment	No Regulatory Action	19	63	17	1	0
	Manufacturer Tax Credits	17	63	17	3	0
120W Segment	No Regulatory Action	26	53	18	3	0
	Manufacturer Tax Credits	23	53	18	6	0

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a manufacturer tax credit.

---

[c] DOE recognizes that this is a conservative assumption, since it is possible that manufacturers or efficiency programs could promote the efficient models covered by the program, which could in turn induce an announcement effect. However, DOE did not find data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

Table 17.14 EPS Product Class C, D, E, and X Efficiency Distributions under the Manufacturer Tax Credit Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
C	No Regulatory Action	42	53	2	3	0
	Manufacturer Tax Credits	39	53	2	6	0
D	No Regulatory Action	24	55	17	4	0
	Manufacturer Tax Credits	21	55	17	7	0
E	No Regulatory Action	30	53	13	4	0
	Manufacturer Tax Credits	27	53	13	7	0
X	No Regulatory Action	5	95	0	0	-
	Manufacturer Tax Credits	0	94	6	0	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a manufacturer tax credit.

Table 17.15 BC Product Class 1, 2, 3, 4, and 10 Efficiency Distributions under the Manufacturer Tax Credit Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
1	No Regulatory Action	78	11	11	0	-
	Manufacturer Tax Credits	72	11	17	0	-
2	No Regulatory Action	18	22	57	3	0
	Manufacturer Tax Credits	13	28	57	3	0
3	No Regulatory Action	17	62	21	0	-
	Manufacturer Tax Credits	12	67	21	0	-
4	No Regulatory Action	9	39	52	0	-
	Manufacturer Tax Credits	6	42	52	0	-
10	No Regulatory Action	87	0	0	13	-
	Manufacturer Tax Credits	83	0	0	17	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which a product would qualify for a manufacturer tax credit.

17.3.5 Voluntary Energy Efficiency Targets

For each product, DOE assumed that voluntary energy efficiency targets would be achieved as manufacturers gradually stopped producing units that operated below the target efficiency levels. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program similar to the ENERGY STAR labeling program jointly administered by the U.S. Environmental Protection Agency (EPA) and DOE. The ENERGY STAR program provides a label to products that meet minimum specified energy efficiency criteria. The presence of this label signals to consumers that the product is efficient, leading to a shift in demand toward the more efficient products and, as a result, a shift in the market efficiency distribution toward the target efficiency level.

17.3.5.1 Voluntary Efficiency Targets for External Power Supplies

The ENERGY STAR program for EPSs ran from January 1, 2005 through December 31, 2010. On July 19, 2010, EPA announced that the ENERGY STAR program for EPSs was to sunset on December 31, 2010. Thus, there is no current ENERGY STAR program for EPSs. To justify this decision, EPA cited relatively high ENERGY STAR market penetration, the existence of Federal efficiency standards for EPSs, as well as overlap between the EPS program and the programs for a number of products that use EPSs, such as imaging equipment, cordless phones, and notebook computers.[14]

Given the reasons cited in EPA's sunset decision for EPSs, DOE concluded that a separate voluntary efficiency program or labeling program for EPSs would be duplicative and its market effects would likely be minimal. Thus, DOE does not believe that a national voluntary efficiency program would be a viable alternative to Federal efficiency standards for EPSs, and did not quantify this policy option.

17.3.5.2 Voluntary Efficiency Targets for Battery Chargers

The ENERGY STAR criteria for BCs took effect on January 1, 2006 and are still in place. The scope of covered products includes universal BCs; BCs packaged with rechargeable products whose intended functions are mechanical motion, light, movement of air, or production of heat; and stand-alone BCs packaged with products that contain detachable batteries.[15] To model the effects of a voluntary energy efficiency policy for BCs, DOE assumed that such a program would be an expansion of the current ENERGY STAR program for BCs.

EPA developed projections for 2006-2025 of the increased market penetration of efficient BCs attributable to the ENERGY STAR program. These estimates are based on a variety of factors, including manufacturers' shipment data. EPA further revised these market share projections by estimating the portion of market share that cannot be directly attributed to the presence of the ENERGY STAR criteria, i.e., free-ridership.[d] The model then subtracts this estimate of free ridership from the market share that meets the ENERGY STAR criteria, yielding the share of efficient product sales that can be directly attributed to the ENEGY STAR program.

DOE focused on ENERGY STAR market share in 2007 and 2008, since these are the years for which EPA's model is based on actual market data, rather than projections. On average, during this period, the attributable market share was found to be 15.4 percent. DOE assumed that an expanded ENERGY STAR program would increase the annual market share of efficient units by 50 percent of the market share currently attributed to the program, or 7.7 percent. This expansion encompasses increases in the scope of covered products as well as increases in shipments of currently covered products. DOE's base case market efficiency distributions already account for the effects of the current ENERGY STAR market share for BCs, so DOE shifted 7.7 percent of inefficient BCs to the target efficiency level to account for the increase due

---

[d] It is assumed that some portion of the market at or above the ENERGY STAR criteria level would still be at those efficiency levels had there not been an ENERGY STAR program. The model attempts to estimate this free ridership and subtract it from the total market share to yield a market-share-less-free-ridership estimate. This latter estimate is the market share that can be directly attributed to the ENERGY STAR program.

to an expanded voluntary efficiency program. Table 17.16 displays the base-case and revised market efficiency distributions that were used as inputs to the NIA-RIA model.

Table 17.16 Battery Charger Efficiency Distributions under the Voluntary Efficiency Targets Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
1	No Regulatory Action	78	11	11	0	-
	Voluntary Efficiency Targets	70	11	19	0	-
2	No Regulatory Action	18	22	57	3	0
	Voluntary Efficiency Targets	10	30	57	3	0
3	No Regulatory Action	17	62	21	0	-
	Voluntary Efficiency Targets	9	69	21	0	-
4	No Regulatory Action	9	39	52	0	-
	Voluntary Efficiency Targets	2	47	52	0	-
5	No Regulatory Action	28	52	7	13	-
	Voluntary Efficiency Targets	20	52	15	13	-
6	No Regulatory Action	36	29	22	13	-
	Voluntary Efficiency Targets	28	29	30	13	-
7	No Regulatory Action	44	57	0	-	-
	Voluntary Efficiency Targets	36	64	0	-	-
8	No Regulatory Action	50	40	10	0	-
	Voluntary Efficiency Targets	42	48	10	0	-
10	No Regulatory Action	87	0	0	13	-
	Voluntary Efficiency Targets	79	0	0	21	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the voluntary efficiency target.

17.3.5.3 Early Replacement

The non-regulatory policy of early replacement refers to a program that encourages the replacement of outdated, inefficient BCs and EPSs with newer, more efficient models. These outdated models would be retired before the end of their useful lives to allow consumers to reap the benefits of improved efficiency sooner. Typically such programs require consumers to turn in and/or recycle the retired product to prevent it from being sold or given to another consumer. The economic feasibility of an early replacement program depends on the vintage of the products being replaced, the installed costs of the new products, and the potential energy cost savings that could be achieved by using newer products. After reviewing a number of reports on the feasibility of early replacement programs, as well as evaluation reports from past programs, DOE concluded that an early replacement program for BCs or EPSs would not be a viable alternative to standards.

Traditional early replacement programs have been for major appliances, such as refrigerators, freezers, and room air conditioners.[16, 17, 18] These programs encourage consumers to turn in outdated and inefficient, yet still functioning, appliances in return for a rebate that can be applied towards the purchase of a newer, more efficient appliance. The turn-in component is critical, as it keeps old, inefficient models from entering the resale market and continuing to consume power. Old appliances are then typically recycled to salvage reusable materials and properly dispose of hazardous materials.

If, for example, a 10-year-old appliance has another 10 years of useful life and consumes 100 kWh/yr more electricity than a newer, more efficient model, replacing it with a newer model would save $100 over the next ten years (assuming a $0.10/kWh electricity rate). This energy savings could be enough to justify purchasing a new unit earlier if the cost of the new model were low enough or offset by a utility rebate.

Early replacement programs are typically most successful with products that have longer lifetimes, such as air conditioners, refrigerators, and other major appliances. Longer lifetimes mean that there is typically a larger differential between the energy consumption of new and old models, especially for appliances where efficiency degradation is a concern. For example, many consumers continue to use older refrigerators as secondary refrigerators, meaning that a "replaced" refrigerator is not removed from the grid, but rather continues to consume electricity in addition to the newer model that it was replaced by. Similarly, room air conditioners may simply be moved to a different room, rather than removed from the grid entirely. These older appliances can be significantly less efficient than newer models, so much so in some cases that early retirement would result in enough energy cost savings to offset the additional cost incurred by purchasing a newer model sooner than would otherwise occur.

Connecticut's appliance retirement program required that the used appliance be at least 10 years old in order to qualify.[18] Similarly, a study conducted by the Energy Center of Wisconsin found the age at which it would be most cost effective to replace a central air conditioner would be 8-12 years.[19] On its website, NYSERDA recommends that consumers replace appliances every 4-6 years to take advantage of potential energy savings from newer, more efficient models.[20] This is the natural rate of replacement for many BCs and EPSs, since only 3.8 percent of EPSs and 3.4 percent of BCs have expected lifetimes of more than 6 years. The lifetime of a BC or EPS is typically determined by the lifetime of the consumer product it operates. These consumer products tend to be small consumer electronics and other products with short lifetimes. The market for consumer electronics evolves rapidly, so applications tend to be replaced well before the BC or EPS ceases to function, leading to a natural early replacement scenario. This, in essence, creates a natural early replacement program that ensures older, inefficient products are removed from the market. For example, mobile phones (and their respective BCs and EPSs) are typically replaced at the end of the phone's service contract, which is typically two years. Notebook computers are typically replaced every four years. Only a handful of applications, such as transportation and medical equipment, have lifetimes that are at or greater than 10 years.

Based on the research detailed above, DOE believes that an early replacement program would be applicable for products with average lifetimes of approximately 10 years or more. A few BCs and EPSs meet this qualification, including BCs and EPSs for amateur radios, home systems, medical devices, and personal mobility equipment. However, for early replacement to be cost-justified, the new unit would need to be used long enough for consumers to recoup the higher purchase price through reduced energy expenses. Herein lies another challenge. If a BC or

EPS with a ten-year lifetime were to be replaced after six to seven years, the new model would only have three to four years to recoup the purchase cost before the application that it powers would need to be replaced. Since the majority of BC and EPS applications are sold with the BCs and EPSs needed to power them, replacing the application would once again cause the BC and/or EPS to be replaced. DOE believes that this would render the replacement program redundant.

Due to the relatively short lifetimes of most BCs and EPSs, as well as other difficulties that may arise with replacing many BCs and EPSs before their associated application is replaced, DOE concluded that an early replacement program would be inappropriate for BCs and EPSs. DOE therefore did not quantify the potential savings of such a program.

17.3.6 Bulk Government Purchases

DOE assumed that a policy requiring bulk government purchases would lead to Federal, State, and local governments purchasing products that meet target efficiency levels. Combining the market demands of multiple public sectors could also provide a market signal to manufacturers and vendors that some of their largest customers seek products that meet an efficiency target at favorable prices.

DOE was unable to find data on the number of purchases or degree of compliance for Federal, State, and municipal government purchasing programs. Government procurement is often decentralized, adding to the difficulty of tracking purchases and compliance. DOE based its assumptions regarding the effects of a policy calling for bulk government purchases on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other equipment. Given that FEMP does cover BCs, EPSs, and office equipment that uses BCs and EPSs, DOE determined that a bulk government purchasing program could potentially be a realistic policy option to achieve energy savings. FEMP, however, does not track purchasing, because of the range of complex purchasing systems, large number of vendors, etc.[21]

DOE reviewed previous research on the potential for market transformation through bulk government purchases. One study considered several compliance scenarios based on the assumption that 20 percent of Federal equipment purchases in the year 2000 already incorporated energy efficiency requirements based on FEMP guidelines. In that study, the scenario considered to be most plausible showed energy-efficient Federal purchasing ramping up from 20 percent to 80 percent of all Federal purchases.[22]

DOE assumed that initial government market share at the target efficiency level would be zero. DOE then determined the government share of purchases for each product class and assumed, based on the study referenced in the previous paragraph, that under a bulk government purchasing program 80 percent of the government share of purchases would be at the target efficiency level.

The BCs and EPSs covered by DOE’s proposed energy conservation rulemaking are primarily intended for use in the residential sector. While considered consumer products, many of these applications, such as mobile phones, notebook computers, and power tools, are frequently purchased and used by the commercial sector, including public entities. For others, such as medical equipment, government agencies play a role in product distribution to consumers and may be able to influence the market through the procurement of efficient products.

DOE reviewed each BC and EPS application to determine which were likely to be purchased in bulk by governments at all levels. DOE then estimated the share of annual shipments that are due to or influenced by government purchases. To do so, DOE assigned each application to one of four categories: Office Equipment, Power Tools, Medical Devices, and Transportation Equipment. Examples of office equipment include notebook computers and mobile phones. Examples of transportation equipment include in-vehicle GPSs and golf carts. DOE assumed that BCs and EPSs powering applications that do not fall under these categories would not be affected by a government purchasing program. A full list of identified applications are listed by category, along with affected shipments, in appendix 17-A.

17.3.6.1 Government Market Share – Office Equipment

Data on government purchases of office equipment were not available, so DOE turned to employment data from the U.S. Bureau of Labor Statistics' (BLS) Occupational Employment Statistics (OES) program to estimate the share of the U.S. workforce employed in the public sector.[23] DOE reviewed all labor categories in the OES survey and determined which primarily consisted of workers in office environments (such as management, legal, financial, and administrative positions, among others). DOE then determined that, of the 41.3 million workers in office environments, 3.7 million (8.9 percent) were employed in the public sector. Assuming 80 percent of government purchases would be at the target efficiency level under the bulk government purchasing scenario, the U.S. market share of commercial office equipment at the target efficiency level would increase by 7.1 percent for these applications.

17.3.6.2 Government Market Share – Power Tools

Applications falling under the power tools category include DIY power tools with integral and detachable batteries as well as professional power tools. Data on government purchases of power tools and related products were not available, so DOE once again turned to employment data from the BLS OES survey.[23] DOE assumed that employees in engineering, building and grounds maintenance, construction, and installation/maintenance/repair occupations comprised the bulk of the work force that uses power tools on a regular basis. Through the OES survey, DOE was then able to determine that of the 17.4 million workers in these fields, approximately 1.4 million (8.0 percent) worked in the public sector. Assuming 80 percent of government purchases would be at the target efficiency level under the bulk government purchasing scenario, the U.S. market share of commercial power tools at the target efficiency level would increase by 6.4 percent for these applications.

17.3.6.3 Government Market Share – Medical Devices

Portable medical devices typically must be prescribed by a physician. DOE assumed that a bulk government purchasing program for these products would require that all portable medical devices prescribed by physicians in publicly owned and operated hospitals and medical facilities use BCs and EPSs that meet the target efficiency levels. According to the 2011 Statistical Abstract of the United States, published by the U.S. Census Bureau, 22.7 percent of hospitals in the U.S. are public hospitals.[24] Assuming 80 percent of government purchases would be at the target efficiency level under the bulk government purchasing scenario, DOE assumed that a bulk government purchasing program would increase U.S. market penetration at the target efficiency level by 18.2%.

17.3.6.4 Government Market Share – Transportation

Applications that fall under the transportation category include golf carts, marine/automotive chargers, and in-vehicle GPSs. Since data on government purchasing of these products were not available, DOE used U.S. Census data on motor vehicle registrations to estimate the public sector’s share of vehicle ownership, which was then used to approximate the government’s share of purchasing in this category. DOE found that 1.7 percent of all motor vehicles are publicly owned.[25] Assuming 80 percent of government purchases would be at the target efficiency level under the bulk government purchasing scenario, DOE assumed that a bulk government purchasing program would increase U.S. market penetration at the target efficiency level by 1.4%.

17.3.6.5 Shifts in Efficiency Distributions due to Government Purchasing

After assigning applications to the four government purchasing product classes, DOE used the shipment distributions of each application across product classes to determine how shipments in each product class would be affected. Initial market distributions and market efficiency distributions under a bulk government purchasing program are displayed in Table 17.17 through Table 17.19.

Table 17.17 EPS Product Class B Efficiency Distributions under the Bulk Government Purchasing Scenario

Segment	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
2.5W Segment	No Regulatory Action	42	49	6	2	0
	Bulk Government Purchasing	42	49	6	3	0
18W Segment	No Regulatory Action	19	52	18	10	0
	Bulk Government Purchasing	18	52	18	12	0
60W Segment	No Regulatory Action	19	63	17	1	0
	Bulk Government Purchasing	16	63	17	4	0
120W Segment	No Regulatory Action	26	53	18	3	0
	Bulk Government Purchasing	22	53	18	7	0

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which products would meet government purchasing guidelines.

Table 17.18 EPS Product Class C, D, E, X, and H Efficiency Distributions under the Bulk Government Purchasing Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
C	No Regulatory Action	42	53	2	3	0
	Bulk Government Purchasing	41	53	2	4	0
D	No Regulatory Action	24	55	17	4	0
	Bulk Government Purchasing	24	55	17	4	0
E	No Regulatory Action	30	53	13	4	0
	Bulk Government Purchasing	30	53	13	4	0
X	No Regulatory Action	5	95	0	0	-
	Bulk Government Purchasing	5	95	0	0	-
H	No Regulatory Action	50	50	0	0	0
	Bulk Government Purchasing	50	50	0	0	0

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which products would meet government purchasing guidelines.

Table 17.19 BC Efficiency Distributions under the Bulk Government Purchasing Scenario

Product Class	Scenario	CSL 0 (%)	CSL 1 (%)	CSL 2 (%)	CSL 3 (%)	CSL 4 (%)
1	No Regulatory Action	78	11	11	0	-
	Bulk Government Purchasing	78	11	11	0	-
2	No Regulatory Action	18	22	57	3	0
	Bulk Government Purchasing	17	23	57	3	0
3	No Regulatory Action	17	62	21	0	-
	Bulk Government Purchasing	17	62	21	0	-
4	No Regulatory Action	9	39	52	0	-
	Bulk Government Purchasing	6	42	52	0	-
5	No Regulatory Action	28	52	7	13	-
	Bulk Government Purchasing	27	52	8	13	-
6	No Regulatory Action	36	29	22	13	-
	Bulk Government Purchasing	34	29	24	13	-
7	No Regulatory Action	44	57	0	-	-
	Bulk Government Purchasing	42	58	0	-	-
8	No Regulatory Action	50	40	10	0	-
	Bulk Government Purchasing	50	40	10	0	-
10	No Regulatory Action	87	0	0	13	-
	Bulk Government Purchasing	84	0	0	16	-

Note: Rows may not sum to 100% due to rounding. The efficiency level highlighted in yellow indicates the minimum efficiency level at which products would meet government purchasing guidelines.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Table 17.20 and Table 17.21 show the increase in market share at the target efficiency level for each EPS and BC product class, respectively. The reference case (no new regulatory action) is assumed not to lead to an increase in market share at the target efficiency level, while it is assumed that under an efficiency standard, 100 percent of the market will be at or above the target efficiency level. In the NIA-RIA model, DOE assumed that these market shares would be constant throughout the analysis period.

Table 17.20 Change in EPS Market Share at Target Efficiency Level, by Product Class

Scenario	Increase in Market Share at Target Efficiency Level (%)								
	B				C	D	E	X	H
	2.5W	18W	60W	120W					
No New Regulatory Action	0	0	0	0	0	0	0	0	0
Consumer Rebates	9	19	6	10	11	10	9	21	-
Consumer Tax Credits	5	11	4	6	6	6	6	13	-
Manufacturer Tax Credits	3	6	2	3	3	3	3	6	-
Voluntary Efficiency Targets	-	-	-	-	-	-	-	-	-
Early Replacement	-	-	-	-	-	-	-	-	-
Bulk Government Purchasing	1	1	3	4	1	0	0	0	0
Federal Efficiency Standards	98	90	99	97	97	96	96	100	100

Table 17.21 Change in BC Market Share at Target Efficiency Level, by Product Class

Scenario	Increase in Market Share at Target Efficiency Level (%)								
	1	2	3	4	5	6	7	8	10
No New Regulatory Action	0	0	0	0	0	0	0	0	0
Consumer Rebates	19	18	16	9	-	-	-	-	13
Consumer Tax Credits	11	11	10	6	-	-	-	-	8
Manufacturer Tax Credits	6	5	5	3	-	-	-	-	4
Voluntary Efficiency Targets	8	8	8	8	8	8	8	8	8
Early Replacement	-	-	-	-	-	-	-	-	-
Bulk Government Purchasing	0	1	0	3	1	1	1	0	3
Federal Efficiency Standards	89	18	17	9	80	65	44	50	87

17.5 SUMMARY OF RESULTS FOR NON-REGULATORY ALTERNATIVES

17.5.1 NPV-RIA Results for External Power Supplies

Table 17.22 through Table 17.25 show the NES and NPV for each of the six non-regulatory policies considered for EPSs. The target level for each policy equals the efficiency level in the corresponding proposed standard. NES and NPV equal zero (equivalent to the no-standards case) in situations where a regulatory alternative was considered to be an inappropriate policy option for a class of EPSs.

The “No New Regulatory Action” scenario is the case in which no regulatory action is taken with regard to EPSs. By definition, the NPV and NES are zero in this case. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads). The NPVs are based on two discount rates, 7 percent and 3 percent. Negative NPVs are shown in parentheses.

Table 17.22 Impacts of Non-Regulatory Alternatives for EPSs in Product Classes B, C, D, and E

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	0.00	0.00	0.00
Consumer Rebates	0.21	0.82	0.42
Consumer Tax Credits	0.13	0.49	0.25
Manufacturer Tax Credits	0.06	0.25	0.13
Voluntary Energy Efficiency Targets	-	-	-
Early Replacement	-	-	-
Bulk Government Purchases	0.02	0.05	0.03
Proposed Standards	*0.92*	*1.53*	*0.61*

Table 17.23 Impacts of Non-Regulatory Alternatives for EPSs in Product Class X

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	0.00	0.00	0.00
Consumer Rebates	0.06	0.33	0.18
Consumer Tax Credits	0.06	0.33	0.18
Manufacturer Tax Credits	0.06	0.33	0.18
Voluntary Energy Efficiency Targets	-	-	-
Early Replacement	-	-	-
Bulk Government Purchases	-	-	-
Proposed Standards	*0.07*	*0.33*	*0.18*

Note: While alternative policy scenarios affect a small portion of shipments in product class X, the shipments that are affected represent a large portion of the potential energy savings. Thus, NES and NPV values for alternative policies are close to the NES and NPV values for standards.

Table 17.24 Impacts of Non-Regulatory Alternatives for EPSs in Product Class H

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	**0.00**	**0.00**	**0.00**
Consumer Rebates	0.0000001	0.0000008	0.0000004
Consumer Tax Credits	0.0000001	0.0000005	0.0000003
Manufacturer Tax Credits	0.0000000	0.0000002	0.0000001
Voluntary Energy Efficiency Targets	-	-	-
Early Replacement	-	-	-
Bulk Government Purchases	-	-	-
Proposed Standards	*0.0013665*	*0.0097256*	*0.0049766*

Table 17.25 Impacts of Non-Regulatory Alternatives for all EPSs

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	**0.00**	**0.00**	**0.00**
Consumer Rebates	0.28	1.15	0.60
Consumer Tax Credits	0.19	0.82	0.43
Manufacturer Tax Credits	0.13	0.58	0.30
Voluntary Energy Efficiency Targets	-	-	-
Early Replacement	-	-	-
Bulk Government Purchases	0.02	0.05	0.03
Proposed Standards	*0.99*	*1.87*	*0.79*

For each of the EPS product class groupings analyzed, the proposed standards are expected to yield higher savings than the alternatives considered. The only product class for which both NES and net consumer benefits for standards and alternatives to standards are comparable is product class X. However, standards would still be the most beneficial policy option for product class X, as they achieve marginally higher energy and cost savings than any of the alternatives to standards. The alternative policy option that yields the most savings for EPSs is consumer rebates; however, DOE estimates that the proposed standards could yield an additional 0.68 quads and $500 million in savings over the consumer rebate scenario.

17.5.2 NPV-RIA Results for Battery Chargers

Table 17.26 through Table 17.31 show the NES and NPV for each of the six non-regulatory policies considered for BCs. The target level for each policy equals the efficiency level in the corresponding proposed standard. NES and NPV equal zero (equivalent to the no-standards case) in situations where a regulatory alternative was considered to be an inappropriate policy option for a class of BCs.

The "No New Regulatory Action" scenario is the case in which no regulatory action is taken with regard to BCs. By definition, the NPV and NES are zero in this case. For comparison, the tables include the impacts of the proposed standards. Energy savings are given in quadrillion British thermal units (quads). The NPVs are based on two discount rates, 7 percent and 3 percent. Negative NPVs are shown in parentheses.

Table 17.26 Impacts of Non-Regulatory Alternatives for BCs in Product Class 1

Policy Alternative	NES (quads)	NPV (2010$ billion)	
		(3%)	**(7%)**
No Standard	0.00	0.00	0.00
Consumer Rebates	0.03	0.14	0.07
Consumer Tax Credits	0.02	0.08	0.04
Manufacturer Tax Credits	0.01	0.04	0.02
Voluntary Energy Efficiency Targets	0.01	0.06	0.03
Early Replacement	-	-	-
Bulk Government Purchases	-	-	-
Proposed Standards	*0.13*	*0.61*	*0.32*

Table 17.27 Impacts of Non-Regulatory Alternatives for BCs in Product Classes 2, 3, and 4

Policy Alternative	NES (quads)	NPV (2010$ billion)	
		(3%)	**(7%)**
No Standard	0.00	0.00	0.00
Consumer Rebates	0.31	1.25	0.66
Consumer Tax Credits	0.19	0.75	0.40
Manufacturer Tax Credits	0.09	0.37	0.20
Voluntary Energy Efficiency Targets	0.18	0.66	0.34
Early Replacement	-	-	-
Bulk Government Purchases	0.05	0.14	0.07
Proposed Standards	*0.31*	*1.26*	*0.66*

Table 17.28 Impacts of Non-Regulatory Alternatives for BCs in Product Classes 5 and 6

Policy Alternative	**NES (quads)**	**NPV (2010$ billion)**	
		(3%)	**(7%)**
No Standard	0.00	0.00	0.00
Consumer Rebates	-	-	-
Consumer Tax Credits	-	-	-
Manufacturer Tax Credits	-	-	-
Voluntary Energy Efficiency Targets	0.10	0.73	0.40
Early Replacement	-	-	-
Bulk Government Purchases	0.02	0.11	0.06
Proposed Standards	*0.60*	*4.65*	*2.54*

Table 17.29 Impacts of Non-Regulatory Alternatives for BCs in Product Class 7

Policy Alternative	**NES (quads)**	**NPV (2010$ billion)**	
		(3%)	**(7%)**
No Standard	0.00	0.00	0.00
Consumer Rebates	-	-	-
Consumer Tax Credits	-	-	-
Manufacturer Tax Credits	-	-	-
Voluntary Energy Efficiency Targets	0.0012	0.021	0.012
Early Replacement	-	-	-
Bulk Government Purchases	0.0002	0.004	0.002
Proposed Standards	*0.0067*	*0.12*	*0.07*

Table 17.30 Impacts of Non-Regulatory Alternatives for BCs in Product Class 8

Policy Alternative	**NES (quads)**	**NPV (2010$ billion)**	
		(3%)	**(7%)**
No Standard	0.00	0.00	0.00
Consumer Rebates	-	-	-
Consumer Tax Credits	-	-	-
Manufacturer Tax Credits	-	-	-
Voluntary Energy Efficiency Targets	0.0015	0.43	0.25
Early Replacement	-	-	-
Bulk Government Purchases	0.0001	0.02	0.01
Proposed Standards	*0.0096*	*2.78*	*1.66*

Table 17.31 Impacts of Non-Regulatory Alternatives for BCs in Product Class 10

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	0.00	0.00	0.00
Consumer Rebates	0.048	0.24	0.12
Consumer Tax Credits	0.029	0.14	0.07
Manufacturer Tax Credits	0.014	0.07	0.04
Voluntary Energy Efficiency Targets	0.028	0.14	0.07
Early Replacement	-	-	-
Bulk Government Purchases	0.009	0.05	0.02
Proposed Standards	*0.312*	*1.55*	*0.79*

Table 17.32 Impacts of Non-Regulatory Alternatives for all BCs

Policy Alternative	NES (quads)	NPV (2010$ billion) (3%)	NPV (2010$ billion) (7%)
No Standard	0.00	0.00	0.00
Consumer Rebates	0.38	1.62	0.85
Consumer Tax Credits	0.23	0.97	0.51
Manufacturer Tax Credits	0.12	0.49	0.26
Voluntary Energy Efficiency Targets	0.33	2.03	1.11
Early Replacement	-	-	-
Bulk Government Purchases	0.08	0.32	0.17
Proposed Standards	*1.36*	*10.96*	*6.04*

With one exception, the proposed standards are expected to yield significantly higher savings than the alternatives considered for each of the BC product class groupings analyzed. Consumer rebates and voluntary energy efficiency targets may achieve the highest level of savings compared to other alternative policy options; however, even these options fall well below the energy and cost savings that can be achieved through standards. The exception is consumer rebates for product classes 2, 3, and 4. For these product classes, the analysis shows that consumer rebates may be sufficient to move the majority of the market up to TSL 1, resulting in national energy savings and net consumer benefits that are almost equivalent to those achieved by standards. However, this result may be overstated, as the analysis does not take into account the complexity of these product classes. The simplifying assumption was that the rebate would be applied universally, however battery chargers in product classes 2, 3, and 4 are used for a wide variety of applications, and it is unlikely that a rebate program would be universally implemented (across all manufacturers of all applications) in these or any other product classes. Additionally, this simplified analysis fails to take into account the costs of implementing a rebate program, which would be significant.

REFERENCES

---

[1] Rufo, M. and Fred Coito. *California's Secret Energy Surplus: The Potential for Energy Efficiency*. 2002. XENERGY Inc. Oakland, CA. Prepared for The Energy Foundation and The Hewlett Foundation. (Last accessed March 2011) <http://www.ef.org/documents/Secret_Surplus.pdf>

[2] ICF International, *Arizona Public Service Energy Efficient Market Potential Study*, 2007. ICF International. Fairfax, VA.

[3] Itron Inc. and KEMA Inc., *California Energy Efficiency Potential Study*, 2008. Submitted to Pacific Gas and Electric Co. by Itron, Inc.: San Diego, CCA, and KEMA, Inc.: Oakland CA. CALMAC Study ID: PGE0264.01. (Last accessed March 2011.) <http://calmac.org/publications/PGE0264_Final_Report.pdf>

[4] Global Energy Partners, *Amerenue Demand Side Management (DSM) Market Potential Study, Volume 2: Market Research*, 2010. Global Energy Partners, LLC: Walnut Creek, CA. Report Number 1287-2. (Last Accessed March 2011.) <http://oa.mo.gov/purch/bids/b3z10177att2-2.pdf>

[5] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for Consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers and Freezers: Regulatory Impact Analysis. September 2010. Washington, D.C. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/refrig_nopr_tsd_2010-09-23.pdf>

[6] U.S. Department of Energy – Office of Energy Efficiency & Renewable Energy. *Database of State Incentives for Renewables & Efficiency*. 2011. (Last accessed March 2011.) <http://www.dsireusa.org/searchby/index.cfm?EE=1&re=1>

[7] Lawrence Berkeley National Laboratory, *Energy End-Use Forecasting: Analysis of Tax Credits for Efficient Equipment*, 1998. LBNL End-Use Forecasting Group. (Last accessed March 2011.) <http://enduse.lbl.gov/projects/taxcredits.html>

[8] U.S. Department of Energy – Office of Codes and Standards, *Technical Support Document: energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers, and Freezers, including Environmental Assessment and Regulatory Impact Analysis*. July 1995. Washington, D.C. Report No. DOE/EE-0064.

[9] U.S. Department of Energy – Energy Efficiency & Renewable Energy, *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment, Residential Dishwashers, Dehumidifiers, Cooking Products, and Commercial Clothes Washers*, 2008. Washington, D.C.

[10] Energy Policy Act of 2005, *Public Law 109-58,* August 8, 2005. <http://frwebgate3.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ058.109.pdf>

[11] American Recovery and Reinvestment Act of 2009, Public Law 111-5, February 17, 2009. <http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h1enr.pdf>

[12] Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, *Public Law 111-312,* December 17, 2010. <http://www.gpo.gov/fdsys/pkg/PLAW-111publ312/pdf/PLAW-111publ312.pdf>

[13] Internal Revenue Service, *SOI Tax Stats – Individual Income Tax Returns, Estimated Data Line Counts,* July 2010. (Last accessed March 2011). <http://www.irs.gov/taxstats/indtaxstats/article/0,,id=154955,00.html>

---

[14] Bailey, Ann, *ENERGY STAR EPS EUB Sunset Decision Memo*. July 19, 2010. U.S. Environmental Protection Agency. (Last accessed 3/23/2011) <http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_eup_sunset_decision_july2010.pdf>

[15] U.S. Environmental Protection Agency, *ENERGY STAR Program Requirements for Products with Battery Charging Systems (BCSs): Final Eligibility Criteria*, January, 2006. (Last accessed April 2011). <https://www.energystar.gov/ia/partners/product_specs/eligibility/battery_chargers_elig.pdf>

[16] KEMA 2004. 2003 EM&V RARP Study: Verification, Degradation & Market Potential Analysis. Prepared for Southern California Edison, Rosemead, California. Prepared by KEMA Inc., Madison, WI. CALMAC Study ID SCE0205. December 23, 2004 (Last accessed March 2011). <http://www.nwcouncil.org/energy/rtf/meetings/2005/06/2003_RARP_Evaluation3.pdf>

[17] ADM et al, 2008. Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program: 2004-2005 Programs: #1114, #1157, #1232 And #1348. ADM Associates, Inc., Athens Research, Hiner & Partners, Innovologie LLC. April 2008. (Last accessed March 2011.) <http://www.calmac.org/publications/EM&V_Study_for_2004-2005_statewide_rarp_-_Final_Report.pdf>

[18] Nexus and RLW Analytics, *Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report, Final.*, 2005. Submitted to Northeast Utilities-Connecticut Light and Power and the United Illuminating Company. Nexus Market Research, Inc., and RLW Analytics, Inc. Cambridge, MA. (Last accessed March 2011.) <http://www.cee1.org/eval/db_pdf/923.pdf>

[19] Energy Center of Wisconsin, *Early Replacement of Inefficient Residential central Air Conditioners*., September 2010. Prepared for Focus on Energy. Prepared by Energy Center of Wisconsin. Madison, WI. (Last accessed March 2011.) <http://www.focusonenergy.com/files/Document_Management_System/Evaluation/airconditionerearlyreplacement_evaluationreport.pdf>

[20] New York State Energy Research and Development Authority, *State Energy efficient Appliance Rebate Program – FAQs*, April 2004, Albany, NY. (Last accessed April 2011). <http://www.nyserda.org/economicrecovery/appliance_faq.asp>

[21] U.S. Department of Energy, Federal Energy Management Program, *Efficient Products Federal Agencies Must Buy*, August 2010, Washington, D.C. (Last accessed April 2011). <http://www1.eere.energy.gov/femp/pdfs/eeprod_categories.pdf>

[22] Harris J. and F. Johnson, Potential Energy, Cost, and CO2 Savings from Energy-Efficient Government Purchasing. In *ACEEE 2000 Summer Study on Energy Efficiency in Buildings*. 2000. Asilomar, CA, August 20-25. American Council for an Energy-Efficient Economy.

[23] U.S. Bureau of Labor Statistics, *Occupational Employment and Wage Estimates: May 2009 Occupational Employment and Wage Estimates*, May 2009, Washington, D.C. (Last accessed April 2011). <http://www.bls.gov/oes/oes_dl.htm>

[24] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 168. Hospitals – Summary Characteristics: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/health.pdf>

[25] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 1095. State Motor Vehicle Registrations: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/trans.pdf>

---

[14] Bailey, Ann, *ENERGY STAR EPS EUB Sunset Decision Memo*. July 19, 2010. U.S. Environmental Protection Agency. (Last accessed 3/23/2011) <http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_eup_sunset_decision_july2010.pdf>

[15] U.S. Environmental Protection Agency, *ENERGY STAR Program Requirements for Products with Battery Charging Systems (BCSs): Final Eligibility Criteria*, January, 2006. (Last accessed April 2011). <https://www.energystar.gov/ia/partners/product_specs/eligibility/battery_chargers_elig.pdf>

[16] KEMA 2004. 2003 EM&V RARP Study: Verification, Degradation & Market Potential Analysis. Prepared for Southern California Edison, Rosemead, California. Prepared by KEMA Inc., Madison, WI. CALMAC Study ID SCE0205. December 23, 2004 (Last accessed March 2011). <http://www.nwcouncil.org/energy/rtf/meetings/2005/06/2003_RARP_Evaluation3.pdf>

[17] ADM et al, 2008. Evaluation Study of the 2004-05 Statewide Residential Appliance Recycling Program: 2004-2005 Programs: #1114, #1157, #1232 And #1348. ADM Associates, Inc., Athens Research, Hiner & Partners, Innovologie LLC. April 2008. (Last accessed March 2011.) <http://www.calmac.org/publications/EM&V_Study_for_2004-2005_statewide_rarp_-_Final_Report.pdf>

[18] Nexus and RLW Analytics, *Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report, Final.*, 2005. Submitted to Northeast Utilities-Connecticut Light and Power and the United Illuminating Company. Nexus Market Research, Inc., and RLW Analytics, Inc. Cambridge, MA. (Last accessed March 2011.) <http://www.cee1.org/eval/db_pdf/923.pdf>

[19] Energy Center of Wisconsin, *Early Replacement of Inefficient Residential central Air Conditioners*., September 2010. Prepared for Focus on Energy. Prepared by Energy Center of Wisconsin. Madison, WI. (Last accessed March 2011.) <http://www.focusonenergy.com/files/Document_Management_System/Evaluation/airconditionerearlyreplacement_evaluationreport.pdf>

[20] New York State Energy Research and Development Authority, *State Energy efficient Appliance Rebate Program – FAQs*, April 2004, Albany, NY. (Last accessed April 2011). <http://www.nyserda.org/economicrecovery/appliance_faq.asp>

[21] U.S. Department of Energy, Federal Energy Management Program, *Efficient Products Federal Agencies Must Buy*, August 2010, Washington, D.C. (Last accessed April 2011). <http://www1.eere.energy.gov/femp/pdfs/eeprod_categories.pdf>

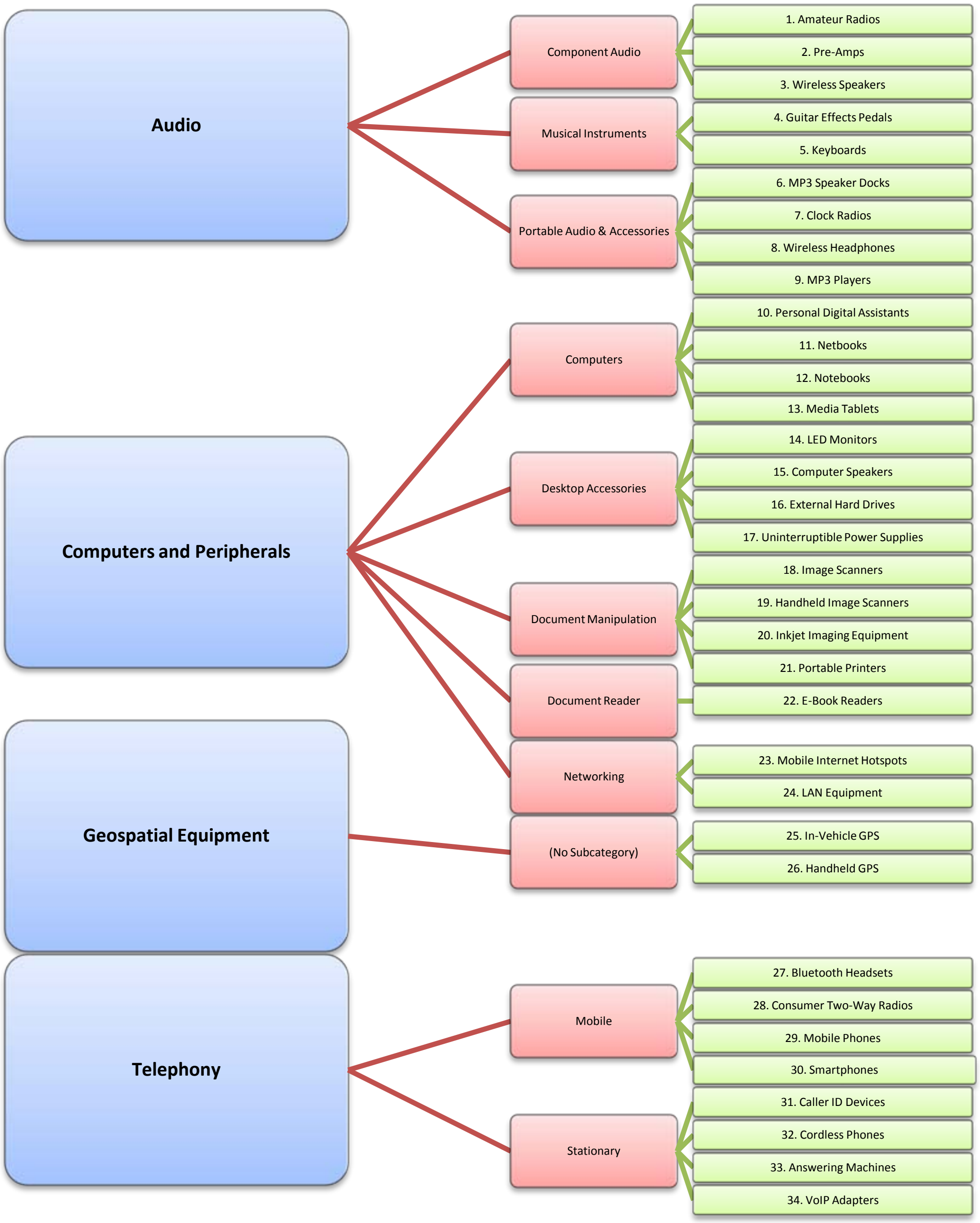
[22] Harris J. and F. Johnson, Potential Energy, Cost, and CO2 Savings from Energy-Efficient Government Purchasing. In *ACEEE 2000 Summer Study on Energy Efficiency in Buildings*. 2000. Asilomar, CA, August 20-25. American Council for an Energy-Efficient Economy.

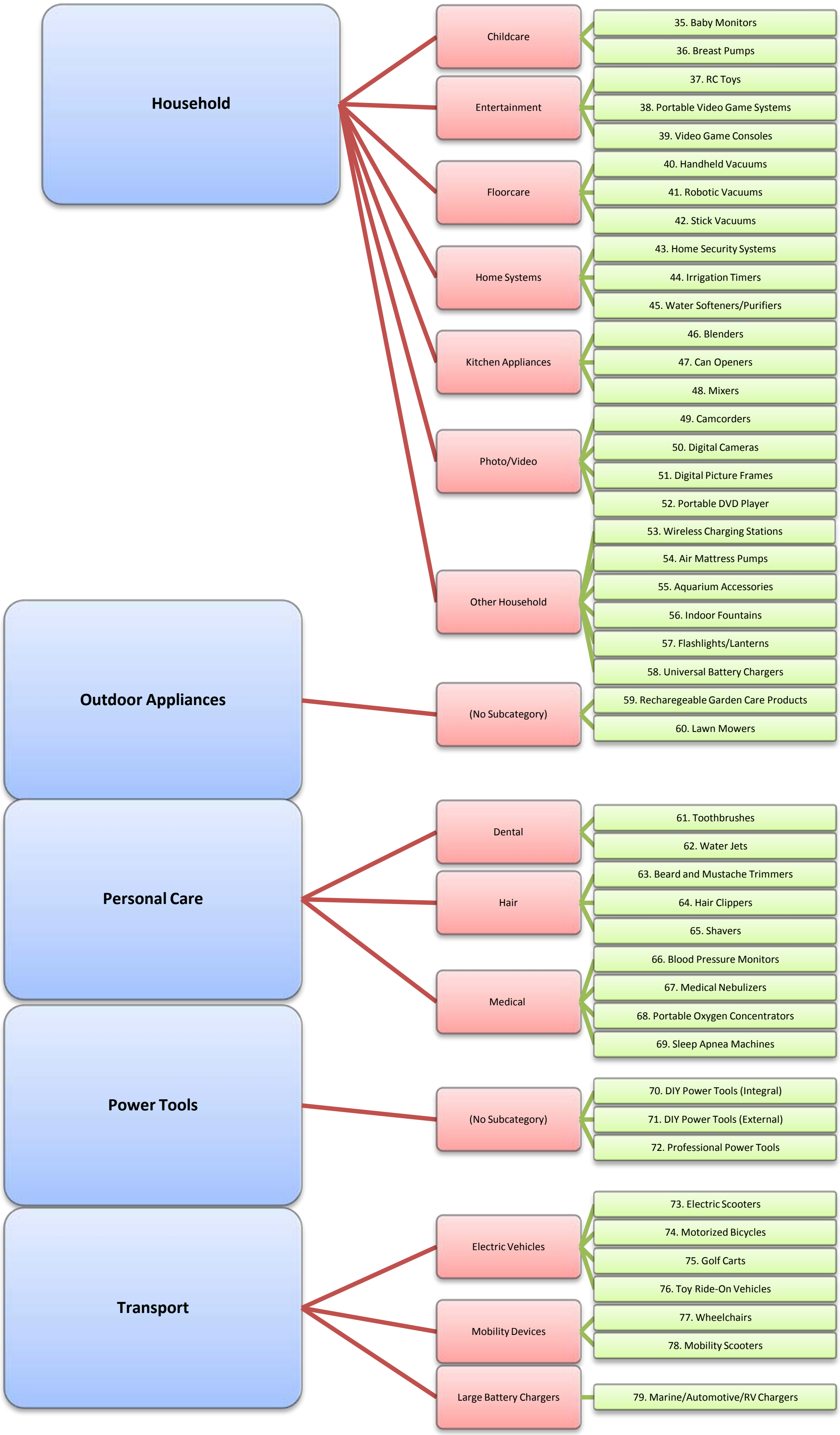
[23] U.S. Bureau of Labor Statistics, *Occupational Employment and Wage Estimates: May 2009 Occupational Employment and Wage Estimates*, May 2009, Washington, D.C. (Last accessed April 2011). <http://www.bls.gov/oes/oes_dl.htm>

[24] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 168. Hospitals – Summary Characteristics: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/health.pdf>

[25] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 1095. State Motor Vehicle Registrations: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/trans.pdf>

APPENDIX 3A. BATTERY CHARGER AND EXTERNAL POWER SUPPLY APPLICATIONS




Household
Childcare
35. Baby Monitors
36. Breast Pumps
Entertainment
37. RC Toys
38. Portable Video Game Systems
39. Video Game Consoles
Floorcare
40. Handheld Vacuums
41. Robotic Vacuums
42. Stick Vacuums
Home Systems
43. Home Security Systems
44. Irrigation Timers
45. Water Softeners/Purifiers
Kitchen Appliances
46. Blenders
47. Can Openers
48. Mixers
Photo/Video
49. Camcorders
50. Digital Cameras
51. Digital Picture Frames
52. Portable DVD Player
Other Household
53. Wireless Charging Stations
54. Air Mattress Pumps
55. Aquarium Accessories
56. Indoor Fountains
57. Flashlights/Lanterns
58. Universal Battery Chargers
Outdoor Appliances
(No Subcategory)
59. Rechareegable Garden Care Products
60. Lawn Mowers
Personal Care
Dental
61. Toothbrushes
62. Water Jets
Hair
63. Beard and Mustache Trimmers
64. Hair Clippers
65. Shavers
Medical
66. Blood Pressure Monitors
67. Medical Nebulizers
68. Portable Oxygen Concentrators
69. Sleep Apnea Machines
Power Tools
(No Subcategory)
70. DIY Power Tools (Integral)
71. DIY Power Tools (External)
72. Professional Power Tools
Transport
Electric Vehicles
73. Electric Scooters
74. Motorized Bicycles
75. Golf Carts
76. Toy Ride-On Vehicles
Mobility Devices
77. Wheelchairs
78. Mobility Scooters
Large Battery Chargers
79. Marine/Automotive/RV Chargers

APPENDIX 3B. BATTERY CHARGER AND EXTERNAL POWER SUPPLY EFFICIENCY PROGRAMS

Table of Contents

List of Tables

B.1 United States – ENERGY STAR for BC and ENERGY STAR Tier I (V1.1) and Tier II (V2.0) for EPS

Revised U.S. ENERGY STAR levels became effective on November 1, 2008. These voluntary levels are stricter than V1.1 levels, and provide separate levels for standard vs. low-voltage models and for AC/AC versus AC/DC models.

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 250 watts, and battery chargers for heat, light, and motion products with a 42-V limit and a 2-watt to 300-watt input limit. Notable exclusions to V1.1 are devices with detachable batteries, motor-operated devices, and medical devices. Notable exclusions to V2.0 are devices with batteries that attach directly. Exclusions to battery charger standards are inductive chargers and systems with additional functions.

B.1.1 Current Standards

- Version: Tier II v2.0 for EPS
- Compliance: Voluntary
- Effective: November 1, 2008

Table 3B.1 U.S. ENERGY STAR Tier II for EPS Active-Mode Efficiency and No-Load Power: Standard Models

Nameplate Output Power	Minimum Efficiency in Active Mode
$0 < W \leq 1$	0.480 * Nameplate Output + 0.140
$1 < W \leq 49$	0.0626 * Ln(Nameplate Output) + 0.622
$49 < W$	0.870

Nameplate Output Power	Maximum No-Load Power Consumption AC/AC	Maximum No-Load Power Consumption AC/DC
$0 < W < 50$	≤ 0.50 W	≤ 0.30 W
$50 \leq W \leq 250$		≤ 0.50 W

Table 3B.2 U.S. ENERGY STAR Tier II for EPS Active-Mode Efficiency and No-Load Power: Low-Voltage Models

Nameplate Output Power	Minimum Efficiency in Active Mode (Less than 6 Volts)
0 < W ≤ 1	0.497 * Nameplate Output + 0.067
1 < W ≤ 49	0.0750 * Ln(Nameplate Output) + 0.561
49 < W	0.86

Nameplate Output Power	Maximum No-Load Power Consumption AC/AC	Maximum No-Load Power Consumption AC/DC
0 < W < 50	≤ 0.50 W	≤ 0.30 W
50 ≤ W ≤ 250		≤ 0.50 W

- Version: ENERGY STAR for BC
- Compliance: Voluntary
- Effective: January 1, 2006

Table 3B.3 ENERGY STAR Specifications for BC Maximum Nonactive Energy Ratio

Nominal Battery Voltage	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0
Maximum Nonactive Energy Ratio	20.0	16.9	13.7	11.6	9.6	7.5	7.0	6.5	6.1	5.6
Nominal Battery Voltage	13.2	14.4	15.6	16.8	18.0	19.2	20.4	21.6	22.8	≥ 24
Maximum Nonactive Energy Ratio	5.1	4.5	4.3	4.2	3.8	3.6	3.5	3.3	3.2	3.0

*Energy Ratio is a function of maintenance mode power and no-load power.

B.2 California – Appliance Efficiency Standards for Battery Chargers

On January 12, 2012, the California Energy Commission (CEC) announced standards for battery chargers that will come into effect beginning on February 1, 2013. CEC's standards will use two different efficiency metrics:

- 24-hour energy (Wh), and
- maintenance mode + standby mode power (W).

Table 3B.4 CEC Standards for Battery Chargers

Performance Parameter	**Battery Energy**	**CEC Proposed Standard**
Maximum 24-hour charge and maintenance energy (Wh) E_b = battery energy N = number of charger ports	$E_b \leq 2.5$ Wh	16 * N
	2.5 Wh < $E_b \leq$ 100 Wh	(12 * N) + (1.6 * E_b)
	100 Wh < $E_b \leq$ 1000 Wh	(22 * N) + (1.5 * E_b)
	E_b > 1000 Wh	(1 * N) + (0.0021 * E_b)
Maintenance Mode Power (W)	All Battery Energies	0.8 + (0.0021* E_b)

B.3 Australia and New Zealand – Minimum Energy Performance Standards (MEPS)

MEPS are administered by the Equipment Energy Efficiency Program, which is co-funded by the Australian and New Zealand Governments, as well as Australian state and territory governments. MEPS are mandatory. Voluntary, higher efficiency levels exist, which will become the new MEPS in the future.

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 250 watts. Notable exclusions are devices with batteries that attach directly, replacements, and medical devices. No-load power requirements only apply to AC/DC power supplies.

The MEPS program does not yet deal with battery chargers but they are currently under consideration. If specific MEPS are not introduced for battery chargers, the 1-watt standby proposal will apply.

B.3.1 Current Standards

- Version: MEPS for EPS
- Compliance: Mandatory MEPS (Mark III), Voluntary High Efficiency (Mark IV and Mark V)
- Effective: Australia - December 1, 2008, New Zealand – April 1, 2009

Table 3B.5 Australia/New Zealand MEPS Levels for EPS Active-Mode Efficiency and No-Load Power

Nameplate Output Power	**Minimum Efficiency in Active Mode**
$0 < W \leq 1$	0.49 * Nameplate Output
$1 < W \leq 49$	0.09 * Ln(Nameplate Output) + 0.49
$49 < W \leq 250$	0.84
Nameplate Output Power	**Maximum No-Load Power Consumption**
$0 < W < 10$	≤ 0.50 W
$10 \leq W \leq 250$	≤ 0.75 W

Table 3B.6 Australia/New Zealand High Efficiency Level IV for EPS Active-Mode Efficiency and No-Load Power

Nameplate Output Power	**Minimum Efficiency in Active Mode**
$0 < W \leq 1$	0.5 * Nameplate Output
$1 < W \leq 51$	0.09 * Ln(Nameplate Output) + 0.5
$51 < W \leq 250$	0.85
Nameplate Output Power	**Maximum No-Load Power Consumption**
$0 < W \leq 250$	≤ 0.50 W

Table 3B.7 Australia/New Zealand High Efficiency Level V for EPS Active-Mode Efficiency and No-Load Power

Nameplate Output Power	Minimum Efficiency in Active Mode – Less than 6 Volts	Minimum Efficiency in Active Mode – Greater than 6 Volts
$0 < W \leq 1$	0.497 * Nameplate Output + 0.067	0.480 * Nameplate Output + 0.140
$1 < W \leq 51$	0.0750 * Ln(Nameplate Output) + 0.561	0.0626 * Ln(Nameplate Output) + 0.622
$51 < W \leq 250$	0.86	0.87

Nameplate Output Power	Maximum No-Load Power Consumption AC/AC	Maximum No-Load Power Consumption AC/DC – Less than 6 Volts	Maximum No-Load Power Consumption AC/DC – Greater than 6 Volts
$0 < W \leq 51$	≤ 0.50 W	≤ 0.30 W	≤ 0.30 W
$51 < W \leq 250$		≤ 0.50 W	No Maximum

B.4 Canada – C381.1 for EPS

Natural Resources Canada’s Office of Energy Efficiency (OEE) published an amendment to Canada’s Energy Efficiency Regulations for external power supplies on June 12, 2010. The standards apply to “products imported or shipped inter-provincially for sale or lease in Canada.” The standards follow EISA levels and scope.[i]

B.4.1 Current Standards

- Version: Minimum Energy Performance Standards for EPSs
- Compliance: Mandatory
- Effective: July 1, 2010

Table 3B.8 CSA Standard C381.1 for EPS

Nameplate Output Power	Minimum Efficiency in Active Mode
0 < W ≤ 1	0.5 * Nameplate Output
1 < W ≤ 51	0.09 * Ln(Nameplate Output) + 0.5
51 < W ≤ 250	0.85
Nameplate Output Power	**Maximum No-Load Power Consumption**
0 < W ≤ 250	≤ 0.50 W

B.5 China – National Development and Reform Commission (NDRC) and China Standard Certification Center (CSC) Standards

Designed and administered by the National Development and Reform Commission (NDRC) and the China Standard Certification Center (CSC), Chinese standards for external power supplies include both mandatory minimum efficiency levels and voluntary high-efficiency levels.

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 250 watts. Notable exclusions to the CSC standards are devices with batteries that attach directly. Battery charger standards do not exist but plans to draft them are in place, with consideration of modes beyond no-load mode.

B.5.1 Current Standards

- Version: GB 20943-2007
- Compliance: Mandatory
- Effective: 2007

Table 3B.9 NDRC MEPS for Active-Mode Efficiency and No-Load Power

Nameplate Output Power	Minimum Efficiency in Active Mode
0 < W ≤ 1	0.39 * Nameplate Output
1 < W ≤ 49	0.107 * Ln(Nameplate Output) + 0.39
49 < W ≤ 250	0.82
Nameplate Output Power	**Maximum No-Load Power Consumption**
0 < W < 10	≤ 0.75 W
10 ≤ W ≤ 250	≤ 1 W

- Version: CSC levels
- Compliance: Voluntary
- Effective: May 2005

Table 3B.10 CSC Levels for Active-Mode Efficiency and No-Load Power (Same as ENERGY STAR Tier 1)

Nameplate Output Power	Minimum Efficiency in Active Mode
0 < W < 1	0.49 * Nameplate Output
1 ≤ W ≤ 49	0.09 * Ln(Nameplate Output) + 0.49
49 < W ≤ 250	0.84
Nameplate Output Power	**Maximum No-Load Power Consumption**
0 < W < 10	≤ 0.50 W
10 ≤ W ≤ 250	≤ 0.75 W

B.6 European Union—Code of Conduct on Efficiency of External Power Supplies, EU Standby Initiative

Developed and administered by the European Commission Joint Research Centre, the EU Code of Conduct is a voluntary agreement. Signatories to the Code of Conduct, which include major manufacturers of external power supplies, agree to meet active-mode efficiency and no-load power consumption targets for at least 90 percent of their product lines.

Power converters covered under this standard include single-voltage ac-ac and ac-dc EPSs and battery charger wall adapters with nameplate output power in the range 0.3 watts to

250 watts. Version 4 of the Code of Conduct includes a separate product class for cellular telephone EPSs, which is subject to different no-load standards.

B.6.1 Current Standards

- Version: 4
- Compliance: Voluntary
- Effective: January 1, 2009

Table 3B.11 EU Code of Conduct Version 4 Active Mode Standards for EPSs Excluding Low Voltage

Nameplate Output Power	Minimum Efficiency in Active Mode
$0 < W \leq 1$	0.48 * Pno + 0.140
$1 < W \leq 49$	[0.0626 * ln(Pno)] + 0.622
$49 < W \leq 250$	0.870

Table 3B.12 EU Code of Conduct Version 4 Active Mode Standards for Low Voltage EPSs

Nameplate Output Power	Maximum Efficiency in Active Mode
$0 < W \leq 1$	0.497 * Pno + 0.067
$1 < W \leq 49$	[0.075 * ln(Pno)] + 0.561

Table 3B.13 EU Code of Conduct Version 4 No-Load Standards for EPSs Excluding Cellular Telephone Adapters with Nameplate Output Power ≤ 8 Watts

Nameplate Output Power	Maximum No-Load Power Consumption
> 0.3 W and < 50 W	0.30 W
> 50 W and < 250 W	0.50 W

Table 3B.14 EU Code of Conduct Version 4 No-Load Standards for Cellular Telephone Adapters with Nameplate Output Power ≤ 8 Watts

Nameplate Output Power	Maximum No-Load Power Consumption
> 0.3 W and < 8.0 W	0.25 W from 1.1.2009 to 31.12.2010
> 0.3 W and < 8.0 W	0.15 W from 1.1.2011

B.7 European Union—Eco-design of Energy-using Products (EuP) Initiative, Directive 2005/32/EC

Developed and administered by the European Commission, the Eco-design of EuP Initiative is a mandatory directive. When complete, the directive will provide EU-wide rules for eco-design so that differences in national regulations do not present barriers to intra-EU trade. Minimum energy-efficiency requirements are among the product characteristics being addressed, including MEPS for external power supplies.

Commission Regulation (EC) 278/2009 covers all single-voltage EPSs with nameplate output power up to 250 watts. In addition, Commission Regulation (EC) 1275/2008 creates standards energy consumption in standby and off-mode for a broad range of products. Specifically the regulation affects all energy using products that meet the following criteria:

- Single function unit (including portable products with a BC)
- Intended for direct use by the individual
- Dependent on mains power
- Nominal voltage less than 250V
- Excludes low voltage EPS

B.7.1 Current Standards

- Version: Commission Regulation (EC) 278/2009, Stage 2
- Compliance: Mandatory
- Effective: April 26, 2011

Table 3B.15 Version 2 Levels for EPS Active-Mode Efficiency and No-Load Power

Nameplate Output Power	Minimum Efficiency in Active Mode – Less than 6 Volts	Minimum Efficiency in Active Mode – Greater than 6 Volts
$0 < W \leq 1$	0.497 * Nameplate Output + 0.067	0.480 * Nameplate Output + 0.140
$1 < W \leq 51$	0.0750 * Ln(Nameplate Output) + 0.561	0.0626 * Ln(Nameplate Output) + 0.622
$51 < W \leq 250$	0.86	0.87

Nameplate Output Power	Maximum No-Load Power Consumption AC/AC	Maximum No-Load Power Consumption AC/DC – Less than 6 Volts	Maximum No-Load Power Consumption AC/DC – Greater than 6 Volts
$0 < W \leq 51$	≤ 0.50 W	≤ 0.30 W	≤ 0.30 W
$51 < W \leq 250$		≤ 0.50 W	No Maximum

- Version: Commission Regulation (EC) 1275/2008, Stage 1
- Compliance: Mandatory
- Effective: January 7, 2010

Table 3B.16 Stage 1 Standby and Off-Mode Power Consumption

Standby/Off-Mode	Standby/Off-Mode w/ Display
1.0 W	2.0 W

B.7.2 Future Standards

- Version: Commission Regulation (EC) 1275/2008, Stage 2
- Compliance: Mandatory
- Effective: January 7, 2013

Table 3B.17 Stage 2 Standby and Off-Mode Power Consumption

Standby/Off-Mode	Standby/Off-Mode w/ Display
0.5 W	1.0 W

B.8 EU (Subset of Member Countries)—Group for Energy Efficient Appliances

Developed by the Group for Energy Efficient Appliances, which includes government agencies and institutions from Denmark, the Netherlands, Sweden, Switzerland, Germany, France, and Austria, the GEEA standards are voluntary. The purpose of the GEEA, organized in 1996, is to harmonize national regulations pertaining to electronics and home office equipment. Minimum energy-efficiency requirements are among the product characteristics GEEA addresses, including MEPS for external power supplies and battery chargers.

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 150 watts. In addition to EPS and BC, this standard applies to portable personal equipment, which is defined as “equipment that is sold as part of a product with non-removable rechargeable batteries and is sold with the aim of recharging batteries.”

B.8.1 Current Standards

- Version: N/A
- Compliance: Voluntary
- Effective: 2007

Table 3B.18 GEEA Levels for EPS and “Portable Personal Equipment” Active-Mode Efficiency and No-Load Power

Nameplate Output Power	Minimum Efficiency in Active Mode
$0 < W \leq 1$	0.49 * Nameplate Output
$1 < W \leq 49$	0.09 * Ln(Nameplate Output) + 0.50
$49 < W \leq 150$	0.84
Nameplate Output Power	**Maximum No-Load Power Consumption***
$0 < W < 150$	0.30 W

* Includes Battery Chargers

B.9 European Union—GSM Association Universal Charging Solution

The Universal Charging Solution is a voluntary agreement between mobile phone manufacturers and service providers to standardize battery chargers for mobile phones, adopt Micro-USB chargers, and limit no-load energy consumption to 0.15 W. The EPS must meet EU directive 278/2009 and comply with USB-IF Battery Charging Specifications 1.1. The first compliant chargers will be available in 2010, and the standard is expected to be widely adopted by 2012.

B.9.1 Future Standards

- Version: N/A
- Compliance: Voluntary
- Effective: January 1, 2012

Table 3B.19 GSMA Universal Charging Solution No-Load Power Consumption

Nameplate Output Power	Maximum No-Load Power Consumption
> 0.3 W and < 8.0 W	0.15 W

B.10 Israel – SI 4665.2 (AS/NZX 4665.2-2005)

Administered by the Standards Institution of Israel (SII), the SI 4665.2 standards are a Hebrew translation of the AS/NZX 4665.2-2005 standards developed by Australia. These voluntary standards apply to external power supplies only.

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 250 watts. Notable exclusions are devices with batteries that attach directly, replacements, and medical devices. The scope and test procedures are identical to those in the Australian standards (*i.e.*, EPA EPS).

B.10.1 Current Standards

- Version: SI 4665.2
- Compliance: Voluntary
- Effective: December 2007

Table 3B.20 SI 4665.2 Levels for EPS Active-Mode Efficiency and No-Load Power

Nameplate Output Power	Minimum Efficiency in Active Mode
0 < W ≤ 1	0.49 * Nameplate Output
1 < W ≤ 49	0.09 * Ln(Nameplate Output) + 0.49
49 < W ≤ 250	0.84
Nameplate Output Power	**Maximum No-Load Power Consumption**
0 < W < 10	≤ 0.50 W
10 ≤ W ≤ 250	≤ 0.75 W

B.11 South Korea – Minimum Energy Performance Standards (MEPS)

Power converters covered under this standard include all single-voltage EPSs with nameplate output power up to 150 watts and cellular telephone chargers. Notable exclusions are EPSs with charge circuitry.

South Korea’s MEPS program for EPSs, developed by the Ministry of Commerce, Industry, and Energy (MOCIE) and Korea Energy Management Corporation (KEMCO) is being implemented in three phases, with the ultimate goal of reducing standby power of all electronic products below 1W. Phase one of this program (2005-2007) was a voluntary limit on efficiency. Currently in effect is phase two, which set mandatory standards for EPSs up to 150 watts (active mode and no-load power consumption) and lithium-ion BCs (no-load power consumption). Phase three will apply to those products not yet covered under the mandatory program.

B.11.1 Current Standards

- Version: N/A
- Compliance: Mandatory
- Effective: January 1, 2009 for EPS

Table 3B.21 Minimum Energy Performance Standards for wall adapters with no charging function

Nameplate Output Power	**Minimum Efficiency in Active Mode**
$0 < W \leq 1$	0.49 * Nameplate Output
$1 < W \leq 49$	0.09 * Ln(Nameplate Output) + 0.49
$49 < W \leq 150$	0.84
Nameplate Output Power	**Maximum No-Load Power Consumption**
$0 < W \leq 10$	≤ 0.50 W
$10 < W \leq 150$	≤ 0.75 W

---

[i] Natural Resources Canada, "Canada's Energy Efficiency Regulations – External Power Supplies." June 2010. Accessed on January 19, 2011 at <http://oee.nrcan.gc.ca/regulations/bulletin/ext-power-supplies-june-2010.cfm>

APPENDIX 3C. EVALUATION METHODS IDENTIFYING EXTERNAL POWER SUPPLIES THAT CAN DIRECTLY POWER AN APPLICATION

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

3C.1 INTRODUCTION

The following appendix proposes an evaluation method to identify EPSs that can directly power an application (Figure 3C-1) versus EPSs whose power first flows through a BC as an intermediary before reaching the application (Figure 3C-2), and hence their resulting product classes. DOE is examining this method in response to comments that DOE should distinguish between these two configurations. EPSs that can directly power the application are grouped into product classes B, C, D, E, X and H. EPSs that use the BC and battery as an intermediary are in product class N. The direct operation test is only necessary for EPSs which can directly connect to the end-use consumer product where the consumer product can operate solely on battery power.

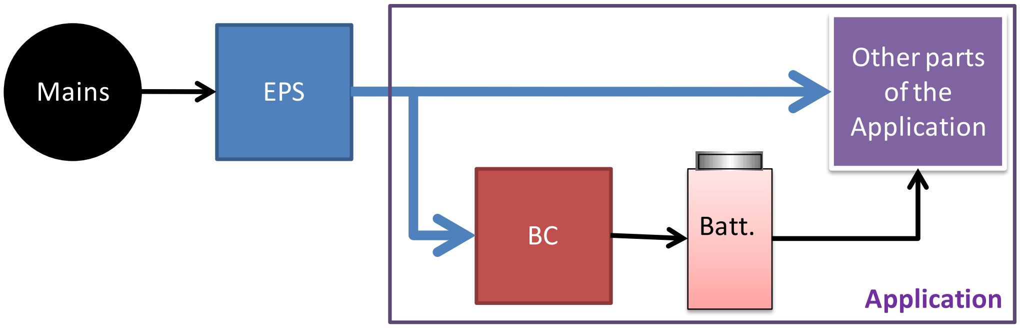


Figure 3C-1 EPS that can directly power the application

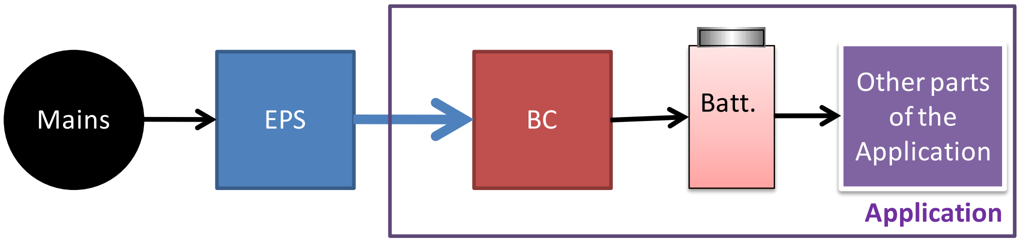


Figure 3C-2 EPS whose power all flows to the BC

In this appendix, DOE presents the steps it took to identify EPSs that directly power applications. Section 2 presents definitions used within this appendix. The evaluation method is presented in detail in Section 3. Section 4 presents the units on which DOE performed the evaluation methods with the results shown in Section 4.

3C.2 DEFINITIONS

Below, DOE provides summary definitions for some important terms used in this appendix. Full definitions are available in chapter 3 of the NOPR TSD:

- *Application*: The application of the EPS is either (1) the consumer product, or the main product used by the consumer, with which the EPS is packaged or, (2) those consumer product(s) identified on the EPSs label with which the EPS is intended for use.

- *Battery*: One or more sealed electrochemical cells that provide power to an application, allowing it to operate while disconnected from the AC mains.

- *To Operate*: Operating an application consists of performing one of the primary functions of the application (e.g., having a laptop boot up; turning the chuck on a drill). An application is considered to be operational if it can perform at least one major function that the application would perform were the battery connected and fully charged.

3C.3 EVALUATION METHODOLOGY

This section of the appendix describes the specific steps involved with the evaluation method, which consists of steps followed by a final evaluation. The steps are questions, procedures, measurements, or calculations. For the steps that are questions, simple "Yes" or "No" answers are required to complete the procedure. The final evaluation of direct operation uses these conventions as well.

The EPS is evaluated based on its ability to operate the application once the battery has been fully discharged while taking into account the time required before the application can operate. By comparing startup times under fully charged and fully discharged battery conditions, the procedure acknowledges firmware limitations or bias conditions which can temporarily restrict power flow from the EPS to the application.

Steps:

1A = Charge the battery in the application via the EPS such that the application can operate as intended before taking any additional steps.
1B = Disconnect the EPS from the application. From an off mode state, turn on the application and record the time necessary for it to become operational to the nearest five second increment (5sec, 10sec, etc.).
1C = Operate the application using power only from the battery until the application stops functioning due to the battery fully discharging.
1D = Connect the EPS first to mains and then to the application. Immediately attempt to operate the application. Record the time necessary for the application to become operational to the nearest five second increment (5sec, 10sec, etc.).

Evaluation:

If the time recorded in 1D is less than or equal to the summation of the time recorded in 1B and five seconds, the external power supply can operate the application directly and is not in product class N.

3C.4 TEST UNITS FOR EVALUATION

DOE selected the test units from a variety of applications, each with an EPS and a battery. These control units are used to verify the evaluation outcome. Table 3C.1 shows the list of units that were evaluated:

Table 3C.1: Direct Operation Units Evaluated

Unit #	Application Type
631	Laptop
632	Laptop
666	Cordless Phone
686	Cell Phone
693	Camcorder
698	Hand-held video game
873	Cordless Phone
879	Camcorder
1007	MP3 Player
1027	Cordless Drill
1031	Hand vacuum
1032	Hand vacuum
1052	Beard Trimmer
1053	Electric Razor
1054	Electric Razor
1055	Beard Trimmer

[*] *These units are replacement units that were not packaged with the original application.*

DOE chose the above test units which were available with all the components from the DOE test laboratory and were not destroyed due to other tests conducted previously.

3C.5 RESULTS

The results of the evaluation method, discussed in Section 3C.3 are given in detail in this section. In the following table the "Yes" and "No" answers to questions are shown as well as the final evaluation for direct operation. An entry of "-" corresponds to an answer of "Not Applicable".

Table 3C.2: Results

Unit	Application Type	1B (s)	1D (s)	DIRECT OPERATION
631	Laptop	20	20	**Yes**
632	Laptop	20	20	**Yes**
666	Cordless Phone	5	45	**No**
686	Cell Phone	10	40	**No**
693	Camcorder	5	5	**Yes**
698	Hand-held video game	5	5	**Yes**
873	Cordless Phone	5	45	**No**
879	Camcorder	5	5	**Yes**
1007	MP3 Player	0	85	**No**
1027	Cordless Drill	0	25	**No**
1031	Hand vacuum	0	15	**No**
1032	Hand vacuum	0	15	**No**
1052	Beard Trimmer	0	5	**Yes**
1053	Electric Razor	0	5	**Yes**
1054	Electric Razor	0	5	**Yes**
1055	Beard Trimmer	0	5	**Yes**

3D. END-USE APPLICATION PRODUCT CLASS ASSIGNMENTS

3D.1. External Power Supplies

				EPS Shipments in 2009 by Product Class (Thousands)									
	Application	Application Shipments (Thousands)	% with EPS	B (2.5 W)	B (18 W)	B (60 W)	B (120 W)	C	D	E	X	H	N
Audio	Amateur radios	3	100%									3	
	Pre-amps	520	100%	520									
	Wireless speakers	760	100%		1,521								
	Guitar effects pedals	1,534	100%	1,534									
	Keyboards	1,130	10%	113									
	MP3 speaker docks	9,239	85%		7,853								
	Clock radios	15,282	10%	764	764								
	Wireless headphones	500	100%	500									
Computers and Peripherals	MP3 players	40,101	10%					401					3,609
	Personal digital assistants	1,7503	100%	350				875					525
	Netbooks	8,676	100%			8,676							
	Notebooks	28,046	100%			21,035	7,012						
	Media tablets	7,371	95%		7,003								
	Computer speakers	10,303	38%		3,915								

				EPS Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with EPS**	**B (2.5 W)**	**B (18 W)**	**B (60 W)**	**B (120 W)**	**C**	**D**	**E**	**X**	**H**	**N**
	External hard drives	773	58%		448								
	Uninterruptible power supplies	8,000	0%	No EPS									
	LED monitors	9,747	20%			1,949							
	Image scanners	7,846	40%		3,138								
	Ink jet imaging equipment	17,162	24%			4,085							
	Portable printers	1,278	100%		1,278								
	E-books	2,200	90%	198				1,782					
	Mobile internet hotspots	1,432	100%	286				1,146					
	LAN equipment	19,408	96%		18,632								
Geo-spatial Equip.	In-vehicle GPS	12,645	25%					316					2,845
	Handheld GPS	1,009	15%					15					136
Telephony	Bluetooth headsets	13,900	100%										13,900
	Consumer two-way radios	6,900	80%	1,104				4,416					
	Mobile phones	94,239	50%	9,424				32,984					4,712
	Smartphones	41,163	50%	4,116				10,291					6,1741
	Caller ID devices	345	100%	345									
	Cordless phones	13,229	100%	13,229									
	Answering machines	16,919	100%	16,919									

				EPS Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with EPS**	**B (2.5 W)**	**B (18 W)**	**B (60 W)**	**B (120 W)**	**C**	**D**	**E**	**X**	**H**	**N**
	VoIP adapters	9,865	80%		5,919			1,973					
Household	Baby monitors	1,700	100%	3,400									
	Breast pumps	550	100%	550									
	RC toys	7,000	5%										350
	Portable video game systems	10,386	79%	6,482				1,723					
	Video game consoles	23,693	81%			11,515					7,677		
	Handheld vacuums	4,000	100%										4,000
	Robotic vacuums	1,000	100%										1,000
	Stick vacuums	4,150	63%										2,615
	Home security Systems	4,219	100%						4,219				
	Irrigation timers	500	75%						375				
	Water softeners/purifiers	1,150	100%						1,150				
	Blenders	1,225	5%					61					
	Can openers	5,703	5%					285					
	Mixers	5,773	1%					58					
	Camcorders	6,267	25%		1,567								
	Digital cameras	32,932	15%					2,470					2,470
	Digital picture frames	9,319	100%		9,319								

				EPS Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with EPS**	**B (2.5 W)**	**B (18 W)**	**B (60 W)**	**B (120 W)**	**C**	**D**	**E**	**X**	**H**	**N**
	Portable DVD players	3,703	100%		3,703								
	Wireless charging stations	3,568	100%		3,568								
	Air mattress pumps	1,000	25%										250
	Aquarium accessories	3,500	100%						1,750	1,750			
	Indoor fountains	1,000	100%						500	500			
	Flashlights/lanterns	100	100%										100
	Universal battery chargers	300	10%		30								
Outdoor Appliances	Rechargeable garden care products	150	5%										8
	Lawn mowers	300	5%										15
	Rechargeable toothbrushes	15,000	100%										15,000
Personal Care	Rechargeable water jets	100	100%										100
	Beard and mustache trimmers	9,400	75%	5,288									1,763
	Hair clippers	6,068	75%	1,138									3,413
	Shavers	8,656	100%	2,164									6,492
	Sleep apnea machines	2,000	50%		700	300							
	Medical nebulizers	3,000	30%		900								
	Portable O2 concentrators	9	100%				9						

				EPS Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with EPS**	**B (2.5 W)**	**B (18 W)**	**B (60 W)**	**B (120 W)**	**C**	**D**	**E**	**X**	**H**	**N**
	Blood pressure monitors	100	100%	50				50					
Power Tools	DIY power tools (integral)	4,675	100%										4,675
	DIY power tools (external)	7,013	5%										351
	Professional power tools	11,688	0%	No EPS									
Transport	Electric scooters	250	70%										175
	Motorized bicycles	150	70%										105
	Golf carts	211	0%	No EPS									
	Toy ride-on vehicles	8,090	0%	No EPS									
	Wheelchairs	166	0%	No EPS									
	Mobility scooters	192	0%	No EPS									
	Marine/ automotive/ RV chargers	500	0%	No EPS									
	Note: Sums may not add to totals due to rounding.												

Battery Chargers

				BC Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with BC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Audio	Amateur radios	3	0%	No BC									
	Pre-amps	520	0%	No BC									
	Wireless speakers	760	15%			228							
	Guitar effects pedals	1,534	0%	No BC									
	Keyboards	1,130	0%	No BC									
	MP3 speaker docks	9,239	15%		1,386								
	Clock radios	15,282	0%	No BC									
	Wireless headphones	500	100%		500								
Computers and Peripherals	MP3 players	40,101	100%		4,010						36,091		
	Personal digital assistants	1,7503	100%		175						1,575		
	Netbooks	8,676	100%				8,676						
	Notebooks	28,046	100%				28,046						
	Media tablets	7,371	100%		7,371								
	Computer speakers	10,303	0%	No BC									
	External hard drives	773	0%	No BC									

				BC Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with BC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Uninterruptible power supplies	8,000	100%										8,000
	LED monitors	9,747	0%	No BC									
	Image scanners	7,846	0%	No BC									
	Ink jet imaging equipment	17,162	0%	No BC									
	Portable printers	1,278	75%			240	719						
	E-books	2,200	100%		1,760						440		
	Mobile internet hotspots	1,432	100%		1,432								
	LAN equipment	19,408	7%			1,282							
Geo-spatial Equip.	In-vehicle GPS	12,645	100%		3,161							9,484	
	Handheld GPS	1,009	15%		121						30		
Telephony	Bluetooth headsets	13,900	100%		12,510						1,390		
	Consumer two-way radios	6,900	80%		11,040								
	Mobile phones	94,239	100%		75,391						18,848		
	Smartphones	41,163	100%		41,163								
	Caller ID devices	345	0%										
	Cordless phones	13,229	100%		13,229								
	Answering machines	16,919	100%		16,919								
	VoIP adapters	9,865	0%	No BC									

				BC Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with BC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Household	Baby monitors	1,700	100%		3,400								
	Breast pumps	550	0%	No BC									
	RC toys	7,000	30%			2,100							
	Portable video game systems	10,386	100%		10,386								
	Video game consoles	23,693	19%		4,502								
	Handheld vacuums	4,000	100%			1,320	2,680						
	Robotic vacuums	1,000	100%				1,000						
	Stick vacuums	4,150	63%			863	1,752						
	Home security Systems	4,219	100%		4,219								
	Irrigation timers	500	0%	No BC									
	Water softeners/purifiers	1,150	0%	No BC									
	Blenders	1,225	5%			61							
	Can openers	5,703	5%		285								
	Mixers	5,773	1%			58							
	Camcorders	6,267	100%			4,700					1,567		
	Digital cameras	32,932	80%		21,076						5,269		
	Digital picture frames	9,319	0%	No BC									
	Portable DVD players	3,703	100%			3,703							

				BC Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with BC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Wireless charging stations	3,568	0%	No BC									
	Air mattress pumps	1,000	25%			250							
	Aquarium accessories	3,500	0%	No BC									
	Indoor fountains	1,000	0%	No BC									
	Flashlights/lanterns	100	100%				50					50	
	Universal battery chargers	300	100%		120	120	60						
Outdoor Appliances	Rechargeable garden care products	150	61%				92						
	Lawn mowers	300	61%						182				
	Rechargeable toothbrushes	15,000	100%	15,000									
Personal Care	Rechargeable water jets	100	100%	100									
	Beard and mustache trimmers	9,400	25%		2,350								
	Hair clippers	6,068	25%		1,517								
	Shavers	8,656	100%		8,656								
	Sleep apnea machines	2,000	25%				500						
	Medical nebulizers	3,000	15%				405					45	
	Portable O2 concentrators	9	100%					5				5	
	Blood pressure monitors	100	0%	No BC									

				BC Shipments in 2009 by Product Class (Thousands)									
	Application	**Application Shipments (Thousands)**	**% with BC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Power Tools	DIY power tools (integral)	4,675	100%		2,338	2,338							
	DIY power tools (external)	7,013	100%			1,753	5,259						
	Professional power tools	11,688	100%				11,688						
Transport	Electric scooters	250	100%						250				
	Motorized bicycles	150	100%						150				
	Golf carts	211	100%							211			
	Toy ride-on vehicles	8,090	100%			4,045		4,045					
	Wheelchairs	166	100%					125	42				
	Mobility scooters	192	100%					192					
	Marine/ automotive/ RV chargers	500	100%					500					
	Note: Sums may not add to totals due to rounding.												

Appendix 5A. **EXTERNAL POWER SUPPLY TEST DATA**

This appendix is available in a separate Excel workbook.

Appendix 5B. **BATTERY CHARGER TEST DATA**

This appendix is available in a separate Excel workbook.

APPENDIX 5C. BILL OF MATERIALS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 5C. BILL OF MATERIALS

5C.1 INTRODUCTION

This appendix presents the bill of materials obtained from iSuppli for all the external power supplies and battery chargers that were torn down to develop the engineering analysis. Tables 5C-1 through 5C-11 present the bill of materials for the direct operation EPSs, Tables 5C-12 through 5C-15 present the bill of materials for the non-Class A EPSs, and Tables 5C-3 through 5C-27 present the bill of materials for the battery chargers.

Table 5C-1 Bill of Materials for External Power Supply unit 118

Component	Quantity	Cost Per Component
Analog IC	1	$0.1408
Analog - Regulator	1	$0.0845
Capacitor (Ceramic)	1	$0.0150
Capacitor (Ceramic)	1	$0.0160
Capacitor (Ceramic)	1	$0.0160
Capacitor (Ceramic)	2	$0.0083
Capacitor (Ceramic)	6	$0.0138
Capacitor (Electrolytic)	1	$0.0094
Capacitor (Electrolytic)	2	$0.0291
Capacitor (Electrolytic)	1	$0.0094
Capacitor (Electrolytic)	1	$0.3566
Capacitor (Film)	1	$0.0704
Optocoupler	1	$0.0422
Diode	1	$0.0375
Diode (Glass)	1	$0.0084
Diode (Rectifier)	4	$0.0042
Diode (Rectifier)	1	$0.0043
Diode (Rectifier)	1	$0.0206
Diode (Rectifier)	1	$0.0563
Diode (Zener)	1	$0.0113
Diode (Zener)	1	$0.0061
Fuse	1	$0.0282
Transformer	1	$0.1454
Transformer	1	$0.3284
Inductor	1	$0.0563
Resistor (Axial)	1	$0.0090
Resistor (Precision)	23	$0.0010
Thermistor	1	$0.0347
Transistor	1	$0.1408

Component	**Quantity**	**Cost Per Component**
Conversion		$0.1819
Jumper	3	$0.0093
Connector (Main Power)	1	$0.1803
Fastener	1	$0.0045
Fastener	1	$0.0090
Fastener	1	$0.0099
Fastener	1	$0.0032
Fastener	3	$0.0090
Conversion		$0.0857
Transistor Mounting Plate	1	$0.0721
Label	1	$0.0384
Thermal Transfer Pad	1	$0.0198
Conversion		$0.1211
Connector (Output Cord)	1	$0.3317
Printed Circuit Board	1	$0.1577
Enclosure	1	$0.2974
Enclosure	1	$0.3155
BOM Total:		**$3.727**

Table 5C-2 Bill of Materials for External Power Supply unit 834

Component	**Quantity**	**Cost Per Component**
Analog - Regulator	2	$0.0943
Analog - Regulator	1	$0.1669
Capacitor (Disc)	1	$0.0825
Capacitor (Disc)	1	$0.0354
Capacitor (Ceramic)	1	$0.0174
Capacitor (Ceramic)	16	$0.0154
Capacitor (Electrolytic)	1	$0.0697
Capacitor (Electrolytic)	3	$0.0697
Capacitor (Electrolytic)	1	$0.1115
Capacitor (Film)	1	$0.0961
Optocoupler	2	$0.0439
Diode (Bridge Rectifier)	1	$0.0613
Diode (Rectifier)	1	$0.0040
Diode (Rectifier)	1	$0.0094
Diode (Rectifier)	1	$0.1581
Diode (Zener)	1	$0.0057
Diode (Zener)	1	$0.0094
Fuse	1	$0.0700
LED	1	$0.0221

Component	Quantity	Cost Per Component
Transformer	1	$0.6182
Inductor	2	$0.1532
Heatsink	2	$0.1171
Resistor (Axial)	1	$0.0132
Resistor (SMD)	36	$0.0011
Thermistor	2	$0.0315
Transistor	1	$0.0024
Transistor	1	$0.2794
Thyristor	1	$0.0630
Jumper	3	$0.0113
Connector (Main Power)	1	$0.1361
Fastener	2	$0.0082
Fastener	2	$0.0145
Fastener	2	$0.0227
Label	1	$0.0750
Connector (DC Plug)	1	$0.1361
Connector (Output Cord)	1	$0.2371
Printed Circuit Board	1	$0.4211
Enclosure	1	$0.2495
Enclosure	1	$0.2650
Enclosure	1	$0.0154
Enclosure	2	$0.0145
Conversion		$0.0851
Conversion		$0.1666
Conversion		$0.0595
BOM Total:		**$5.2714**

Table 5C-3 Bill of Materials for External Power Supply unit 838

Component	Quantity	Cost Per Component
Analog - Amplifier	1	$0.0790
Analog - PWM controller	1	$0.1184
Capacitor (Ceramic)	3	$0.0301
Capacitor (Ceramic)	3	$0.0104
Capacitor (Ceramic)	6	$0.0156
Capacitor (Electrolytic)	2	$0.0758
Capacitor (Electrolytic)	1	$0.0156
Capacitor (Electrolytic)	2	$0.0409
Capacitor (Electrolytic)	1	$0.1193
Capacitor (Film)	1	$0.0138
Capacitor (Film)	1	$0.0938

Component	**Quantity**	**Cost Per Component**
Optocoupler	2	$0.0543
Diode (Bridge Rectifier)	1	$0.1332
Diode	1	$0.0089
Diode (Rectifier)	2	$0.0079
Diode (Rectifier)	2	$0.1875
Diode (TVS)	1	$0.0493
Diode (Zener)	3	$0.0089
Fuse	1	$0.0888
Fuse	1	$0.0740
Transformer	1	$0.4807
Ferrite Bead	1	$0.0033
Inductor	1	$0.1244
Inductor	1	$0.2132
Heatsink	2	$0.1311
Heatsink	1	$0.0812
Heatsink	1	$0.0303
Resistor (Axial)	1	$0.0061
Resistor (Axial)	2	$0.0099
Resistor (SMD)	31	$0.0011
Thermistor	1	$0.0642
Varistor	1	$0.0375
Transistor	1	$0.0074
Transistor	1	$0.1530
Jumper	4	$0.0098
Connector (Main Power)	1	$0.1389
Fastener	3	$0.0117
Fastener	3	$0.0166
Fastener	2	$0.0204
EMI Shield	1	$0.1634
Insulating Tape	4	$0.0257
Label	1	$0.0646
Label	1	$0.0094
Thermal Transfer Pad	1	$0.0705
Connector (Output Cord)	1	$0.1370
Connector (Output Cord)	1	$0.2250
Printed Circuit Board	1	$0.2290
Enclosure	1	$0.2250
Enclosure	1	$0.2358
Conversion		$0.1919

Component	**Quantity**	**Cost Per Component**
Conversion		$0.1301
Conversion		$0.1963
BOM Total:		**$5.5695**

Table 5C-4 Bill of Materials for External Power Supply unit 854

Component	**Quantity**	**Cost Per Component**
Analog - Amplifier	1	$0.1486
Analog - PWM controller	1	$0.0180
Analog - PFC	1	$0.1180
Capacitor (Ceramic)	3	$0.0070
Capacitor (Ceramic)	27	$0.0114
Capacitor (Electrolytic)	1	$0.0831
Capacitor (Electrolytic)	2	$0.1158
Capacitor (Electrolytic)	1	$0.0141
Capacitor (Electrolytic)	2	$0.0118
Capacitor (Film)	1	$0.0950
Capacitor (Film)	1	$0.0145
Capacitor (Film)	1	$0.0140
Optocoupler	2	$0.0550
Diode (Bridge Rectifier)	1	$0.0900
Diode (Zener)	10	$0.0089
Diode (Rectifier)	1	$0.0603
Diode (Rectifier)	1	$0.0350
Diode (Rectifier)	1	$0.0190
Diode (Rectifier)	2	$0.2200
Diode (Rectifier)	1	$0.0134
Diode (TVS)	1	$0.0326
Diode (Zener)	1	$0.0025
Diode (Zener)	4	$0.0090
Fuse	1	$0.0675
LED	1	$0.0200
Transformer	1	$0.4550
Transformer	1	$0.7250
Inductor	2	$0.1370
Inductor	1	$0.1930
Inductor	1	$0.2020
Heatsink	2	$0.0916
Heatsink	1	$0.1600
Heatsink	1	$0.2400
Resistor (Axial)	1	$0.0062

Component	Quantity	Cost Per Component
Resistor (Axial)	1	$0.0120
Resistor (Axial)	2	$0.0172
Resistor	1	$0.0031
Resistor (SMD)	67	$0.0011
Resistor (SMD)	1	$0.0112
Thermistor	1	$0.0318
Transistor	4	$0.0054
Transistor	2	$0.0300
Transistor	2	$0.0042
Transistor	1	$0.4442
Transistor	1	$0.3450
Connector (DC Plug)	1	$0.1400
Jumper	4	$0.0250
Jumper	5	$0.0200
Connector (Main Power)	1	$0.6750
Connector (Main Power)	1	$0.1200
Fastener	5	$0.0090
Fastener	2	$0.0150
Fastener	3	$0.0173
EMI Shield	1	$0.3211
EMI Shield	1	$0.3142
EMI Shield	1	$0.1328
EMI Shield	1	$0.1706
Stiffener	1	$0.0355
Cushion	1	$0.2000
Connector (Output Cord)	1	$0.6500
Printed Circuit Board	1	$0.8540
Enclosure	1	$0.3460
Enclosure	1	$0.3440
Enclosure	3	$0.1477
Enclosure	1	$0.0160
Conversion		$0.1664
Conversion		$0.3124
Conversion		$0.2168
BOM Total:		**$11.3713**

Table 5C Bill of Materials for External Power Supply unit 876

Component	Quantity	Cost Per Component
Capacitor (Electrolytic)	1	$0.1031
Diode (Rectifier)	4	$0.0162

Component	**Quantity**	**Cost Per Component**
Transformer	1	$0.4008
Cushion	1	$0.0426
Connector (DC Plug)	1	$0.1204
Connector (Output Cord)	1	$0.1111
Printed Circuit Board	1	$0.0491
Enclosure	1	$0.1278
Enclosure	1	$0.1630
Conversion		$0.0240
Conversion		$0.0204
Conversion		$0.0600
BOM Total:		**$1.2872**

Table 5C-5 Bill of Materials for External Power Supply unit 935

Component	**Quantity**	**Cost Per Component**
Analog - PWM controller	1	$0.2000
Capacitor (Ceramic)	1	$0.0120
Capacitor (Ceramic)	4	$0.0047
Capacitor (Electrolytic)	1	$0.0466
Capacitor (Electrolytic)	1	$0.0550
Diode (Rectifier)	2	$0.0050
Diode (Rectifier)	1	$0.0056
Diode (Rectifier)	1	$0.0118
Diode (Zener)	1	$0.0075
Transformer	1	$0.3352
Inductor	1	$0.0200
Resistor (Axial)	1	$0.0155
Resistor (SMD)	7	$0.0008
Connector (DC Plug)	1	$0.1400
Connector (Output Cord)	1	$0.1680
Fastener	1	$0.0137
Enclosure	1	$0.1210
Enclosure	1	$0.0720
Conversion		$0.0255
Conversion		$0.0490
Conversion		$0.2168
BOM Total:		**$1.5495**

Table 5C-6 Bill of Materials for External Power Supply unit 941

Component	**Quantity**	**Cost Per Component**
Analog - Regulator	1	$0.0700

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	1	$0.0250
Capacitor (Ceramic)	1	$0.0100
Capacitor (Ceramic)	1	$0.0070
Capacitor (Ceramic)	3	$0.0137
Capacitor (Electrolytic)	1	$0.0258
Capacitor (Electrolytic)	2	$0.0401
Capacitor (Film)	1	$0.0900
Diode	3	$0.0090
Diode (Rectifier)	4	$0.0050
Diode (Rectifier)	1	$0.1016
Fuse	1	$0.0743
Transformer	1	$0.2150
Transformer	1	$0.3500
Inductor	1	$0.1880
Resistor (Axial)	1	$0.0016
Resistor (SMD)	8	$0.0011
Varistor	1	$0.0380
Transistor	1	$0.2317
Transistor	1	$0.0052
Label	1	$0.0136
Label	1	$0.0630
Connector (DC Plug)	1	$0.1400
Connector (Output Cord)	1	$0.2500
Printed Circuit Board	1	$0.2490
Enclosure	1	$0.1480
Enclosure	1	$0.1380
Insulator	1	$0.0830
Conversion		$0.0573
Conversion		$0.0882
Conversion		$0.2166
BOM Total:		**$3.057**

Table 5C-7 Bill of Materials for External Power Supply unit 949

Component	Quantity	Cost Per Component
Analog - Regulator	1	$0.0171
Analog - Regulator	1	$0.2242
Capacitor (Ceramic)	1	$0.0139
Capacitor (Ceramic)	1	$0.0161
Capacitor (Ceramic)	4	$0.0133
Capacitor (Ceramic)	3	$0.0189
Capacitor (Electrolytic)	2	$0.0396

Component	Quantity	Cost Per Component
Capacitor (Electrolytic)	1	$0.0151
Capacitor (Electrolytic)	1	$0.0413
Capacitor (Film)	2	$0.0948
Optocoupler	1	$0.0442
Diode (Rectifier)	5	$0.0030
Diode (Rectifier)	2	$0.1294
Diode (Rectifier)	2	$0.0057
Fuse	1	$0.0485
Transformer	1	$0.4103
Inductor	1	$0.1241
Inductor	1	$0.0720
Heatsink	1	$0.0825
Heatsink	2	$0.0161
Resistor (SMD)	23	$0.0012
Thermistor	1	$0.0337
Connector (Main Power)	2	$0.1067
Connector (Main Power)	1	$0.2271
Cushion	1	$0.0345
Insulator	1	$0.0458
Label	1	$0.0353
Connector (DC Plug)	1	$0.1374
Connector (Output Cord)	1	$0.2344
Printed Circuit Board	1	$0.2518
Enclosure	1	$0.2070
Enclosure	1	$0.1905
Enclosure	2	$0.0266
Conversion		$0.0936
Conversion		$0.1341
Conversion		$0.0597
BOM Total:		**$3.7833**

Table 5C-8 Bill of Materials for External Power Supply unit 951

Component	Quantity	Cost Per Component
Analog - Amplifier	1	$0.1386
Analog - PWM Controller	1	$0.1998
Capacitor (Ceramic)	1	$0.0146
Capacitor (Ceramic)	7	$0.0088
Capacitor (Ceramic)	21	$0.0095
Capacitor (Electrolytic)	2	$0.0933
Capacitor (Electrolytic)	1	$0.1188

Component	Quantity	Cost Per Component
Capacitor (Electrolytic)	2	$0.0118
Capacitor (Film)	1	$0.0951
Capacitor (Film)	2	$0.0560
Optocoupler	2	$0.0435
Diode (Bridge Rectifier)	1	$0.0653
Diode	1	$0.0040
Diode	1	$0.0074
Diode (Rectifier)	1	$0.0061
Diode (Rectifier)	1	$0.0466
Diode (Rectifier)	1	$0.0131
Diode (Rectifier)	2	$0.1687
Fuse	1	$0.0933
Transformer	1	$0.4244
Transformer	1	$0.6763
Inductor	1	$0.1278
Inductor	1	$0.1782
Inductor	1	$0.1884
Heatsink	2	$0.1470
Heatsink	1	$0.0862
Heatsink	1	$0.3720
Heatsink	1	$0.0155
Resistor (Axial)	4	$0.0140
Resistor	1	$0.0135
Resistor (SMD)	50	$0.0010
Thermistor	1	$0.0340
Transistor	1	$0.0026
Transistor	1	$0.1658
Transistor	1	$0.3278
Connector (Main Power)	1	$0.1268
Fastener	4	$0.0125
Fastener	4	$0.0152
EMI Shielding	1	$0.2367
EMI Shielding	1	$0.1192
EMI Shielding	1	$0.2438
EMI Shielding	1	$0.1184
Cushion	6	$0.0174
Insulator	1	$0.1381
Label	1	$0.0504
Label	1	$0.0268

Component	Quantity	Cost Per Component
Connector (DC Plug)	1	$0.1429
Connector (Output Cord)	1	$0.2459
Printed Circuit Board	1	$0.7589
Enclosure	1	$0.3321
Enclosure	1	$0.3259
Conversion		$0.1308
Conversion		$0.2222
Conversion		$0.0593
BOM Total:		**$8.3174**

Table 5C-9 Bill of Materials for External Power Supply unit 996

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	3	$0.0020
Capacitor (Ceramic)	3	$0.0095
Capacitor (Electrolytic)	1	$0.0256
Capacitor (Electrolytic)	2	$0.0361
Diode (Rectifier)	4	$0.0050
Diode (Rectifier)	1	$0.0118
Diode (Rectifier)	1	$0.0025
Diode (Zener)	2	$0.0025
Transformer	1	$0.0185
Inductor	1	$0.0050
Resistor (Axial)	1	$0.0075
Resistor (SMD)	11	$0.0009
Transistor	1	$0.0150
Transistor	1	$0.0320
Fastener	2	$0.0365
Connector (DC Plug)	1	$0.0864
Connector (Output Cord)	1	$0.1240
Printed Circuit Board	1	$0.0790
Enclosure	1	$0.1500
Enclosure	1	$0.0800
Conversion		$0.0155
Conversion		$0.0731
Conversion		$0.0716
BOM Total:		**$1.0125**

Table 5C-10 Bill of Materials for External Power Supply unit 999

Component	Quantity	Cost Per Component

Component	Quantity	Cost Per Component
Analog - PWM Controller	1	$0.1319
Analog - Regulator	1	$0.0565
Capacitor (Ceramic)	2	$0.0154
Capacitor (Ceramic)	1	$0.0148
Capacitor (Ceramic)	2	$0.0299
Capacitor (Ceramic)	2	$0.0066
Capacitor (Ceramic)	2	$0.0090
Capacitor (Electrolytic)	2	$0.0716
Capacitor (Electrolytic)	1	$0.0602
Capacitor (Electrolytic)	1	$0.0099
Capacitor (Film)	1	$0.0942
Optocoupler	1	$0.0493
Diode (Bridge Rectifier)	1	$0.0592
Diode (Rectifier)	1	$0.0909
Diode (Rectifier)	1	$0.0030
Diode (Switching)	1	$0.0027
Diode (Switching)	1	$0.0105
Fuse	1	$0.0613
Transformer	1	$0.5390
Inductor	1	$0.1234
Inductor	1	$0.0895
Heatsink	2	$0.0795
Resistor (Axial)	1	$0.0146
Resistor (Axial)	2	$0.0146
Resistor (SMD)	20	$0.0010
Thermistor	1	$0.0299
Transistor	1	$0.1626
Jumper	1	$0.1134
Connector (Main Power)	1	$0.1289
Fastener	2	$0.0082
Fastener	2	$0.0164
Fastener	2	$0.0037
Label	1	$0.0117
Label	1	$0.0513
Connector (DC Plug)	1	$0.1361
Connector (Output Cord)	1	$0.1964
Printed Circuit Board	1	$0.3557
Enclosure	1	$0.2132
Enclosure	1	$0.2151

Component	Quantity	Cost Per Component
Conversion		$0.0936
Conversion		$0.0928
Conversion		$0.0595
BOM Total:		**$3.7994**

Table 5C-11 Bill of Materials for External Power Supply unit 203

Component	Quantity	Cost Per Component
Analog - IC	1	$0.3500
Analog - Amplifier	2	$0.0450
Analog - Amplifier	1	$0.0430
Analog - IC	1	$0.0500
Analog - PWM Controller	1	$0.1200
Capacitor (Ceramic)	1	$0.0150
Capacitor (Ceramic)	1	$0.0160
Capacitor (Ceramic)	2	$0.0160
Capacitor (Ceramic)	2	$0.0126
Capacitor (Ceramic)	2	$0.0068
Capacitor (Ceramic)	2	$0.0135
Capacitor (Ceramic)	1	$0.0280
Capacitor (Ceramic)	7	$0.0053
Capacitor (Ceramic)	34	$0.0073
Capacitor (Electrolytic)	1	$0.0330
Capacitor (Electrolytic)	2	$0.2800
Capacitor (Electrolytic)	1	$0.7200
Capacitor (Electrolytic)	2	$0.0170
Capacitor (Electrolytic)	1	$0.0170
Capacitor (Electrolytic)	2	$0.0100
Capacitor (Electrolytic)	1	$0.0100
Capacitor (Film)	1	$0.0800
Capacitor (Film)	1	$0.0800
Optocoupler	3	$0.0450
Diode	2	$0.0100
Diode	15	$0.0120
Diode (Rectifier)	1	$0.0052
Diode (Rectifier)	1	$0.1400
Diode (Rectifier)	1	$0.0350
Diode (Rectifier)	1	$0.0052
Diode (Rectifier)	1	$0.0315
Diode (Rectifier)	1	$0.4700
Diode (Rectifier)	2	$0.0075

Component	**Quantity**	**Cost Per Component**
Diode (Rectifier)	1	$0.0300
Diode (Rectifier)	2	$0.0285
Diode	3	$0.0180
Fuse	1	$0.0750
LED	1	$0.0550
Transformer	1	$0.1550
Transformer	2	$0.4900
Inductor	1	$0.0380
Inductor	1	$0.1700
Inductor	1	$0.5000
Inductor	1	$0.3700
Inductor	1	$0.4500
Resistor (Axial)	10	$0.0064
Resistor (Film)	15	$0.0100
Potentiometer	1	$0.0800
Resistor (SMD)	138	$0.0005
Thermistor	1	$0.0500
Thermistor	2	$0.0350
Varistor	1	$0.0320
Varistor	2	$0.0420
Transistor	5	$0.0038
Transistor	1	$0.0320
Transistor	3	$0.0035
Transistor	1	$0.5800
Transistor	1	$0.1700
Transistor	5	$0.0050
Transistor	1	$0.1200
Transistor	1	$0.9000
Conversion		$0.4218
Jumper	12	$0.0080
Jumper	6	$0.0080
Connector (Pin Header)	1	$0.0600
Connector (Pin Header)	1	$0.0660
Connector (Main Power)	1	$0.2200
Connector (Wire Harness)	1	$0.0300
Connector (Wire Harness)	1	$0.0900
Label	1	$0.0800
Conversion		$0.3058
Printed Circuit Board	1	$0.4450

Component	Quantity	Cost Per Component
Printed Circuit Board	1	$0.2220
Enclosure	1	$0.7500
BOM Total:		**$11.9104**

Table 5C-12 Bill of Materials for External Power Supply unit 213

Component	Quantity	Cost Per Component
Analog - Regulator	2	$0.0175
Analog - PWM Controller	1	$0.1200
Analog - Regulator	1	$0.1200
Capacitor (Ceramic)	4	$0.0180
Capacitor (Ceramic)	1	$0.0110
Capacitor (Ceramic)	1	$0.0125
Capacitor (Ceramic)	3	$0.0088
Capacitor (Ceramic)	19	$0.0121
Capacitor (Electrolytic)	2	$0.0300
Capacitor (Electrolytic)	2	$0.3800
Capacitor (Electrolytic)	2	$0.2000
Capacitor (Electrolytic)	1	$0.0430
Capacitor (Electrolytic)	1	$0.0100
Capacitor (Electrolytic)	3	$0.0100
Capacitor (Film)	2	$0.0800
Optocoupler	3	$0.0450
Diode (Bridge Rectifier)	1	$0.1500
Diode	9	$0.0090
Diode (Rectifier)	2	$0.0120
Diode (Rectifier)	1	$0.0315
Fan	1	$1.3000
Fuse	1	$0.0550
LED	1	$0.0300
Transformer	2	$0.5900
Inductor	1	$0.0400
Inductor	3	$0.1400
Resistor (Axial)	10	$0.0058
Jumper	14	$0.0100
Resistor (SMD)	50	$0.0006
Thermistor	1	$0.1100
Transistor	6	$0.0035
Transistor	6	$0.0035
Transitor	2	$0.1700
Transistor	1	$0.0950

Component	Quantity	Cost Per Component
Transistor	1	$0.0950
Conversion		$0.3932
Connector (Pin Header)	1	$0.0170
Connector (Main Power)	1	$0.2100
Fastener	2	$0.0090
Fastener	2	$0.0190
Fastener	2	$0.0130
Fastener	2	$0.0270
Fastener	4	$0.0450
Fastener	2	$0.0095
Conversion		$0.1874
Metal	2	$0.2000
Label	1	$0.0900
Thermal Transfer Pad	2	$0.0500
Conversion		$0.2218
Printed Circuit Board	1	$0.4500
Enclosure	1	$0.7500
Enclosure	1	$0.7500
Enclosure	1	$0.0470
BOM Total:		**$10.3982**

Table 5C-13 Bill of Materials for External Power Supply unit 401

Component	Quantity	Cost Per Component
Analog - Regulator	1	$0.3500
Capacitor (Ceramic)	2	$0.0600
Capacitor (Ceramic)	3	$0.0560
Capacitor (Ceramic)	1	$0.0800
Capacitor (Ceramic)	1	$0.0600
Capacitor (Electrolytic)	1	$0.4000
Capacitor (Electrolytic)	1	$0.0300
Capacitor (Electrolytic)	1	$0.0280
Capacitor (Electrolytic)	1	$22.0000
Capacitor (Electrolytic)	1	$0.7500
Capacitor (Film)	3	$0.0640
Diode (Bridge Rectifier)	1	$1.5500
Diode	1	$0.0150
Diode (Rectifier)	2	$0.0276
Diode (Rectifier)	2	$0.0110
Diode (Rectifier)	1	$0.8000
Diode (Zener)	1	$0.0213

Component	Quantity	Cost Per Component
Diode (Zener)	1	$0.1760
Fuse	1	$0.3800
Transformer	1	$60.0000
Heatsink	1	$12.1100
Heatsink	3	$0.3000
Heatsink	3	$0.5500
Resistor (Axial)	14	$0.0120
Resistor	4	$1.2500
Potentiometer	1	$0.9500
Varistor	1	$0.0700
Transistor	4	$1.7000
Transistor	1	$0.4500
Transistor	1	$0.0250
Conversion		$2.9009
Connector (DIP socket)	1	$0.1260
Connector (Fuse Holder)	1	$2.0000
Connector (Ground Contact)	2	$0.3000
Jumper	5	$0.0250
Connector (Socket)	4	$0.5500
Connector (Main Power)	1	$1.1000
Connector (Wire)	4	$0.0350
Connector (Wire Harness)	1	$2.5000
Fastener	4	$0.0150
Fastener	6	$0.0120
Fastener	10	$0.0120
Fastener	2	$0.0120
Fastener	4	$0.0120
Fastener	4	$0.0135
Fastener	2	$0.0400
Fastener	3	$0.0470
Fastener	3	$0.0250
Fastener	4	$0.0270
Fastener	1	$0.0480
Fastener	6	$0.0380
Fastener	8	$0.0320
Fastener	3	$0.0340
Fastener	4	$0.0410
Fastener	4	$0.0330
Fastener	4	$0.0130

Component	Quantity	Cost Per Component
Fastener	3	$0.0100
Metal	1	$1.6800
Enclosure	1	$7.2700
Enclosure	1	$7.3300
Insulator	4	$0.0330
Switch	1	$1.7500
Conversion		$3.1515
Printed Circuit Board	1	$0.3540
Enclosure	4	$0.4230
BOM Total:		**$152.1659**

Table 5C-14 Bill of Materials for External Power Supply unit 402

Component	Quantity	Cost Per Component
Analog - PWM Controller	1	$0.1700
Capacitor (Ceramic)	5	$0.0900
Capacitor (Ceramic)	1	$0.0560
Capacitor (Ceramic)	2	$0.1200
Capacitor (Electrolytic)	4	$1.2500
Capacitor (Electrolytic)	2	$1.4700
Capacitor (Electrolytic)	1	$0.0300
Capacitor (Electrolytic)	1	$0.0500
Capacitor (Electrolytic)	2	$0.0280
Capacitor (Electrolytic)	4	$0.0285
Capacitor (Film)	1	$0.1000
Capacitor (Film)	1	$0.5400
Capacitor (Film)	1	$0.9000
Capacitor (Film)	4	$0.0640
Capacitor (Film)	1	$0.0420
Capacitor (Film)	2	$0.0420
Capacitor (Film)	1	$0.0280
Diode (Bridge Rectifier)	1	$0.3000
Diode	11	$0.0150
Diode (Rectifier)	4	$0.0200
Diode (Rectifier)	2	$0.0200
Diode (Rectifier)	2	$1.6500
Fan	1	$4.2500
Fuse	1	$0.3500
Transformer	1	$0.4500
Transformer	1	$0.7500
Transformer	1	$1.3500

Component	**Quantity**	**Cost Per Component**
Transformer	1	$2.2500
Transformer	1	$1.5500
Inductor	2	$0.0950
Inductor	3	$0.7800
Heatsink	2	$0.6650
Resistor (Axial)	43	$0.0096
Jumper	7	$0.0200
Potentiometer	1	$0.3500
Thermistor	2	$0.1700
Varistor	2	$0.0450
Transistor	3	$0.0090
Transistor	2	$1.2500
Transistor	1	$0.0280
Conversion		$3.5628
Jumper	2	$0.0172
Connector (Pin Header)	1	$0.3000
Connector (Pin Header)	2	$0.0600
Connector (Main Power)	1	$1.6000
Connector (Housing)	2	$0.0400
Connector (Wire Harness)	1	$0.0414
Connector (Wire Harness)	1	$0.0435
Connector (Wire Harness)	2	$0.0394
Connector (Wire Harness)	1	$0.0367
Connector (Wire Harness)	1	$0.4600
Connector (Wire Harness)	1	$1.1000
Fastener	6	$0.0110
Fastener	2	$0.0110
Fastener	5	$0.0110
Fastener	4	$0.0300
Fastener	2	$0.0220
Fastener	4	$0.0220
Fastener	2	$0.0250
Fastener	4	$0.0450
Fastener	8	$0.0250
Fastener	3	$0.0260
Fastener	2	$0.0120
Enclosure	1	$5.6000
Enclosure	1	$1.8820
Enclosure	1	$5.8400

Component	Quantity	Cost Per Component
Cushion	1	$0.0462
Insulator	1	$0.3300
Label	2	$0.0554
Thermal Transfer Pad	4	$0.1510
Switch	1	$1.3500
Switch	1	$1.8000
Switch	2	$6.2500
Conversion		$3.1515
Printed Circuit Board	2	$0.4500
Enclosure	4	$0.2500
BOM Total:		**$77.138**

Table 5C-15 Bill of Materials for Battery Charger unit 616

Component	Quantity	Cost Per Component
Analog (Transistor)	1	$0.0031
Analog IC	1	$0.1600
Capacitor (Ceramic)	2	$0.0020
Capacitor (Ceramic)	7	$0.0014
Capacitor (Ceramic)	11	$0.0031
Capacitor (Ceramic)	3	$0.0079
Capacitor (Ceramic)	5	$0.0095
Capacitor (Ceramic)	2	$0.0219
Capacitor (Electrolytic)	1	$0.0167
Capacitor (Electrolytic)	1	$0.0314
Capacitor (Electrolytic)	1	$0.0146
Capacitor (Electrolytic)	2	$0.0138
Capacitor (Electrolytic)	1	$0.0145
Capacitor (Film)	2	$1.2000
Diode	2	$0.0400
Diode (Bridge Rectifier)	1	$0.0500
Diode (Rectifier)	6	$0.0087
Diode (Schottky Rectifier)	1	$0.0185
Diode (Surge Arrestor)	2	$0.0400
Diode (Switching)	3	$0.0200
Diode (Zener)	1	$0.0350
Diode (Zener)	1	$0.0380
Diode (Zener)	1	$0.0300
Ferrite Bead	4	$0.0058
Fuse	1	$0.1300
Inductor	2	$0.0110

Component	Quantity	Cost Per Component
Inductor	1	$0.0173
Inductor	1	$0.7320
Inductor	1	$0.0672
Inductor	2	$0.1000
Inductor	1	$0.0119
Precision SMD	2	$0.0010
Regulator	1	$0.1400
Resistor (Axial)	2	$0.1165
SMD Flat Chip	13	$0.0004
SMD Flat Chip	29	$0.0005
SMD Flat Chip	11	$0.0008
SMD Flat Chip	5	$0.0013
SMD Flat Chip	2	$0.0034
Thermistor	1	$0.0700
Transistor	10	$0.0238
Transistor	2	$0.0085
BOM Total:		**$5.2200**

Table 5C-16 Bill of Materials for Battery Charger unit 617

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	4	$0.0100
Capacitor (Electrolytic)	1	$0.0401
Diode (Rectifier)	4	$0.0050
Resistor (Axial)	1	$0.0051
Transformer	1	$0.4200
BOM Total:		**$0.5252**

Table 5C-17 Bill of Materials for Battery Charger unit 630

Component	Quantity	Cost Per Component
Amplifier	1	$0.0821
Battery Charger	1	$1.2314
Capacitor (Ceramic)	1	$0.0278
Capacitor (Ceramic)	1	$0.0203
Capacitor (Ceramic)	2	$0.0042
Capacitor (Ceramic)	25	$0.0016
Capacitor (Ceramic)	12	$0.0034
Capacitor (Ceramic)	5	$0.0143
Capacitor (Ceramic)	8	$0.0257
Capacitor (Electrolytic)	2	$0.0308
Capacitor (Electrolytic)	1	$0.0130

Component	Quantity	Cost Per Component
Capacitor (Electrolytic)	1	$0.0845
Capacitor (Film)	1	$0.0975
Diode (Bridge Rectifier)	1	$0.0718
Diode (Glass)	4	$0.0092
Diode (Rectifier)	1	$0.0051
Diode (Rectifier)	1	$0.0190
Diode (Rectifier)	1	$0.0544
Diode (Rectifier)	1	$0.1313
Diode (Schottky Barrier)	2	$0.0065
Diode (Switching)	3	$0.0065
Ferrite Bead	3	$0.0032
Fuse (Box Type)	1	$0.0770
Heatsink	1	$0.0230
Heatsink	1	$0.0908
Inductor	1	$0.1703
Inductor	1	$0.1088
Optocoupler	1	$0.0564
Precision SMD	1	$0.0016
Precision SMD	2	$0.0328
PWM Controller	1	$0.1231
Resistor (Axial)	1	$0.0052
SMD Flat Chip	44	$0.0004
SMD Flat Chip	8	$0.0006
SMD Flat Chip	11	$0.0011
Thermistor	1	$0.0359
Transformer	1	$0.3684
Transistor	1	$0.0041
Transistor	2	$0.0041
Transistor	1	$0.0041
Transistor	3	$0.0181
Transistor	2	$0.1197
Transistor	1	$0.0704
Transistor	1	$0.1642
Transistor	1	$0.1283
Battery	1	$1.8174
BOM Total:		**$5.9949**

Table 5C-18 Bill of Materials for Battery Charger unit 664

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	2	$0.0095

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	4	$0.0031
Capacitor (Ceramic)	1	$0.0020
Capacitor (Ceramic)	14	$0.0014
Capacitor (Ceramic)	17	$0.0013
Capacitor (Electrolytic)	1	$0.0289
Capacitor (Tantalum)	1	$0.0638
Capacitor (Tantalum)	4	$0.0424
Capacitor (Tantalum)	2	$0.0558
Diode	2	$0.0100
Diode	3	$0.0250
Diode (Rectifier)	4	$0.0426
Diode (Switching)	1	$0.0063
Diode (Zener)	1	$0.0090
Inductor	2	$0.0326
Inductor	1	$0.0693
SMD Flat Chip	4	$0.0013
SMD Flat Chip	6	$0.0005
SMD Flat Chip	13	$0.0004
Transformer	1	$0.6312
Transistor	2	$0.0099
Transistor	2	$0.0044
Transistor	2	$0.0077
Transistor	1	$0.0055
BOM Total:		**$1.5587**

Table 5C-19 Bill of Materials for Battery Charger unit 673

Component	Quantity	Cost Per Component
Diode (Button Diode)	2	$0.0800
Diode (SCR)	1	$0.7980
Regulator	1	$0.0450
Transformer	1	$7.6520
Transistor	3	$0.0150
Transistor	4	$0.0150
BOM Total:		**$8.7600**

Table 5C-20 Bill of Materials for Battery Charger unit 674

Component	Quantity	Cost Per Component
Amplifier	1	$0.0546
Capacitor (Ceramic)	2	$0.1030
Capacitor (Ceramic)	4	$0.1200

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	1	$0.0516
Capacitor (Ceramic)	2	$0.0761
Capacitor (Electrolytic)	1	$0.2401
Capacitor (Electrolytic)	4	$0.3523
Capacitor (Electrolytic)	2	$0.0191
Capacitor (Electrolytic)	3	$0.0382
Capacitor (Electrolytic)	2	$0.0214
Capacitor (Film)	2	$0.0100
Capacitor (Film)	3	$0.0100
Capacitor (Film)	12	$0.0210
Capacitor (Film)	1	$0.0340
Capacitor (Film)	9	$0.0300
Capacitor (Film)	2	$0.3600
Crystal	1	$0.1400
Diode	4	$0.0550
Diode	2	$0.0470
Diode (Bridge Rectifier)	1	$3.3128
Diode (Glass)	1	$0.0095
Diode (Rectifier)	7	$0.0060
Diode (Rectifier)	2	$0.6488
Diode (Switching)	12	$0.0095
Diode (Transient Voltage Suppressor)	1	$0.0440
Diode (Zener)	1	$0.0125
Fan	1	$2.3000
Fuse	1	$0.2133
Fuse	1	$0.2361
Heatsink	1	$4.3236
Inductor	1	$0.8160
Inductor	2	$0.7000
Inverter	1	$0.0590
LED	5	$0.0200
Microcontroller	1	$0.4389
Optocoupler	2	$0.0587
Potentiometer	1	$0.1600
Regulator	1	$0.0505
Relay	2	$0.1500
Resistor (Axial)	2	$0.0318
Resistor (Axial)	12	$0.0100
Resistor (Axial)	50	$0.0050

Component	Quantity	Cost Per Component
Resistor (Axial)	31	$0.0050
Resistor (Axial)	2	$0.0300
Resistor (Axial)	4	$0.0361
Resistor (Ceremic)	1	$0.5000
SMPS Controller	1	$0.1130
Thermal Cut Out	1	$0.0100
Thermistor	1	$0.0500
Transformer	1	$1.1000
Transformer	1	$3.3650
Transistor	2	$0.1050
Transistor	2	$0.0640
Transistor	1	$0.1412
Transistor	1	$0.0080
Transistor	1	$0.0070
Transistor	1	$0.0970
Transistor	6	$0.0170
Transistor	4	$0.5380
Varistor	1	$0.1500
BOM Total:		**$28.8426**

Table 5C-21 Bill of Materials for Battery Charger unit 687

Component	Quantity	Cost Per Component
Battery Charger	1	$0.5606
Capacitor (Ceramic)	1	$0.0183
Capacitor (Ceramic)	1	$0.0158
Capacitor (Ceramic)	1	$0.0019
Capacitor (Ceramic)	1	$0.0034
Capacitor (Ceramic)	10	$0.0016
Capacitor (Ceramic)	5	$0.0142
Capacitor (Electrolytic)	1	$0.0204
Capacitor (Electrolytic)	1	$0.0367
Capacitor (Electrolytic)	2	$0.0459
Capacitor (Tantalum Niobium Oxide)	1	$0.0968
Diode (High-Speed Switching)	1	$0.0025
Diode (Rectifier)	5	$0.0051
Diode (Rectifier)	1	$0.0469
Diode (Rectifier)	2	$0.0306
Diode (Rectifier)	1	$0.0153
Diode (Schottky - Triple Array)	2	$0.0306

Component	Quantity	Cost Per Component
Diode (Schottky Barrier)	6	$0.0076
Diode (Zener)	3	$0.0122
Inductor	1	$0.0561
Optocoupler	1	$0.0561
Regulator	1	$0.0194
Resistor (Axial)	1	$0.0102
Resistor (Axial)	1	$0.0204
SMD Flat Chip	35	$0.0004
SMD Flat Chip	7	$0.0011
SMD Flat Chip	12	$0.0006
Thin Film	1	$0.0224
Transformer	1	$0.2405
Transistor	1	$0.0087
Transistor	6	$0.0092
Transistor	1	$0.0153
Transistor	1	$0.0092
Transistor	1	$0.0530
Transistor	2	$0.0204
Transistor	1	$0.1223
Transistor	2	$0.0255
Transistor	1	$0.0102
Battery	1	$0.4110
BOM Total:		**$2.4569**

Table 5C-22 Bill of Materials for Battery Charger unit 703

Component	Quantity	Cost Per Component
Amplifier	1	$0.0591
Capacitor (Ceramic)	1	$0.0122
Capacitor (Ceramic)	10	$0.0034
Capacitor (Ceramic)	1	$0.0042
Capacitor (Ceramic)	4	$0.0016
Capacitor (Ceramic)	1	$0.0019
Capacitor (Electrolytic)	1	$0.0102
Capacitor (Electrolytic)	1	$0.0367
Capacitor (Electrolytic)	1	$0.0245
Capacitor (Electrolytic)	2	$0.0571
Carbon Film	1	$0.0076
Diode (Rectifier)	5	$0.0051
Diode (Rectifier)	1	$0.0066

Component	Quantity	Cost Per Component
Diode (Rectifier)	2	$0.0214
Diode (Switching)	4	$0.0025
Diode (Switching)	1	$0.0025
Diode (Zener)	3	$0.0099
Fuse (Subminiature)	1	$0.0448
Inductor	2	$0.0448
LED	1	$0.0122
Microcontroller	1	$0.7134
Optocoupler	1	$0.0561
SMD Flat Chip	6	$0.0011
SMD Flat Chip	1	$0.0006
SMD Flat Chip	62	$0.0004
Transformer	1	$0.1814
Transistor	1	$0.0132
Transistor	1	$0.0061
Transistor	1	$0.0046
Battery	1	$0.4110
BOM Total:		**$1.9907**

Table 5C-23 Bill of Materials for Battery Charger unit 706

Component	Quantity	Cost Per Component
Amplifier	2	$0.0306
Capacitor (Ceramic)	2	$0.0200
Capacitor (Ceramic)	13	$0.0200
Capacitor (Ceramic)	2	$0.0200
Capacitor (Electrolytic)	1	$0.0156
Capacitor (Electrolytic)	2	$0.0103
Diode (Rectifier)	3	$0.0025
Diode (Rectifier)	4	$0.0080
Diode (SCR)	2	$0.1804
EEPROM	1	$0.0665
Fuse	1	$0.0166
LED	1	$0.0200
LED	1	$0.0200
Microcontroller	1	$0.5000
Multiplexor	1	$0.0340
Resistor (Axial)	46	$0.0062
Resistor (Axial)	14	$0.0062
Resistor (Axial)	2	$0.0200

Component	Quantity	Cost Per Component
Resistor (Varistor)	1	$0.0412
Resonator	1	$0.0700
Transformer	1	$8.1540
Transistor	6	$0.0150
Transistor	1	$0.0150
Transistor	1	$0.0115
BOM Total:		**$10.2885**

Table 5C-24 Bill of Materials for Battery Charger unit 713

Component	Quantity	Cost Per Component
Amplifier	1	$0.0320
Capacitor (Ceramic)	1	$0.0217
Capacitor (Ceramic)	1	$0.0196
Capacitor (Ceramic)	1	$0.0318
Capacitor (Ceramic)	2	$0.0305
Capacitor (Ceramic)	17	$0.0034
Capacitor (Electrolytic)	2	$0.0115
Capacitor (Electrolytic)	2	$0.0413
Capacitor (Electrolytic)	1	$0.0114
Capacitor (Electrolytic)	1	$0.0167
Capacitor (Electrolytic)	1	$0.1219
Capacitor (Electrolytic)	1	$0.0095
Capacitor (Electrolytic)	1	$0.0099
Capacitor (Film)	1	$0.0480
Diode (Avalanche)	2	$0.0300
Diode (Rectifier)	4	$0.0100
Diode (Rectifier)	1	$0.0080
Diode (Rectifier)	1	$0.1550
Diode (Switching)	2	$0.0025
Diode (Switching)	1	$0.0079
Diode (Zener)	1	$0.0060
Fuse (Glass Tube)	1	$0.0600
Fuse (Time-Lag)	1	$0.0500
Heatsink	2	$0.1275
Inductor	1	$0.1940
LED	1	$0.0135
LED	1	$0.0120
Microcontroller	1	$0.4000
Optocoupler	1	$0.0550

Component	Quantity	Cost Per Component
Regulator	1	$0.0330
Regulator	1	$0.2749
Resistor (Axial)	2	$0.0062
Resistor (Axial)	2	$0.0058
Resistor (Axial)	1	$0.0170
Resistor (Axial)	1	$0.0100
Resistor (Varistor)	1	$0.0380
SMD Flat Chip	5	$0.0010
SMD Flat Chip	6	$0.0006
SMD Flat Chip	29	$0.0004
Thermistor	1	$0.0500
Transformer	1	$0.6520
Transistor	1	$0.0040
Transistor	1	$0.0040
Transistor	1	$0.0055
Transistor	1	$0.0070
Transistor	1	$0.0070
Transistor	1	$0.0725
Battery	1	$1.1070
BOM Total:		**$4.1926**

Table 5C-25 Bill of Materials for Battery Charger unit 715

Component	Quantity	Cost Per Component
Amplifier	1	$0.0580
Capacitor (Ceramic)	1	$0.0154
Capacitor (Ceramic)	2	$0.0369
Capacitor (Ceramic)	2	$0.0041
Capacitor (Ceramic)	8	$0.0034
Capacitor (Electrolytic)	1	$0.0972
Capacitor (Electrolytic)	1	$0.0189
Capacitor (Electrolytic)	1	$0.0095
Capacitor (Electrolytic)	1	$0.0615
Capacitor (Electrolytic)	2	$0.0135
Capacitor (Film)	1	$0.0600
Capacitor (Film)	1	$0.0480
Diode	1	$0.1600
Diode (Bridge Rectifier)	1	$0.1350
Diode (Rectifier)	1	$0.0065
Diode (Rectifier)	4	$0.0065

Component	Quantity	Cost Per Component
Diode (Switching)	8	$0.0025
Diode (Zener)	1	$0.0085
Diode (Zener)	1	$0.0085
Diode (Zener)	1	$0.0060
Fuse (Glass Tube)	1	$0.0600
Fuse (Glass Tube)	1	$0.0700
Inductor	1	$0.2290
LED	1	$0.0130
Optocoupler	2	$0.0550
Potentiometer	1	$0.0830
PWM Controller	1	$0.1000
Regulator	1	$0.0330
Resistor (Axial)	4	$0.0062
Resistor (Axial)	10	$0.0058
Resistor (Axial)	1	$0.0100
Resistor (Axial)	2	$0.0140
Resistor (Varistor)	2	$0.0300
SMD Flat Chip	26	$0.0004
Transformer	1	$0.6460
Transistor	1	$0.0045
Transistor	4	$0.0040
Transistor	1	$0.0040
Transistor	1	$0.1625
BOM Total:		**$2.5960**

Table 5C-26 Bill of Materials for Battery Charger unit 716

Component	Quantity	Cost Per Component
Amplifier	1	$0.0580
Capacitor (Ceramic)	3	$0.0092
Capacitor (Ceramic)	2	$0.0111
Capacitor (Ceramic)	1	$0.0145
Capacitor (Ceramic)	1	$0.0145
Capacitor (Ceramic)	4	$0.0162
Capacitor (Ceramic)	2	$0.0338
Capacitor (Electrolytic)	1	$0.0872
Capacitor (Electrolytic)	3	$0.0150
Capacitor (Film)	1	$0.0835
Diode (Rectifier)	4	$0.0050
Diode (Rectifier)	2	$0.0080

Component	Quantity	Cost Per Component
Diode (Rectifier)	1	$0.1320
Diode (Switching)	3	$0.0025
Diode (Zener)	1	$0.0060
Fuse (Glass Tube)	1	$0.0550
Heatsink	2	$0.1820
Inductor	1	$0.1940
Inductor	1	$0.2420
LED	1	$0.0355
LED	1	$0.0340
Microcontroller	1	$0.3300
Optocoupler	1	$0.0600
PWM Controller	1	$0.1000
Resistor (Axial)	1	$0.0155
Resistor (Axial)	39	$0.0120
Thermistor	1	$0.0440
Transformer	1	$0.5800
Transistor	1	$0.0050
Transistor	1	$0.2800
Voltage Reference	1	$0.0450
Battery	1	$1.1070
BOM Total:		**$4.6253**

Table 5C-27 Bill of Materials for Battery Charger unit 726

Component	Quantity	Cost Per Component
Amplifier	1	$0.0411
Amplifier	1	$0.2386
Capacitor (Ceramic)	6	$0.0137
Capacitor (Ceramic)	10	$0.0211
Capacitor (Ceramic)	6	$0.0168
Capacitor (Ceramic)	5	$0.0030
Capacitor (Ceramic)	7	$0.0095
Capacitor (Ceramic)	13	$0.0067
Capacitor (Ceramic)	58	$0.0091
Capacitor (Electrolytic)	4	$0.1776
Capacitor (Electrolytic)	3	$0.0590
Capacitor (Electrolytic)	2	$0.0640
Capacitor (Electrolytic)	2	$0.1884
Capacitor (Film)	1	$0.0550
Capacitor (Film)	2	$0.0050

Component	Quantity	Cost Per Component
Capacitor (Film)	2	$0.0550
Capacitor (Film)	2	$0.0550
Capacitor (Film)	2	$0.0550
Capacitor (Film)	1	$0.0100
Capacitor (Tantalum)	1	$0.0309
Crystal	1	$0.1700
Current Sense	1	$0.1257
Diode	1	$0.2274
Diode	1	$0.0071
Diode (Bridge Rectifier)	1	$0.4138
Diode (Rectifier)	2	$0.0042
Diode (Rectifier)	4	$0.0477
Diode (Rectifier)	1	$0.5889
Diode (Rectifier)	2	$0.0559
Diode (Rectifier)	2	$0.0379
Diode (Schottky Barrier)	4	$0.0459
Diode (Schottky Barrier)	1	$0.0079
Diode (Switching)	10	$0.0050
Diode (Switching)	3	$0.0065
Diode (Transient Voltage Suppressor)	1	$0.0509
Diode (Zener)	1	$0.0199
Diode (Zener)	1	$0.0071
Ferrite Bead	2	$0.0051
Fuse	2	$0.4532
Heatsink	2	$3.8890
Heatsink	2	$0.0900
Heatsink	2	$0.0500
Inductor	2	$0.2264
Inductor	2	$2.1000
Inductor	1	$2.2000
Inductor	2	$2.0600
Inductor	1	$0.0362
LED	10	$0.0300
Logic	1	$0.0390
Microcontroller	1	$1.7909
MOSFET Driver	2	$0.6131
Optocoupler	2	$0.0627
Power Factor Corrector	1	$0.8034
Regulator	1	$0.0435

Component	Quantity	Cost Per Component
Resistor (Axial)	4	$0.0375
Resistor (Axial)	3	$0.0475
Resistor (Axial)	10	$0.0175
SMD Flat Chip	24	$0.0005
SMD Flat Chip	155	$0.0008
SMD Flat Chip	2	$0.0013
SMD Flat Chip	4	$0.0013
SMPS Controller	1	$0.5315
SMPS Controller	1	$0.7913
Transformer	1	$0.3260
Transformer	1	$4.3200
Transformer	1	$0.5310
Transistor	1	$0.0156
Transistor	11	$0.0071
Transistor	1	$0.0710
Transistor	1	$0.0075
Transistor	2	$0.0027
Transistor	4	$0.5708
Transistor	7	$0.0128
Transistor	3	$0.6010
Transistor	1	$0.0227
Varistor	1	$0.4349
Voltage Detector	1	$0.0550
BOM Total:		**$41.7384**

Table 5C-28 Bill of Materials for Battery Charger unit 740

Component	Quantity	Cost Per Component
Applications Processor	1	$4.2600
Capacitor (Ceramic)	7	$0.0056
Diode (Zener)	2	$0.0117
Ferrite Bead	6	$0.0044
Inductor	1	$0.0391
Regulator	1	$0.3803
SMD Flat Chip	6	$0.0009
Battery	1	$0.2280
BOM Total:		**$5.0018**

Table 5C-29 Bill of Materials for Battery Charger unit 1007

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	17	$0.0014

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	15	$0.0020
Capacitor (Ceramic)	2	$0.0025
Capacitor (Ceramic)	7	$0.0031
Capacitor (Ceramic)	1	$0.0220
Capacitor (Tantalum)	1	$0.0500
Crystal	1	$0.1396
Diode (Rectifier)	1	$0.0264
Diode (Rectifier)	1	$0.0077
Diode (Zener)	1	$0.0269
Inductor	4	$0.0301
Power Management	1	$0.9698
Precision SMD	1	$0.0007
Regulator	1	$0.3993
Regulator	1	$0.4663
SMD Flat Chip	31	$0.0018
Thermistor	1	$0.0065
Transistor	1	$0.0291
Transistor	1	$0.1084
Transistor	3	$0.0232
Battery	1	$0.1850
BOM Total:		**$2.7630**

Table 5C-30 Bill of Materials for Battery Charger unit 1013

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	12	$0.0014
Capacitor (Ceramic)	7	$0.0013
Capacitor (Ceramic)	5	$0.0031
Capacitor (Ceramic)	4	$0.0095
Capacitor (Electrolytic)	1	$0.0852
Capacitor (Electrolytic)	1	$0.0550
Capacitor (Tantalum)	2	$0.0283
Capacitor (Tantalum)	1	$0.0361
Capacitor (Tantalum)	1	$0.0628
Capacitor (Tantalum)	1	$0.0354
Capacitor (Tantalum)	1	$0.0206
Capacitor (Tantalum)	2	$0.0809
Capacitor (Tantalum)	3	$0.0328
Diode (Rectifier)	1	$0.0089
Diode (Rectifier)	1	$0.0330

Component	Quantity	Cost Per Component
Diode (Rectifier)	2	$0.0143
Ferrite Bead	8	$0.0044
Fuse	1	$0.0613
Inductor	2	$0.0463
Inductor	1	$0.1500
LED	1	$0.0120
Power Management	1	$0.3960
Regulator	1	$0.2682
Regulator	2	$0.0590
Regulator	1	$0.0590
Regulator	1	$0.0590
Resistor (Axial)	2	$0.0066
SMD Flat Chip	31	$0.0004
SMD Flat Chip	2	$0.0008
Transistor	1	$0.0133
Transistor	1	$0.0944
Battery	1	$0.2633
BOM Total:		**$2.4119**

Table 5C-31 Bill of Materials for Battery Charger unit 1015

Component	Quantity	Cost Per Component
Analog IC	2	$0.0590
Capacitor (Ceramic)	4	$0.0145
Capacitor (Ceramic)	4	$0.0200
Capacitor (Ceramic)	12	$0.0014
Capacitor (Ceramic)	7	$0.0095
Capacitor (Electrolytic)	1	$0.0738
Capacitor (Electrolytic)	1	$0.0340
Capacitor (Tantalum)	2	$0.0628
Charger IC	1	$0.2333
Diode (Rectifier)	1	$0.0089
Diode (Rectifier)	1	$0.0287
Diode (Rectifier)	1	$0.0689
Diode (Rectifier)	1	$0.1003
Diode (Zener)	1	$0.0620
Fuse	1	$0.0613
Inductor	2	$0.0454
Inductor	1	$0.1200
LED	1	$0.0120

Component	Quantity	Cost Per Component
Regulator	1	$0.2682
Resistor (Axial)	4	$0.0126
SMD Flat Chip	23	$0.0004
SMD Flat Chip	3	$0.0005
Transistor	1	$0.1053
Transistor	2	$0.0618
Transistor	1	$0.0761
Battery	1	$0.3537
BOM Total:		**$2.3468**

Table 5C-32 Bill of Materials for Battery Charger unit 1017

Component	Quantity	Cost Per Component
Amplifier	1	$0.0424
Capacitor (Ceramic)	4	$0.0013
Capacitor (Ceramic)	12	$0.0014
Capacitor (Ceramic)	9	$0.0031
Capacitor (Ceramic)	8	$0.0095
Capacitor (Ceramic)	1	$0.0220
Capacitor (Electrolytic)	1	$0.0332
Capacitor (Electrolytic)	2	$0.0550
Diode (Rectifier)	1	$0.0226
Diode (Transient Voltage Suppressor)	1	$0.0419
Diode (Transient Voltage Suppressor)	1	$0.0630
Diode (Zener)	1	$0.0125
Ferrite Bead	2	$0.0047
Fuse	1	$0.0430
Inductor	1	$0.0500
Inductor	3	$0.0534
Inductor	1	$0.1490
LED	1	$0.0120
Power Management	1	$1.3286
Regulator	1	$0.0590
SMD Flat Chip	1	$0.0013
SMD Flat Chip	24	$0.0004
SMD Flat Chip	18	$0.0005
Transistor	1	$0.0706
Transistor	1	$0.0944
Battery	1	$0.2379
BOM Total:		**$2.7080**

Table 5C-33 Bill of Materials for Battery Charger unit 1021

Component	Quantity	Cost Per Component
Battery Charger	1	$0.3960
Capacitor (Ceramic)	2	$0.0013
Capacitor (Ceramic)	5	$0.0014
Capacitor (Ceramic)	8	$0.0095
Capacitor (Ceramic)	3	$0.0220
Capacitor (Electrolytic)	1	$0.0332
Capacitor (Electrolytic)	2	$0.0215
Diode (Glass)	1	$0.0165
Diode (Rectifier)	1	$0.0977
Diode (Rectifier)	1	$0.0685
Diode (Zener)	1	$0.0139
Ferrite Bead	4	$0.0054
Fuse	1	$0.0613
Inductor	1	$0.0500
Inductor	1	$0.1634
LED	1	$0.0120
Regulator	1	$0.0875
Resistor (Axial)	1	$0.0080
Resistor (Axial)	1	$0.0126
SMD Flat Chip	14	$0.0008
SMD Flat Chip	2	$0.0013
SMD Flat Chip	19	$0.0004
Transistor	1	$0.0042
Transistor	1	$0.0081
Transistor	2	$0.0052
Transistor	1	$0.1122
Battery	1	$0.2511
BOM Total:		**$1.6446**

Table 5C-34 Bill of Materials for Battery Charger unit 1044

Component	Quantity	Cost Per Component
Transformer	1	$0.6513
BOM Total:		**$0.6513**

Table 5C-35 Bill of Materials for Battery Charger unit 1045

Component	Quantity	Cost Per Component
Amplifier	1	$0.1754
Analog IC	2	$0.0624

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	1	$0.0020
Capacitor (Ceramic)	36	$0.0031
Capacitor (Ceramic)	3	$0.0095
Capacitor (Ceramic)	3	$0.0219
Capacitor (Ceramic)	3	$0.0314
Capacitor (Ceramic)	2	$0.0412
Capacitor (Ceramic)	1	$0.0943
Capacitor (Electrolytic)	1	$0.0315
Capacitor (Electrolytic)	1	$0.0966
Capacitor (Electrolytic)	1	$0.6530
Capacitor (Electrolytic)	2	$0.8650
Capacitor (Electrolytic)	1	$0.0146
Capacitor (Film)	1	$0.1620
Capacitor (Tantalum)	1	$0.0441
Controller	1	$0.1450
Crystal	1	$0.1400
Diode	3	$0.0550
Diode	1	$0.0080
Diode (Bridge Rectifier)	1	$0.1480
Diode (Rectifier)	1	$0.0600
Diode (Rectifier)	1	$0.4360
Diode (Schottky Barrier)	2	$0.3000
Diode (Schottky Barrier)	1	$0.2890
Diode (Switching)	4	$0.0085
Diode (Switching)	4	$0.0140
Diode (Zener)	4	$0.0300
Diode (Zener)	9	$0.0350
Diode (Zener)	1	$0.0380
Diode (Zener)	4	$0.0400
Fan	1	$2.1400
Fuse	1	$0.1300
Fuse	1	$0.1100
Heatsink	2	$0.1915
Inductor	1	$0.6180
Inductor	1	$0.3600
LED	3	$0.0200
Microcontroller	1	$0.7890
Microcontroller	1	$0.6061
Optocoupler	3	$0.0594

Component	Quantity	Cost Per Component
Potentiometer	1	$0.0500
Precision SMD	4	$0.0008
Precision SMD	2	$0.0010
Regulator	1	$0.0449
Resistor (Axial)	2	$0.0100
Resistor (Axial)	1	$0.0082
Resistor (Axial)	2	$0.0050
SMD Flat Chip	106	$0.0005
SMD Flat Chip	12	$0.0008
SMD Flat Chip	12	$0.0013
Thermistor	3	$0.0367
Transformer	1	$1.2000
Transformer	1	$0.2516
Transistor	1	$0.0157
Transistor	3	$0.0090
Transistor	7	$0.0180
Transistor	1	$0.0157
Transistor	1	$0.0144
Transistor	1	$0.6900
Transistor	4	$0.0095
Transistor	1	$0.0125
Transistor	1	$0.0105
Transistor	1	$0.0080
Transistor	2	$0.0220
Varistor	1	$0.1500
Wirewound	1	$0.1680
Battery	1	$1.2302
BOM Total:		**$15.9280**

Table 5C-36 Bill of Materials for Battery Charger unit 1046

Component	Quantity	Cost Per Component
Amplifier	1	$0.0700
Analog IC	1	$0.1730
Capacitor (Ceramic)	2	$0.1000
Capacitor (Ceramic)	1	$0.0100
Capacitor (Ceramic)	1	$0.0431
Capacitor (Ceramic)	1	$0.0213
Capacitor (Ceramic)	13	$0.0031
Capacitor (Electrolytic)	1	$0.0164

Component	Quantity	Cost Per Component
Capacitor (Electrolytic)	1	$0.0352
Capacitor (Electrolytic)	1	$0.0352
Capacitor (Electrolytic)	1	$0.0200
Capacitor (Electrolytic)	1	$0.0240
Capacitor (Electrolytic)	1	$0.3061
Capacitor (Electrolytic)	1	$0.3561
Capacitor (Electrolytic)	1	$0.0214
Diode	1	$0.0080
Diode (Glass)	4	$0.0085
Diode (Rectifier)	1	$0.0348
Diode (Rectifier)	5	$0.0063
Diode (Rectifier)	1	$0.0308
Diode (Rectifier)	1	$0.2750
Fuse	1	$0.1400
Heatsink	2	$0.0700
Inductor	1	$0.5610
LED	2	$0.0200
Optocoupler	1	$0.0594
Power Supply	1	$0.2100
Precision SMD	2	$0.0008
Precision SMD	3	$0.0010
Regulator	1	$0.1500
Resistor (Axial)	1	$0.0100
Resistor (Axial)	3	$0.0082
Resistor (Ceremic)	1	$0.0020
SMD Flat Chip	18	$0.0005
SMD Flat Chip	18	$0.0008
SMD Flat Chip	24	$0.0013
Transformer	1	$0.4600
Transistor	2	$0.0080
Transistor	1	$0.0050
Transistor	3	$0.0200
Varistor	1	$0.1500
Voltage / Current Control IC	1	$0.1397
Wirewound	1	$0.1300
Battery	1	$0.4921
BOM Total:		**$4.6354**

Table 5C-37 Bill of Materials for Battery Charger unit 1047

Component	Quantity	Cost Per Component
Analog IC	1	$0.3472
Capacitor (Ceramic)	20	$0.0014
Capacitor (Ceramic)	16	$0.0020
Capacitor (Ceramic)	4	$0.0025
Capacitor (Ceramic)	9	$0.0031
Capacitor (Ceramic)	1	$0.0095
Capacitor (Ceramic)	1	$0.0220
Capacitor (Tantalum)	1	$0.0925
Capacitor (Tantalum)	1	$0.0734
Capacitor (Tantalum)	1	$0.0852
Crystal	1	$0.1396
Diode (Rectifier)	2	$0.0284
Diode (Rectifier)	1	$0.0735
Fuse	1	$0.0060
Inductor	4	$0.0312
Inductor	1	$0.0478
Power Management	1	$1.4865
Precision SMD	1	$0.0029
Regulator	1	$0.5435
Regulator	1	$1.1000
SMD Flat Chip	2	$0.0004
SMD Flat Chip	1	$0.0005
SMD Flat Chip	44	$0.0018
Transistor	2	$0.0640
Transistor	3	$0.0598
Battery	1	$0.1931
BOM Total:		**$4.8888**

Table 5C-38 Bill of Materials for Battery Charger unit 1051

Component	Quantity	Cost Per Component
Capacitor (Ceramic)	3	$0.0095
Capacitor (Electrolytic)	1	$0.0121
Capacitor (Electrolytic)	1	$0.0201
Capacitor (Electrolytic)	1	$0.0200
Capacitor (Electrolytic)	1	$0.0214
Capacitor (Electrolytic)	1	$0.0260
Diode (Rectifier)	5	$0.0085
Diode (Rectifier)	1	$0.0200
Diode (Rectifier)	1	$0.0235

Component	Quantity	Cost Per Component
Diode (Switching)	2	$0.0063
Diode (Switching)	1	$0.0120
Diode (Transistor)	1	$0.0350
Inductor	1	$0.1230
LED	1	$0.0316
Regulator	1	$0.1315
Resistor (Axial)	3	$0.0050
Resistor (Axial)	1	$0.0361
SMD Flat Chip	10	$0.0005
SMD Flat Chip	32	$0.0008
SMD Flat Chip	16	$0.0013
Transformer	1	$0.7650
Transistor	2	$0.0050
Transistor	6	$0.0099
Transistor	1	$0.0350
Transistor	1	$0.1800
Transistor	1	$0.3300
Voltage Comparator	1	$0.0580
Voltage Comparator	1	$0.0612
Battery	1	$0.5393
BOM Total:		**$2.7003**

Table 5C-39 Bill of Materials for Battery Charger unit 1058

Component	Quantity	Cost Per Component
Amplifier	1	$0.0371
Regulator	1	$0.1062
Regulator	1	$0.1115
Capacitor (Ceramic)	2	$0.0242
Capacitor (Ceramic)	1	$0.0502
Capacitor (Ceramic)	4	$0.0161
Capacitor (Ceramic)	3	$0.0102
Capacitor (Ceramic)	1	$0.0112
Capacitor (Electrolytic)	2	$0.1191
Capacitor (Electrolytic)	1	$0.1151
Capacitor (Electrolytic)	3	$0.0129
Capacitor (Electrolytic)	2	$0.0112
Capacitor (Electrolytic)	2	$0.0187
Capacitor (Film)	1	$0.0144
Capacitor (Film)	2	$0.0201

Component	Quantity	Cost Per Component
Capacitor (Film)	1	$0.0165
Capacitor (Film)	1	$0.0611
Capacitor (Film)	1	$0.1224
Diode (Bridge Rectifier)	1	$0.1375
Diode (Glass)	4	$0.0165
Diode (Rectifier)	1	$0.1076
Diode (Rectifier)	2	$0.0716
Diode (Rectifier)	11	$0.0978
Diode (Zener)	1	$0.0120
Fan	1	$0.8875
Fuse	1	$0.1062
LED	2	$0.0200
Inductor	1	$0.4312
Inductor	1	$0.0341
Inductor	1	$0.1844
Transformer	2	$0.5539
Resistor (Axial)	7	$0.0100
Resistor (Axial)	3	$0.0142
Resistor (Axial)	10	$0.0082
Resistor (Axial)	30	$0.0050
Resistor (Axial)	1	$0.0361
Resistor (Axial)	1	$0.0661
Formed Bare Wire	1	$0.0243
Jumper Wire	1	$0.3178
Potentiometer	2	$0.0441
Thermistor	1	$0.3178
Thermistor	1	$0.0622
Varistor	1	$0.0416
Transistor	1	$0.0120
Transistor	2	$0.2826
Transistor	4	$0.0150
BOM Total:		**$7.4353**

APPENDIX 7A. BATTERY CHARGER AND EXTERNAL POWER SUPPLY USAGE PROFILES

LIST OF TABLES

This appendix lists the assumptions used to calculate reference-case unit energy consumption values for external power supplies (Table 7A.1) and battery chargers (Table 7A.2). Applications states, usage profiles, and loading points used to calculate UECs for the low-savings and high-savings sensitivity analyses can be found in Appendix 8B. Applications are ordered by product category, per the diagram found in Appendix 3A. Sources for all of the usage profiles below can be found in the Excel workbook that accompanies chapter 7. For a discussion on how these values were derived and used, see chapter 7 of the technical support document for battery chargers and external power supplies.

Table 7A.1 Application States, Loading Points, and Weekly Usage Values Used to Calculate Energy Consumption for Class A External Power Supplies

Application	**Application State 1**		**Application State 2**		**Applications State 3**		**Application State 4**		**Application State 5**		**Application State 6**		**No Load [hrs/wk]**	**Unplugged [hrs/wk]**
	Loading Point	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**		
Amateur Radios (Res)	Active – Operational		Active – Receiving		Active – Standby						Off			
	60.0%	2.7	20.0%	2.7	20.0%	46.2					1.0%	116.4		
Pre-Amps (Res)	Active								Idle		Sleep/Off			
	60.0%	6.7							2.0%	40.3	1.0%	121		
Wireless Speakers (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Guitar Effects Pedals (Res)	Active								Idle					160.0
	60.0%	5.0							2.00%	3.0				
Keyboards (Res)	Active								Idle		Sleep/Off			
	60.0%	5.0							2.00%	3.0	1.00%	160.0		
MP3 Speaker Docks (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Clock Radios (Res)	Active													
	60.0%	168.0												
Clock Radios (Comm)	Active													
	60.0%	168.0												

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
Wireless Headphones (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
MP3 Players (Res)					Charging		Maintenance						59.5	56.0
					37.1%	10.1	17.2%	42.4						
Personal Digital Assistants (Res)					Charging		Maintenance						59.5	84.0
					37.1%	4.0	17.2%	20.5						
Personal Digital Assistants (Comm)					Charging		Maintenance						59.5	84.0
					37.1%	4.0	17.2%	20.5						
Netbooks (Res)*	On – Charging				Off – Charging		On – Not Charging		Sleep		Off			42.4
	66.3%	5.8			38.2%	5.8	28.1%	18.2	1.3%	6.0	0.6%	90.0		
Netbooks (Comm)*	On – Charging				Off – Charging		On – Not Charging		Sleep		Off			42.4
	66.3%	5.8			38.2%	5.8	28.1%	18.2	1.3%	6.0	0.6%	90.0		
Notebooks (Res)*	On – Charging		On – DVD playing		Off – Charging		On – Not Charging		Sleep		Off			26.6
	66.3%	4.1	57.1%	5.2	38.2%	4.1	28.1%	25.0	1.3%	21.8	0.6%	81.1		
Notebooks (Comm)*	On – Charging		On – DVD playing		Off – Charging		On – Not Charging		Sleep		Off			12.8
	66.3%	4.1	57.1%	5.3	38.2%	2.7	28.1%	35.6	1.3%	35.6	0.6%	73.4		
Media Tablets (Res)					Charging		Maintenance						59.5	56.0
					37.1%	10.1	17.2%	42.4						
Media Tablets (Comm)					Charging		Maintenance						11.0	133.0
					37.1%	10.0	17.2%	14.0						
Computer Speakers (Res)	Active										Off			
	60.0%	63.3									1.0%	104.7		
Computer Speakers	Active										Off			
	60.0%	63.3									1.0%	104.7		

Application	**Application State 1**		**Application State 2**		**Applications State 3**		**Application State 4**		**Application State 5**		**Application State 6**		**No Load [hrs/wk]**	**Unplugged [hrs/wk]**
	Loading Point	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**		
External Hard Drives (Res)	Active								Idle				63.0	63.0
	60.0%	21.0							2.0%	21.0				
External Hard Drives (Comm)	Active								Idle				63.0	63.0
	60.0%	21.0							2.0%	21.0				
LED Monitors (Res)	Active								Idle		Sleep/Off			
		35.7								16.7		115.6		
LED Monitors (Comm)	Active								Idle		Sleep/Off			10.0
		66.4								70.5		21.1		
Image Scanners (Res)	Active								Idle		Sleep/Off			
	60.0%	5.0							2.0%	3.0	1.0%	160.0		
Image Scanners (Comm)					Charging		Maintenance						3.5	
					37.1%	7.0	17.2%	157.5						
Ink Jet Imaging Equipment (Res)	Active								Ready		Off			
	60.0%	5.1							15.2%	11.4	10.3%	151.6		
Ink Jet Imaging Equipment (Comm)	Active								Ready		Off			10.3
	60.0%	6.2							15.2%	116.9	10.3%	34.7		
Portable Printers (Res)					Charging		Maintenance							164.5
					37.1%	1.4	17.2%	2.1						
Portable Printers (Comm)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
E-Books (Res)					Charging		Maintenance						11.0	133.0
					37.1%	10.0	17.2%	14.0						
Mobile Internet Hotspots (Res)					Charging		Maintenance						11.0	133.0
					37.1%	10.0	17.2%	14.0						

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
Mobile Internet hotspots (Comm)					Charging		Maintenance						11.0	133.0
					37.1%	10.0	17.2%	14.0						
LAN Equipment (Res)*					On									
					45.5%	168.0								
LAN Equipment (Comm)*					On									
					45.5%	168.0								
In-Vehicle GPS (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Handheld GPS (Res)					Charging		Maintenance							164.5
					37.1%	1.4	17.2%	2.1						
Bluetooth Headsets (Res)					Charging		Maintenance							77.0
					37.1%	6.0	17.2%	85.0						
Bluetooth Headsets (Comm)					Charging		Maintenance							77.0
					37.1%	6.0	17.2%	85.0						
Consumer Two-Way Radios (Res)					Charging		Maintenance							164.5
					37.1%	1.4	17.2%	2.1						
Consumer Two-Way Radios (Comm)					Charging		Maintenance						84.3	
					37.1%	31.9	17.2%	51.8						
Mobile Phones (Res)*					Charging		Maintenance						49.0	77.0
					42.7%	20.9	23.9%	21.1						
Mobile Phones (Comm)*					Charging		Maintenance						25.2	100.8
					42.7%	20.9	23.9%	21.1						
Smartphone (Res)					Charging		Maintenance						45.9	71.8
					42.7%	17.9	23.9%	32.3						

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
Smartphone (Comm)					Charging		Maintenance						23.5	94.2
					42.7%	17.9	23.9%	32.3						
Caller ID Devices (Res)	Active													
	60.0%	168.0												
Cordless Phones (Res)*					Charging		Maintenance		No Battery					
					32.9%	58.8	27.4%	94.1	14.1%	15.1				
Cordless Phones (Comm)*					Charging		Maintenance		No Battery					
					32.9%	58.8	27.4%	94.1	14.1%	15.1				
Answering Machines*					Charging		Maintenance		No Battery					
					32.9%	58.8	27.4%	94.1	14.1%	15.1				
Answering Machines*					Charging		Maintenance		No Battery					
					32.9%	58.8	27.4%	94.1	14.1%	15.1				
VoIP Adapters (Res)	Transmitting								Idle					
	60.0%	7.0							2.0%	161.0				
Baby Monitors (Res)					Charging		Maintenance						3.5	
					37.1%	7.0	17.2%	157.5						
Breast Pumps (Res)	Active								Idle					160.0
	60.0%	5.0							2.0%	3.0				
RC Toys (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Portable Video Game Systems (Res)*					Charging				Maintenance				59.5	56.0
					35.1%	3.9			2.4%	48.6				
Video Game Consoles (Res)*	Video Game - Active		Video Game - Idle		DVD – Active		DVD – Idle		No Disc – Idle		Off			
	50.6%	15.7	50.0%	10.7	46.8%	1.7	46.8%	2.9	42.6%	2.9	1.2%	134.1		

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
Handheld Vacuums (Res)					Charging		Maintenance		No Battery					
					37.1%	8.0	17.2%	159.0	14.1%	1.0				
Robotic Vacuums (Res)					Charging		Maintenance						3.5	
					37.1%	7.0	17.2%	157.5						
Stick Vacuums (Res)					Charging		Maintenance		No Battery					
					37.1%	8.0	17.2%	159.0	14.1%	1.0				
Home Security Systems (Res)							Maintenance							
							17.0%	168.0						
Irrigation Timers (Res)	Active													
	60.0%	168.0												
Water Softeners/Purifiers (Res)	Active								Idle		Sleep/Off			
	60.0%	5.0							2.0%	3.0	1.0%	160.0		
Blenders (Res)					Charging		Maintenance							164.5
					37.1%	1.4	17.2%	2.1						
Can Openers (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Mixers (Res)					Charging		Maintenance							164.5
					37.1%	1.4	17.2%	2.1						
Camcorders (Res)					Charging		Maintenance						1.9	164.2
					37.1%	0.8	17.2%	1.1						
Digital Cameras (Res)					Charging		Maintenance						3.7	161.0
					37.1%	1.3	17.2%	2.0						
Digital Cameras (Comm)					Charging		Maintenance						59.5	56.0
					37.1%	10.1	17.2%	42.4						

Application	**Application State 1**		**Application State 2**		**Applications State 3**		**Application State 4**		**Application State 5**		**Application State 6**		**No Load [hrs/wk]**	**Unplugged [hrs/wk]**
	Loading Point	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**	**Loading Point**	**Usage [hrs/wk]**		
Digital Picture Frames (Res)	Active													
	60.0%	168.0												
Digital Picture Frames (Comm)	Active													
	60.0%	168.0												
Portable DVD Players (Res)	Operating - High		Idle		Charging - Application Off		Off - BC in Maint. Mode							140.0
	60.0%	0.3	54.0%	6.7	37.1%	0.8	1.0%	20.2						
Wireless Charging Stations (Res)					Charging		Maintenance						59.5	56.0
					37.1%	10.1	17.2%	42.4						
Wireless Charging Stations (Comm)					Charging		Maintenance						59.5	56.0
					37.1%	10.1	17.2%	42.4						
Air Mattress Pumps (Res)					Charging		Maintenance							164.5
					1.4%	10.1	2.1%	42.4						
Aquarium Accessories (Res)	Active													
	60.0%	168.0												
Aquarium Accessories (Comm)	Active													
	60.0%	168.0												
Indoor Fountains (Res)	Active													
	60.0%	168.0												
Flashlights/Lanterns (Res)					Charging		Maintenance						0.1	82.2
					37.1%	1.5	17.2%	84.2						
Universal Battery Chargers (Res.)					Charging		Maintenance		No Battery					28.0
					37.1%	3.0	17.2%	109.0	2.0%	28.0				
Rechargeable Garden Care Products (Res.)					Charging		Maintenance						0.4	124.6
					37.1%	3.5	17.2%	29.6						

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
Rechargeable Toothbrushes (Res)					Charging		Maintenance							22.6
					37.1%	20.7	17.2%	124.0	14.1%	0.7				
Rechargeable Water Jets (Res)					Charging		Maintenance							22.6
					37.1%	20.7	17.2%	124.0	14.1%	0.7				
Beard and Mustache Trimmers (Res)	Active - Application in Use				Charging		Maintenance							161.0
	60.0%	0.1			37.1%	2.7	17.2%	4.2						
Hair Clippers (Res)	Active - Application in Use				Charging		Maintenance							161.0
	60.0%	0.1			37.1%	2.7	17.2%	4.2						
Shavers (Res)	Active - Application in Use				Charging		Maintenance						14.2	54.7
	60.0%	0.6			37.1%	11.1	17.2%	87.4						
Sleep Apnea Machines (Res)	Active - Operating								Active – Idle					
	60.0%	56.0							2.0%	112.0				
Medical Nebulizers (Res)	Active – Nebulizing								Idle		Off			
	60.0%	2.3							10.0%	151.9	2.0%	13.8		
Portable 02 Concentrators (Res)					Charging		Maintenance							161.0
					37.1%	2.8	17.2%	4.2						
Blood Pressure Monitors (Res)	Active													
	60.0%	168.0												
DIY Power Tools (Integral) (Res)					Charging		Maintenance						4.3	76.4
					37.1%	3.7	17.2%	83.5						
DIY Power Tools (Integral) (Comm)					Charging		Maintenance						31.5	57.8
					37.1%	70.0	17.2%	8.8						

Application	Application State 1		Application State 2		Applications State 3		Application State 4		Application State 5		Application State 6		No Load [hrs/wk]	Unplugged [hrs/wk]
	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]	Loading Point	Usage [hrs/wk]		
DIY Power Tools (External) (Res)					Charging		Maintenance		No battery					130.5
					37.1%	9.5	17.2%	21.7	14.1%	6.3				
DIY Power Tools (External) (Comm)					Charging		Maintenance		No battery					57.8
					37.1%	70.0	17.2%	8.8	14.1%	31.5				
Electric Scooters					Charging		Maintenance						59.5	56.0
					37.1%	24.0	17.2%	84.5						
Motorized Bicycles					Charging		Maintenance						59.5	56.0
					37.1%	24.0	17.2%	84.5						

Note: Total hours of use may not sum to 168 due to rounding.
*Loading points derived from DOE test data.

Table 7A.2 Daily Usage Values Used to Calculate Energy Consumption for Battery Chargers

Application	Active + Maintenance [hrs/day]	No battery (Standby) [hrs/day]	Off [hrs/day]	Unplugged [hrs/day]	Charges/Day
Wireless Speakers (Res.)	1.00			23.00	0.14
MP3 Speaker Docks (Res.)	1.00			23.00	0.14
Wireless Headphones (Res.)	1.00			23.00	0.14
MP3 Players (Res.)	7.50	8.50		8.00	0.55
Personal Digital Assistants (Res.)	3.50	8.50		12.00	0.29
Personal Digital Assistants (Comm.)	3.50	8.50		12.00	0.29
Netbooks (Res.)	18.84	0.06		5.10	0.64
Netbooks (Comm.)	18.00			6.00	0.71
Notebooks (Res.)	20.50	1.50		2.00	0.28
Notebooks (Comm.)	19.39	0.11		4.50	0.59
Media Tablets (Res.)	7.50	8.50		8.00	0.29
Media Tablets (Comm.)	3.50	1.50		19.00	0.29
Uninterruptible Power Supplies (Res.)	24.00				0.00
Uninterruptible Power Supplies (Comm.)	24.00				0.00
Handheld Image Scanners (Res.)	1.00			23.00	0.14
Handheld Image Scanners (Comm.)	1.00			23.00	0.14
Portable Printers (Res.)	0.50			23.50	0.07
Portable Printers (Comm.)	1.00			23.00	0.14
E-Books (Res.)	3.50	1.50		19.00	0.29
Mobile Internet Hotspots (Res.)	3.50	1.50		19.00	0.29
Mobile Internet Hotspots (Comm.)	3.50	1.50		19.00	0.29
LAN Equipment (Res.)	24.00				0.02
LAN Equipment (Comm.)	24.00				0.02
In-Vehicle GPS (Res.)	1.00			23.00	0.14
Handheld GPS (Res.)	0.50			23.50	0.07
Bluetooth Headsets (Res.)	13.00			11.00	0.43
Bluetooth Headsets (Comm.)	13.00			11.00	0.43

Application	Active + Maintenance [hrs/day]	No battery (Standby) [hrs/day]	Off [hrs/day]	Unplugged [hrs/day]	Charges/Day
Consumer Two-Way Radios (Res.)	0.50	0.50		23.00	0.02
Consumer Two-Way Radios (Comm.)	12.00	12.00			1.00
Mobile Phones (Res.)	6.00	7.00		11.00	0.71
Mobile Phones (Comm.)	6.00	3.60		14.40	0.71
Smartphone (Res.)	7.18	6.56		10.26	0.80
Smartphone (Comm.)	7.18	3.36		13.46	0.80
Cordless Phones (Res.)	21.84	2.16			0.71
Cordless Phones (Comm.)	21.84	2.16			0.71
Answering Machines (Res.)	21.84	2.16			0.71
Answering Machines (Comm.)	21.84	2.16			0.71
VoIP Adapters (Res.)	24.00				0.02
Baby Monitors (Res.)	23.50	0.50			0.14
RC Toys (Res.)	1.00			23.00	0.14
Portable Video Game Systems (Res.)	7.50	8.50		8.00	0.29
Video Game Consoles (Res.)	1.00			23.00	0.14
Handheld Vacuums (Res.)	23.90	0.10			0.20
Robotic Vacuums (Res.)	23.50	0.50			0.50
Stick Vacuums (Res.)	23.90	0.10			0.20
Home Security Systems (Res.)	24.00				0.02
Blenders (Res.)	0.50			23.50	0.07
Can Openers (Res.)	1.00			23.00	0.14
Mixers (Res.)	0.50			23.50	0.07
Camcorders (Res.)	0.27	0.27		23.46	0.04
Digital Cameras (Res.)	0.47	0.53		23.00	0.07
Digital Cameras (Comm.)	7.50	8.50		8.00	0.58
Portable DVD Players (Res.)	4.00			20.00	0.04
Air Mattress Pumps (Res.)	0.50			23.50	0.07
Flashlights/Lanterns (Res.)	12.25	0.01		11.75	0.02

Application	Active + Maintenance [hrs/day]	No battery (Standby) [hrs/day]	Off [hrs/day]	Unplugged [hrs/day]	Charges/Day
Universal Battery Chargers (Res.)	16.00	4.00		4.00	0.07
Rechargeable Garden Care Products (Res.)	6.15	0.05		17.80	0.05
Lawn Mowers (Res.)	22.00	2.00			0.05
Rechargeable Toothbrushes (Res.)	20.66	0.10		3.24	0.15
Rechargeable Water Jets (Res.)	20.66	0.10		3.24	0.15
Beard and Moustache Trimmers (Res.)	1.00			23.00	0.14
Hair Clippers (Res.)	1.00			23.00	0.14
Shavers (Res.)	14.15	2.03		7.82	0.19
Sleep Apnea Machines (Res.)	24.00				0.02
Medical Nebulizers (Res.)	1.00			23.00	0.14
Portable O2 Concentrators (Res.)	1.00			23.00	0.14
DIY Power Tools (Integral) (Res.)	12.46	0.62		10.92	0.06
DIY Power Tools (Integral) (Comm.)	11.25	4.50		8.25	0.72
DIY Power Tools (External) (Res.)	4.46	0.90		18.65	0.18
DIY Power Tools (External) (Comm.)	11.25	4.50		8.25	1.43
Professional Power Tools (Res.)	7.85	1.30		14.85	0.31
Professional Power Tools (Comm.)	11.25	4.50		8.25	1.43
Electric Scooters (Res.)	15.50	8.50			0.43
Motorized Bicycles (Res.)	15.50	8.50			0.43
Golf Carts (Res.)	11.45	0.30		12.25	0.05
Golf Carts (Comm.)	7.74	8.13		8.13	0.36
Toy Ride-On Vehicles (Res.)	3.91	0.10		20.00	0.07
Wheelchairs (Res.)	12.00	12.00			0.70
Mobility Scooters (Res.)	12.00	12.00			0.70
Marine/Automotive/RV Chargers (Res.)	22.00	2.00			0.05

APPENDIX 8A. USER INSTRUCTIONS FOR LCC AND PBP SPREADSHEETS

TABLE OF CONTENTS

APPENDIX 8A. USER INSTRUCTIONS FOR LCC AND PBP SPREADSHEETS

8A.1 INTRODUCTION

It is possible to examine and reproduce the detailed results of the life-cycle cost (LCC) and payback period (PBP) analyses using Microsoft Excel® spreadsheets available on the U.S. Department of Energy (DOE) website at: http://www.eere.energy.gov/buildings/appliance_standards/.

Running the spreadsheet sample calculations requires Microsoft Excel. Additionally, Crystal Ball® software is required to run the Monte Carlo simulations. Both applications are commercially available. Crystal Ball is available at http://www.decisioneering.com.

The spreadsheets posted on the DOE website represent the latest versions and have been tested with Microsoft Excel 2007 and Crystal Ball 11.1.1.1.00.

8A.2 LCC AND PBP WORKBOOK

The LCC and PBP spreadsheet or workbook consists of the following worksheets:

App. Sample Calc. Summary	Presents shipment-weighted results for the application-specific Sample Calculation. The application-specific sample calculation “run” button on the LCC Summary worksheet must be clicked first to populate the results.
Application LCC Results	Presents LCC and PBP results for each application within a representative unit or product class.
Avg. Sample Calc. Summary	Presents results for the basic Sample Calculation. These results are based on a Sample Calculation for each representative unit or product class where application-specific inputs are averaged *prior* to calculation.
LCC Summary	Contains the input selections and summary tables of energy use, operating costs, LCC, and PBP for each selection. This worksheet also works as an interface between user inputs and the rest of the worksheets.
Setup	Contains tables listing the contents of the menus shown in the "LCC Summary" worksheet along with indicators showing the current user selections.
Cash Flows	Contains the undiscounted cash flows for each unit, the electricity prices for each year, and the discount factor applied to each year.

Variables	Contains a list of the major variables (Excel defined names) used in the LCC model, along with their values.
Rep Unit Summary	Contains a list of the parameters for the representative units and product classes.
NCA EPS Input Selection	Contains the inputs for the Non-Class A External Power Supply scenario chosen.
Direct Operation EPS Input Selection	Contains the inputs for the Direct Operation External Power Supply scenario chosen.
BC Input Selection	Contains the inputs for the Battery Charger scenario chosen.
Non-Class A EPS Inputs	Contains all Non-Class A External Power Supply product information, such as unit energy consumption (UEC), markups, and lifetimes for each input scenario.
Direct Op. EPS Inputs	Contains all Direct Operation External Power Supply product information, such as unit energy consumption (UEC), markups, and lifetimes for each input scenario.
BC Inputs	Contains Battery Charger product information, such as UEC, markups, and lifetimes for each input scenario.
Application Data	Contains a summary of all the application-specific data from the input sheets so that applications can be sampled in the LCC model.
Lifetime	Contains information on the lifetimes of the units so that a lifetime estimate can be selected for input into the LCC model.
Markups	Contains information related to the price markups used in the analysis, including sales tax.
Unit Price	Contains information used in the development of unit purchase prices, including markups and sales tax.
Maintenance Cost	Contains information used in the development of maintenance cost estimates for selected representative units and product classes.
Base Case Eff Dist	Contains tables of the unit base case efficiency distributions sampled for each representative unit and product class so that the CSLs of the baseline units can be determined.

Discount Rate	Contains information used to develop the discount rate for the LCC analysis.
Gas Prices	Contains gasoline price data, engine efficiency assumptions, and consumer price indices used to develop the gasoline prices for the LCC and PBP analyses for Battery Charger product class 9 (DC-DC, ≥9 V Input).
Elec Prices	Contains electricity price data and consumer price indices used to develop the electricity prices for the LCC and PBP analyses.
Elec Price Trends	Contains data used to develop the electricity price trends for projection of electricity prices into the future.

8A.3 BASIC INSTRUCTIONS

Basic instructions for operating the LCC spreadsheets are as follows:

1. Once you have downloaded the LCC file from the Web, open the file using Excel. At the bottom, click on the tab for sheet LCC Summary.

2. Use Excel’s “View/Zoom” commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user interacts with the spreadsheet by clicking choices or entering data using the interface that comes with the spreadsheet. Select choices from the various inputs listed under "User Input" heading.

4. Under the "User Input" heading, select choices from the selection buttons and boxes for the following: (1) Type of calculation (Sample Calculation or Crystal Ball), (2) Run the application-specific sample calculation, (3) Energy Price Trend, (4) Start Year, (5) Sector, (6) Lifetime, (7) Market Distribution, (8) Energy Usage Scenario, and (9) LCC Subgroups (Low Income Consumers, Small Businesses, and Top Tier Marginal Electricity Prices). Under the “Application Selection” heading, the user can select a specific application to examine within a given representative unit or product class.

5. To change inputs listed under "User Input", select the input you wish to change by either clicking on the appropriate button or selecting the appropriate input from the input box.

6. This spreadsheet gives the user three types of calculation methods:
    a. If the "Sample Calculation" is selected, then all calculations are performed for single input values, usually an average. This calculation averages all application-specific data *prior* to performing calculations. The new results are shown on the same sheet as soon as the new values are entered, and are summarized on the “Avg. Sample Calc. Summary” tab.

b. If "Crystal Ball" is selected, the spreadsheet generates results that are distributions. Some of the inputs are also distributions. The results from the LCC distribution are shown as single values and refer only to the results from the last Monte Carlo sample and are therefore not meaningful. To run the distribution version of the spreadsheet, the Microsoft Excel add-in software called Crystal Ball must be enabled.

c. If the “Run” button next to “Application-Specific Sample Calculation” is clicked, the spreadsheet will execute a macro to perform a sample calculation on each individual application within a representative unit or product class. Each run typically takes 5-20 minutes to finish. Once finished, results will be presented in the “Application LCC Results” worksheet, and summarized in the “App. Sample Calc. Summary” worksheet. The shipment-weighted results of this sample calculation differ from the basic “Sample Calculation” in that application inputs are not averaged prior to performing calculations. This methodology generates results that better approximate Crystal Ball results than the basic “Sample Calculation” tool.

To produce sensitivity results using Crystal Ball, simply select Run from the Run menu (on the menu bar). To make basic changes in the run sequence, including altering the number of trials, select Run Preferences from the Run menu. After each simulation run, the user needs to select Reset (also from the Run menu) before Run can be selected again. Once Crystal Ball has completed its run sequence it will produce a series of distributions. Using the menu bars on the distribution results, it is possible to obtain further statistical information. The time taken to complete a run sequence can be reduced by minimizing the Crystal Ball window in Microsoft Excel. A step-by-step summary of the procedure for running a distribution analysis is outlined below:

1. Find the Crystal Ball toolbar (at top of screen)

2. Click on Run from the menu bar

3. Select Run Preferences and choose from the following choices:
   a. Monte Carlo[a]
   b. Latin Hypercube (recommended)
   c. Initial seed choices and whether you want it to be constant between runs
   d. Select number of Monte Carlo Trials

4. To run the simulation, select the green right arrow (“Start Simulation”) button on the Crystal Ball toolbar or select “Start Simulation” from the Run menu.

5. Now wait until the program informs you that the simulation is completed. Note that to run a new simulation, “Reset Simulation” must first be selected from the Run menu.

The following instructions are provided to view the output generated by Crystal Ball.

---

[a] Because of the nature of the program, there is some variation in results due to random sampling when Monte Carlo or Latin Hypercube sampling is used.

1. After the simulation has finished, to see the distribution charts generated, select the Crystal Ball window in the task bar.

2. The life-cycle cost savings and payback periods are defined as Forecast cells. The frequency charts display the results of the simulations, or trials, performed by Crystal Ball. Click on any chart to bring it into view. The charts show the low and high endpoints of the forecasts. The View selection on the Crystal Ball toolbar can be used to specify whether you want cumulative or frequency plots shown.

3. To calculate the probability that a particular value of LCC savings will occur, either type “0” in the box by the left arrow, or move the arrow key with the cursor to “0” on the scale. The value in the Certainty box shows the likelihood that the LCC savings will occur. To calculate the certainty of payback period being below a certain number of years, choose that value as the high endpoint.

4. To generate a printout report, select Create Report from the Run menu and then select the charts and statistics that you are interested in. For further information on Crystal Ball outputs, please refer to Understanding the Forecast Chart in the Crystal Ball manual.

APPENDIX 8B. SUPPLEMENTARY LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 8B. SUPPLEMENTARY LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

8B.1 INTRODUCTION

This appendix discusses uncertainty and variability analyses and presents results for various input scenarios other than the reference case scenario presented in chapter 8. Results for the reference case of the life-cycle cost (LCC) and payback period (PBP) analysis using a distribution of unit energy consumption amounts, discount rates, sales tax, and electricity prices are presented in chapter 8. The average LCC savings for non-reference scenarios at each efficiency level (EL) for each battery charger (BC) and external power supply (EPS) design are presented in this appendix. DOE also presents the median PBP because it is the most statistically robust measure of the PBP.

This appendix presents the LCC and PBP analysis results using high- and low-economic-growth electricity price trends, as well as electricity price trends based on a carbon cap and trade scenario. These datasets were generated using the Energy Information Administration's (EIA's) *Annual Energy Outlook 2010* (*AEO2010*) and the S.2191 report accompanying the Lieberman-Warner Climate Security Act of 2007 (S2191), respectively.

8B.2 INTRODUCTION TO UNCERTAINTY AND VARIABILITY

Analysis of an energy-efficiency standard involves calculations of impacts, for example, the impact of a standard on consumer LCC. In order to perform the calculation, the analyst must first: 1) specify the equation or model that will be used; 2) define the quantities in the equation; and 3) provide numerical values for each quantity. In the simplest case, the equation is unambiguous (contains all relevant quantities and no others), each quantity has a single numerical value, and the calculation results in a single value. However, certainty and precision are rarely the case. In almost all cases, the model and/or the numerical values for each quantity in the model are not completely known (i.e., there is uncertainty) or the model and/or the numerical values for each quantity in the model depend upon other conditions (i.e., there is variability).

Thorough analysis involves accounting for uncertainty and variability. While the simplest analysis involves a single numerical value for each quantity in a calculation, arguments can arise about what the appropriate value is for each quantity. Explicit analysis of uncertainty and variability is intended to provide more complete information to the decision-making process.

8B.3 UNCERTAINTY

When making observations of past events or speculating about the future, imperfect knowledge is the rule rather than the exception. For example, the energy actually consumed by a particular appliance type (such as the average BC or EPS) is not directly recorded, but rather estimated based upon available information. Even direct laboratory measurements have some margin of error. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

8B.4 VARIABILITY

Variability means that different applications or situations produce different numerical values when calculating a quantity. Specifying an exact value for a quantity may be difficult because the value depends on something else. For example, the amount of energy a representative unit consumes depends upon the specific circumstances and behaviors of the consumer who is operating it and which application the unit is powering (e.g., how frequently the product is used, the duration of use, etc.). Variability makes specifying an appropriate population value more difficult in as much as any one value may not be representative of the entire population. Surveys can be helpful here, and analysis of surveys can relate the variable of interest (e.g., unit energy consumption) to other variables that are better known or easier to forecast (e.g., duration of typical use for typical applications).

8B.5 APPROACHES TO UNCERTAINTY AND VARIABILITY

This section describes two approaches to uncertainty and variability:

1. Scenario Analysis, and
2. Probability Analysis.

Scenario analysis uses a single numerical value for each quantity in a calculation, then changes one (or more) of the numerical values and repeats the calculation. A number of calculations are done, which provide some indication of the extent to which the result depends upon the assumptions. For example, the life-cycle cost of a BC or EPS could be calculated for energy rates of 2, 8, and 14¢ per kWh.

The advantages of scenario analysis are that each calculation is simple; a range of estimates is used; and crossover points can be identified. (An example of a crossover point is the energy rate above which the life-cycle cost is reduced, holding all other inputs constant. That is, the crossover point is the energy rate at which the consumer achieves savings in operating expense that more than compensate for the increased purchase expense). The disadvantage of scenario analysis is that there is no information about the likelihood of each scenario.

Probability analysis considers the probabilities within a range of values. For quantities with variability (e.g., electricity rates of different consumers), surveys can be used to generate a frequency distribution of numerical values (e.g., the number of households with electricity rates at particular levels) to estimate the probability of each value. For quantities with uncertainty, statistical or subjective measures can be used to provide probabilities (e.g., manufacturing cost to improve energy efficiency to some level may be estimated to be $10 ± $3).

The major disadvantage of the probability approach is that it requires more information, namely information about the shapes and magnitudes of the variability and uncertainty of each quantity. The advantage of the probability approach is that it provides greater information about the outcome of the calculations, that is, it provides the probability that the outcome will be in a particular range.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.6 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL

To quantify the uncertainty and variability that exist in inputs to the LCC and payback period analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball®, a commercially available add-in, to conduct probability analyses. The probability analyses used Monte Carlo simulation and probability distributions.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario. Spreadsheet risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables again and again to simulate a system. Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance, such as roulette wheels, dice, and slot machines, exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation utilizes variable values at random to simulate a model. For example, one knows that a rolled die will present a 1, 2, 3, 4, 5, or 6 after coming to rest, but one does not know which value will be presented on any particular roll. It is the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g., electricity prices and discount rate).

For each uncertain variable (one that has a range of possible values), possible values are defined with a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include:

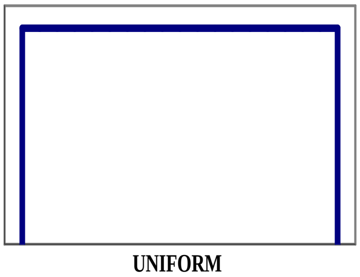


Figure 8B.6.1 Uniform Probability Distribution

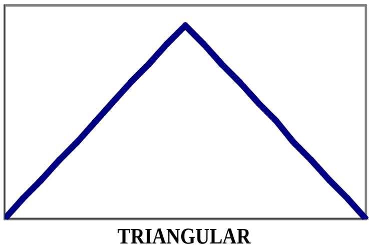


Figure 8B.6.2 Triangular Probability Distribution

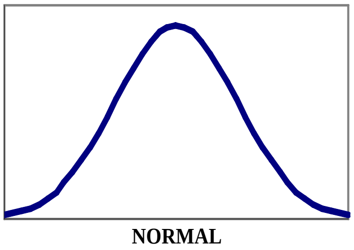


Figure 8B.6.3 Normal Probability Distribution

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values in the simulation. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. During a single trial, Crystal Ball randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the spreadsheet.

8B.7 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS FOR DIFFERENT USAGE SCENARIOS

This section presents LCC and PBP results using high and low unit energy consumption (UEC) estimates and reference case inputs for all other variables. DOE changed two variables for each application to determine the high and low UEC estimates. First, DOE altered the usage profile for a given application based on heavy usage or light usage for a user. Second, DOE altered the loading points for each application to account for varying levels of loading. The combination of these two sensitivities yielded a high UEC and low UEC, representative of a high usage scenario and a low usage scenario.

B.7.1 Usage Profile Adjustments for High Usage and Low Usage Scenarios

Usage profiles are inputs to the calculation of annual unit energy consumption (UECs). For many applications, DOE identified multiple sources that provided BC or EPS usage profiles. To calculate reference case profiles, DOE either chose the usage profile from the source it believed to best characterize the typical use of a BC or EPS, or it chose a weighted average of multiple sources. This methodology is detailed in chapter 7.

In the high and low usage scenarios, DOE varied the usage profiles where multiple sources were available for a single application, or where considerable uncertainty over an assumed usage profile existed. For the high usage scenario, DOE selected the sources that maximized annual energy consumption. For the low usage scenario, DOE selected the sources that minimized annual energy consumption. Table 8B.7.1 and Table 8B.7.2 contain the usage profiles, listed by application, that were adjusted in the high and low usage scenarios, along with the reference case usage profiles for those applications.

Table 8B.7.1 Usage Profile Adjustments for EPS High and Low Usage Scenarios

Application	Sector	Savings Case	Active 1	Active 2	Active 3	Active 4	Active 5	Active 6	No-Load	Un-Plugged
			[hours/week]							
Amateur Radios	Res	App. State	Active Transmit	Idle (Receive)	Idle (Standby)			Off		
		High	8.40	8.40	151.20					
		Ref.	2.67	2.67	46.24			116.42		
		Low	0.19	0.19	1.53			166.08		
Netbooks	Res	App. State	On and Charging		Off & Charging	On	Sleep	Off		
		High	6.57		6.57	20.76	6.83	102.77	10.50	14.00
		Ref.	5.75		5.75	18.18	5.98	89.99		42.35
Netbooks	Comm	App. State	On and Charging		Off and Charging	On	Sleep	Off		
		High	6.66		6.66	21.06	6.93	104.23	1.46	21.00
		Ref.	5.75		5.75	18.18	5.98	89.99		42.35
Notebooks	Res	App. State	On and Charging	On - DVD playing	Off and Charging	On	Sleep	Off		
		High	4.55	5.69	4.55	27.49	23.89	89.10	2.23	10.50

		Ref.	4.14	5.18	4.14	25.03	21.76	81.14		26.60
		Low	3.69	4.62	3.69	22.31	19.39	72.31		41.99
Notebooks	Comm	App. State	On and Charging	On with DVD playing	Off and Charging	On	Sleep	Off		
		High	2.90	5.51	2.90	37.81	37.82	78.05	3.01	
		Ref.	2.73	5.18	2.73	35.56	35.57	73.40		12.83
		Low	2.22	4.21	2.22	28.88	28.88	59.60		41.99
Media Tablets	Res	App. State			Charging	Main-tenance				
		Ref.			10.08	42.42			59.50	56.00
		Low			10.00	14.00			11.00	133.00
Media Tablets	Comm	App. State			Charging	Main-tenance				
		High			10.08	42.42			59.50	56.00
		Ref.			10.00	14.00			11.00	133.00
LED Monitors	Res	App. State	Active				Idle	Sleep/Off		
		High	62.92				57.04	48.04		
		Ref.	35.69				16.67	115.64		
LED Monitors	Comm	App. State	Active				Idle	Sleep/Off		
		Ref.	66.41				70.53	21.07		9.99
		Low	35.69				16.67	115.64		
Ink Jet Imaging Equipment	Res	App. State	Active				Ready	Off		
		High	5.43				12.64	149.93		
		Ref.	5.06				11.38	151.57		
		Low	1.00				30.80	136.20		
Ink Jet Imaging Equipment	Comm	App. State	Active				Ready	Off		
		Ref.	6.15				116.85	34.74		10.26
		Low	5.06				11.38	151.57		
Portable Printers	Res	App. State			Charging	Main-tenance				
		High			2.80	4.20				161.00
		Ref.			1.40	2.10				164.50
Mobile Phones	Res	App. State			Charging	Main-tenance				
		Ref.			20.93	21.07			49.00	77.00
		Low			16.10	25.90			49.00	77.00
Mobile Phones	Comm	App. State			Charging	Main-tenance				
		High			20.93	21.07			49.00	77.00
		Ref.			20.93	21.07			25.20	100.80
Cordless Phones	Res	App. State		Charging	Main-tenance	No Battery				
		High		144.68	8.20	15.12				
		Ref.		58.80	94.08	15.12				
		Low		13.44	115.92	38.64				
Cordless Phones	Comm	App. State		Charging	Main-tenance	No Battery				
		High		144.68	8.20	15.12				

		Ref.		58.80	94.08	15.12				
		Low		13.44	115.92	38.64				
Answering Machines	Res	App. State		Charging	Maintenance	No Battery				
		High		144.68	8.20	15.12				
		Ref.		58.80	94.08	15.12				
		Low		13.44	115.92	38.64				
Answering Machines	Comm	App. State		Charging	Maintenance	No Battery				
		High		144.68	8.20	15.12				
		Ref.		58.80	94.08	15.12				
		Low		13.44	115.92	38.64				
Video Game Consoles	Res	App. State	Game-Active	Game - Idle	DVD - Active	DVD - Idle	No Disc - Idle	Off		
		High	40.27	10.74	1.73	2.88	2.88	109.51		
		Ref.	15.73	10.74	1.73	2.88	2.88	134.05		
		Low	9.59	10.74	1.73	2.88	2.88	140.19		
Blenders	Res	App. State			Charging	Maintenance				
		High			2.80	4.20				161.00
		Ref.			1.40	2.10				164.50
Mixers	Res	App. State			Charging	Maintenance				
		High			2.80	4.20				161.00
		Ref.			1.40	2.10				164.50
Flashlights/Lanterns	Res	App. State			Charging	Maintenance				
		High			2.52	165.41			0.07	
		Ref.			1.54	84.21			0.07	82.18
		Low			1.52	84.19			0.04	82.25
Rechargeable Garden Care Products	Res	App. State			Charging	Maintenance				
		Ref.			3.50	39.55			0.35	124.60
		Low			2.23	25.14			0.70	139.93
Rechargeable Toothbrushes	Res	App. State			Charging	Maintenance	No battery			
		High			35.00	132.30	0.70			
		Ref.			20.72	123.97	0.70			22.61
		Low			6.37	115.57	0.70			45.36
Rechargeable Water Jets	Res	App. State			Charging	Maintenance	No battery			
		High			35.00	132.30	0.70			
		Ref.			20.72	123.97	0.70			22.61
		Low			6.37	115.57	0.70			45.36
Beard and Moustache Trimmers	Res	App. State	Active - In Use		Charging	Maintenance				
		High	0.15		2.79	20.09				144.97
		Ref.	0.14		2.66	4.20				161.00
		Low	0.07		1.33	2.10				164.50
Hair Clippers	Res	App. State	Active - In Use		Charging	Maintenance				
		High	0.15		2.79	20.09				144.97
		Ref.	0.14		2.66	4.20				161.00

		Low	0.07		1.33	2.10				164.50
Shavers	Res	App. State	Active - In Use		Charging	Main-tenance				
		High	0.88		16.69	149.87			0.56	
		Ref.	0.58		11.11	87.36			14.21	54.74
		Low	0.51		9.71	14.00			7.00	136.78
Medical Nebulizers	Res	App. State	Active - Nebulizing				Idle	Off		
		High	3.50				164.50			
		Ref.	2.33				151.91	13.76		
		Low	1.20				125.10	41.70		
DIY Power Tools (Integral)	Res	App. State			Charging	Main-tenance				
		High			0.66	9.84			3.50	154.00
		Ref.			3.70	83.54			4.34	76.42
		Low			0.69	4.83				162.48
DIY Power Tools (External)	Res	App. State			Charging	Main-tenance	No battery			
		High			10.26	154.24	3.50			
		Ref.			9.46	21.73	6.30			130.52
		Low			0.66	9.84	3.50			154.00
DIY Power Tools (External)	Comm	App. State			Charging	Main-tenance	No battery			
		Ref.			70.00	8.75	31.50			57.75
		Low			49.78	6.22	0.00			112.00

Table 8B.7.2 Usage Profile Adjustments for BC High and Low Usage Scenarios

Application	Sector	Savings-Case	Active + Maintenance	No Battery	Unplugged	Charges/ Day
			[hours/day]			
MP3 Players	Residential	Reference	7.50	8.50	8.00	0.55
		Low	7.50	8.50	8.00	0.29
Netbooks	Residential	High	23.57	0.43	0.00	0.21
		Reference	18.84	0.06	5.10	0.64
		Low	14.40	7.20	2.40	0.40
Netbooks	Commercial	High	20.79	0.21	3.00	0.63
		Reference	18.00	0.00	6.00	0.71
		Low	14.40	7.20	2.40	0.40
Notebooks	Residential	High	22.18	0.32	1.50	0.34
		Reference	20.50	1.50	2.00	0.28
		Low	14.40	7.20	2.40	0.40
Notebooks	Commercial	High	23.57	0.43	0.00	0.21
		Reference	19.39	0.11	4.50	0.59
		Low	14.40	7.20	2.40	0.40
Media Tablets	Residential	Reference	7.50	8.50	8.00	0.29
		Low	3.50	1.50	19.00	0.29
Media Tablets	Commercial	High	7.50	8.50	8.00	0.29
		Reference	3.50	1.50	19.00	0.29
Portable Printers	Residential	High	1.00	0.00	23.00	0.14
		Reference	0.50	0.00	23.50	0.07
E-Books	Residential	Reference	3.50	1.50	19.00	0.29

		Low	1.00	0.00	23.00	0.14
In-Vehicle GPS	Residential	Reference	1.00	0.00	23.00	0.14
		Low	0.50	0.00	23.50	0.07
Mobile Phones	Residential	Reference	6.00	7.00	11.00	0.71
		Low	7.92	4.56	11.52	0.30
Mobile Phones	Commercial	High	6.00	7.00	11.00	0.71
		Reference	6.00	3.60	14.40	0.71
Cordless Phones	Residential	Reference	21.84	2.16	0.00	0.71
		Low	18.48	5.52	0.00	0.21
Cordless Phones	Commercial	Reference	21.84	2.16	0.00	0.71
		Low	18.48	5.52	0.00	0.21
Answering Machines	Residential	Reference	21.84	2.16	0.00	0.71
		Low	18.48	5.52	0.00	0.21
Answering Machines	Commercial	Reference	21.84	2.16	0.00	0.71
		Low	18.48	5.52	0.00	0.21
Blenders	Residential	High	1.00	0.00	23.00	0.14
		Reference	0.50	0.00	23.50	0.07
Can Openers	Residential	Reference	1.00	0.00	23.00	0.14
		Low	0.50	0.00	23.50	0.07
Mixers	Residential	High	1.00	0.00	23.00	0.14
		Reference	0.50	0.00	23.50	0.07
Flashlights/Lanterns	Residential	High	23.99	0.01	0.00	0.04
		Reference	12.25	0.01	11.75	0.02
Rechargeable Garden Care Products	Residential	Reference	6.15	0.05	17.80	0.05
		Low	3.91	0.10	20.00	0.07
Lawn Mowers	Residential	Reference	22.00	2.00	0.00	0.05
		Low	3.91	0.10	20.00	0.07
Rechargeable Toothbrushes	Residential	High	23.90	0.10	0.00	0.26
		Reference	20.66	0.10	3.24	0.15
		Low	17.42	0.10	6.48	0.05
Rechargeable Water Jets	Residential	High	23.90	0.10	0.00	0.26
		Reference	20.66	0.10	3.24	0.15
		Low	17.42	0.10	6.48	0.05
Beard and Moustache Trimmers	Residential	High	3.30	0.00	20.70	0.07
		Reference	1.00	0.00	23.00	0.14
		Low	0.50	0.00	23.50	0.07
Hair Clippers	Residential	High	3.30	0.00	20.70	0.07
		Reference	1.00	0.00	23.00	0.14
		Low	0.50	0.00	23.50	0.07
Shavers	Residential	High	23.92	0.08	0.00	0.29
		Reference	14.15	2.03	7.82	0.19
		Low	3.46	1.00	19.54	0.17
DIY Power Tools (Integral)	Residential	High	23.50	0.50	0.00	0.07
		Reference	12.46	0.62	10.92	0.06
		Low	1.50	0.50	22.00	0.07
DIY Power Tools (External)	Residential	High	23.50	0.50	0.00	0.07
		Reference	4.46	0.90	18.65	0.18
		Low	1.50	0.50	22.00	0.07
DIY Power Tools (External)	Commercial	Reference	11.25	4.50	8.25	1.43
		Low	8.00	0.00	16.00	1.43
Professional Power Tools	Residential	High	23.50	0.50	0.00	0.07
		Reference	7.85	1.30	14.85	0.31
		Low	1.50	0.50	22.00	0.07

Professional Power Tools	Commercial	High	14.50	9.00	0.50	1.43
		Reference	11.25	4.50	8.25	1.43
		Low	8.00	0.00	16.00	1.43
Golf Carts	Residential	High	7.74	8.13	8.13	0.36
		Reference	11.45	0.30	12.25	0.05
Golf Carts	Commercial	High	16.32	3.12	4.56	0.36
		Reference	7.74	8.13	8.13	0.36
Wheelchairs	Residential	Reference	12.00	12.00	0.00	0.70
		Low	15.30	8.50	0.20	0.50
Mobility Scooters	Residential	High	19.00	5.00	0.00	1.00
		Reference	12.00	12.00	0.00	0.70
		Low	15.30	8.40	0.30	0.50
Marine/Automotive/RV Chargers	Residential	High	10.40	5.60	2.40	0.50
		Reference	22.00	2.00	0.00	0.05

B.7.2 Loading Point Adjustments for High Usage and Low Usage Scenarios

Loading points, as described in chapter 7, are inputs in the calculation of EPS UECs. DOE assumed in the non-Class A EPS determination analysis that standard active-mode loading points for EPSs that do not power a BC are approximately 80-percent loaded. The results of subsequent tests suggested that this value may be closer to 60-percent, so DOE adopted a default loading point of 60-percent in the reference case scenario.

To calculate UECs in the high usage case, DOE readjusted the highest active-mode loading points to 80-percent, reflecting the assumption used in the non-Class A EPS determination analysis. In the low usage case, DOE assumed the highest active-mode loading point to be 40-percent.[1]

In the high and low usage analysis, DOE did not alter the loading points of any application for which loading point test data were available. Loading points derived from test data are indicated as such in appendix 7A.

B.7.3 Non-Class A External Power Supply Results for the High Usage Scenario

Table 8B.7.3 and Table 8B.7.4 present the LCC and PBP results for the two Non-Class A EPS representative units using the high usage scenario.

---

[1] EPSs for home security systems are the one exception to this methodology. Since these EPSs operate almost entirely in maintenance mode (which is assumed to have a loading point of 17-percent), DOE adjusted this value up to 20-percent in the high-savings case and left it at 17-percent in the low-savings case.

Table 8B.7.3 203W Multiple Voltage Non-Class A External Power Supplies, High Usage

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	82.4	12.330	0.00	66.62	66.62	-	-	-
1	86.4	0.400	3.81	25.96	29.77	1.84	95.0	0.4
2	86.4	0.300	4.13	25.69	29.82	1.79	0.0	4.9
3	88.5	0.300	11.97	21.26	33.23	-1.61	0.0	7.2

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.4 345W High-Power Non-Class A External Power Supplies, High Usage

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	62.4	15.430	176.92	390.65	567.56	-	-	-
1	81.3	6.010	139.38	148.80	288.18	139.69	50.0	0.0
2	84.6	0.500	139.38	111.78	251.16	176.71	0.0	0.0
3	87.5	0.500	143.08	87.88	230.96	196.91	0.0	0.0
4	92.0	0.266	191.90	53.44	245.34	182.53	0.0	2.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.7.4 Non-Class A External Power Supply Results for the Low Usage Scenario

Table 8B.7.5 and Table 8B.7.6 present the LCC and PBP results for the two Non-Class A EPS representative units using the low usage scenario.

Table 8B.7.5 203W Multiple Voltage Non-Class A External Power Supplies, Low Usage

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	82.4	12.330	0.00	59.06	59.06	-	-	-
1	86.4	0.400	3.81	13.84	17.65	2.07	95.0	0.4
2	86.4	0.300	4.13	13.50	17.62	2.10	0.0	3.8
3	88.5	0.300	11.97	11.27	23.25	-3.53	0.0	13.1

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.6 345W High-Power Non-Class A External Power Supplies, Low Usage

CSL	Efficiency Level %	No Load Power W	Life-Cycle Cost Avg. Installed Price 2010$	Life-Cycle Cost Avg. Operating Cost 2010$	Life-Cycle Cost Avg. LCC 2010$	Life-Cycle Cost Savings Wtd. Avg. Savings 2010$	Life-Cycle Cost Savings Consumers with No Impact* %	Median Payback Period yrs.
0	62.4	15.430	176.92	132.67	309.58	-	-	-
1	81.3	6.010	139.38	51.49	190.87	59.36	50.0	0.0
2	84.6	0.500	139.38	9.64	149.02	101.21	0.0	0.0
3	87.5	0.500	143.08	8.35	151.43	98.80	0.0	0.0
4	92.0	0.266	191.90	4.80	196.71	53.52	0.0	4.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.7.5 Direct Operation External Power Supply Results for the High Usage Scenario

Table 8B.7.7 through Table 8B.7.10 present the LCC and PBP results for the four Direct Operation EPS representative units using the high usage scenario.

Table 8B.7.7 2.5W Direct Operation External Power Supplies, High Usage

CSL	Efficiency Level %	No Load Power W	Life-Cycle Cost Avg. Installed Price† 2010$	Life-Cycle Cost Avg. Operating Cost 2010$	Life-Cycle Cost Avg. LCC† 2010$	Life-Cycle Cost Savings Wtd. Avg. Savings 2010$	Life-Cycle Cost Savings Consumers with No Impact* %	Median Payback Period yrs.
0	58.3	0.500	0.00	1.70	1.70	-	-	-
1	67.9	0.300	0.22	1.10	1.33	0.17	57.6	1.5
2	71.0	0.130	0.48	0.88	1.36	0.14	8.3	3.5
3	73.5	0.100	0.65	0.76	1.42	0.09	2.2	4.1
4	74.8	0.039	0.75	0.68	1.43	0.07	0.0	4.1

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.8 18W Direct Operation External Power Supplies, High Usage

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	76.0	0.500	0.00	6.61	6.61	-	-	-
1	80.3	0.300	0.00	5.05	5.05	0.33	80.6	0.0
2	83.0	0.200	0.24	4.17	4.41	0.81	28.4	0.9
3	85.4	0.100	0.90	3.41	4.30	0.90	10.5	2.2
4	91.1	0.039	4.06	1.94	6.00	-0.80	0.0	5.5

† Based on an incremental MSP over the baseline.

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.9 60W Direct Operation External Power Supplies, High Usage

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	85.0	0.500	0.00	5.92	5.92	-	-	-
1	87.0	0.500	0.00	5.18	5.18	0.11	81.4	0.0
2	87.0	0.200	1.19	4.53	5.72	-0.33	18.3	5.8
3	88.0	0.073	1.86	3.90	5.76	-0.37	1.4	4.7
4	92.2	0.050	3.93	2.43	6.36	-0.97	0.0	5.0

† Based on an incremental MSP over the baseline.

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.10 120W Direct Operation External Power Supplies, High Usage

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	85.0	0.500	0.00	7.21	7.21	-	-	-
1	87.0	0.500	0.00	6.25	6.25	0.25	74.2	0.0
2	88.0	0.230	0.44	5.27	5.70	0.68	21.2	1.2
3	88.4	0.210	0.63	5.04	5.67	0.71	3.0	1.7
4	93.5	0.089	8.98	2.62	11.60	-5.22	0.0	8.0

† Based on an incremental MSP over the baseline.

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.7.6 Direct Operation External Power Supply Results for the Low Usage Scenario

Table 8B.7.11 through Table 8B.7.14 present the LCC and PBP results for the four Direct Operation EPS representative units using the low usage scenario.

Table 8B.7.11 2.5W Direct Operation External Power Supplies, Low Usage

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	58.3	0.500	0.00	1.43	1.43	-	-	-
1	67.9	0.300	0.22	0.92	1.15	0.13	57.6	1.8
2	71.0	0.130	0.48	0.71	1.20	0.09	8.3	3.8
3	73.5	0.100	0.65	0.62	1.27	0.02	2.2	4.6
4	74.8	0.039	0.75	0.54	1.29	0.00	0.0	4.6

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.12 18W Direct Operation External Power Supplies, Low Usage

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	76.0	0.500	0.00	4.82	4.82	-	-	-
1	80.3	0.300	0.00	3.68	3.68	0.22	80.6	0.0
2	83.0	0.200	0.24	3.02	3.26	0.50	28.4	1.2
3	85.4	0.100	0.90	2.46	3.36	0.40	10.5	2.9
4	91.1	0.039	4.06	1.40	5.46	-1.70	0.0	7.4

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.13 60W Direct Operation External Power Supplies, Low Usage

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	85.0	0.500	0.00	4.15	4.15	-	-	-
1	87.0	0.500	0.00	3.68	3.68	0.08	81.4	0.0
2	87.0	0.200	1.19	3.05	4.23	-0.36	18.3	6.3
3	88.0	0.073	1.86	2.55	4.41	-0.54	1.4	5.6
4	92.2	0.050	3.93	1.59	5.53	-1.65	0.0	6.8

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.14 120W Direct Operation External Power Supplies, Low Usage

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	85.0	0.500	0.00	5.66	5.66	-	-	-
1	87.0	0.500	0.00	4.91	4.91	0.19	74.2	0.0
2	88.0	0.230	0.44	4.14	4.57	0.46	21.2	1.5
3	88.4	0.210	0.63	3.96	4.59	0.44	3.0	2.1
4	93.5	0.089	8.98	2.06	11.04	-6.01	0.0	10.2

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.7.7 Battery Charger Results for the High Usage Scenario

Table 8B.7.15 through Table 8B.7.24 present the LCC and PBP results for the BC representative units using inputs for the high usage scenario.

Table 8B.7.15 Low Energy, Inductive Battery Chargers (PC1), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	4.39	4.95	9.34	-	-	-
1	6.1	4.72	3.46	8.18	0.90	22.2	1.1
2	3.0	5.38	1.73	7.11	1.85	11.1	1.5
3	1.3	10.63	0.74	11.37	-2.41	0.0	7.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.16 Low Energy, Low Voltage Battery Chargers (PC2), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	8.7	1.42	3.24	4.65	-	-	-
1	6.5	1.55	2.45	4.00	0.16	82.0	0.5
2	2.9	3.68	1.22	4.90	-0.11	60.1	5.2
3	1.0	6.25	0.35	6.60	-1.77	2.9	8.4
4	0.8	9.07	0.25	9.33	-4.49	0.0	15.6

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.17 Low Energy, Medium Voltage Battery Chargers (PC3), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	11.9	1.79	8.08	9.86	-	-	-
1	4.7	3.51	3.22	6.73	0.71	82.8	3.9
2	0.8	8.51	0.51	9.02	-1.17	20.9	21.9
3	0.8	8.56	0.49	9.06	-1.20	0.0	20.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.18 Low Energy, High Voltage Battery Chargers (PC4), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	37.7	8.04	18.29	26.33	-	-	-
1	9.9	12.24	4.63	16.87	1.16	90.7	1.1
2	4.6	20.65	1.91	22.57	-1.53	51.5	10.7
3	3.0	28.61	1.35	29.96	-8.92	0.0	29.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.19 Medium Energy, Low Voltage Battery Chargers (PC5), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	84.6	46.61	62.77	109.38	-	-	-
1	56.1	51.40	44.53	95.93	9.20	72.0	1.7
2	29.3	39.57	20.93	60.50	38.17	20.1	0.0
3	15.4	207.82	16.74	224.56	-104.58	13.0	54.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.20 Medium Energy, High Voltage Battery Chargers (PC6), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	120.6	45.37	97.26	142.63	-	-	-
1	81.7	50.13	66.66	116.78	9.96	64.6	1.2
2	38.3	38.52	30.55	69.07	40.78	35.2	0.0
3	16.8	205.10	10.60	215.71	-86.76	13.0	20.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.21 High Energy Battery Chargers (PC7), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	255.0	222.08	97.29	319.37	-	-	-
1	191.7	153.47	69.71	223.18	41.88	56.5	0.0
2	136.8	335.09	49.46	384.55	-119.49	0.0	23.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.22 DC-DC, <9V Input Battery Chargers (PC8), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	0.9	13.40	0.32	13.71	-	-	-
1	0.7	7.40	0.23	7.63	3.04	50.0	0.0
2	0.2	13.10	0.08	13.19	-1.96	10.0	0.0
3	0.2	13.48	0.06	13.54	-2.31	0.0	24.9

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.23 DC-DC, ≥9V Input Battery Chargers (PC9), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	0.8	5.41	1.67	7.07	-	-	-
1	0.3	6.90	0.51	7.42	-0.04	74.8	7.2
2	0.1	7.36	0.27	7.63	-0.19	24.9	8.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.24 Low Energy, AC Out Battery Chargers (PC10), High Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	19.3	5.94	13.29	19.22	-	-	-
1	6.1	7.63	4.23	11.85	6.41	13.0	1.3
2	4.0	8.09	2.78	10.87	7.26	13.0	1.4
3	1.5	8.65	1.03	9.68	8.30	13.0	1.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.7.8 Battery Charger Results for the Low Usage Scenario

Table 8B.7.25 through Table 8B.7.34 present the LCC and PBP results for the BC representative units using inputs for the low usage scenario.

Table 8B.7.25 Low Energy, Inductive Battery Chargers (PC1), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	8.7	4.39	3.69	8.08	-	-	-
1	6.1	4.72	2.57	7.29	0.61	22.2	1.3
2	3.0	5.38	1.27	6.65	1.18	11.1	1.9
3	1.3	10.63	0.53	11.16	-3.33	0.0	12.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.26 Low Energy, Low Voltage Battery Chargers (PC2), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	8.7	1.42	2.60	4.01	-	-	-
1	6.5	1.55	1.95	3.50	0.16	82.0	0.5
2	2.9	3.68	0.91	4.60	-0.12	60.1	6.1
3	1.0	6.25	0.27	6.52	-1.99	2.9	11.8
4	0.8	9.07	0.18	9.25	-4.72	0.0	21.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.27 Low Energy, Medium Voltage Battery Chargers (PC3), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	11.9	1.79	4.67	6.46	-	-	-
1	4.7	3.51	1.86	5.37	0.17	82.8	8.3
2	0.8	8.51	0.32	8.83	-2.59	20.9	24.4
3	0.8	8.56	0.30	8.86	-2.63	0.0	23.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.28 Low Energy, High Voltage Battery Chargers (PC4), Low Usage

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	37.7	8.04	11.57	19.61	-	-	-
1	9.9	12.24	3.42	15.66	0.22	90.7	12.2
2	4.6	20.65	1.41	22.06	-3.01	51.5	13.6
3	3.0	28.61	1.02	29.63	-10.57	0.0	60.2

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.29 Medium Energy, Low Voltage Battery Chargers (PC5), Low Usage

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	84.6	46.61	52.45	99.06	-	-	-
1	56.1	51.40	33.98	85.39	9.39	72.0	1.7
2	29.3	39.57	18.23	57.79	31.87	20.1	0.0
3	15.4	207.82	8.04	215.86	-105.72	13.0	53.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.30 Medium Energy, High Voltage Battery Chargers (PC6), Low Usage

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	120.6	45.37	83.43	128.80	-	-	-
1	81.7	50.13	58.50	108.63	9.46	64.6	1.2
2	38.3	38.52	25.71	64.23	37.81	35.2	0.0
3	16.8	205.10	10.30	215.40	-93.67	13.0	23.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.31 High Energy Battery Chargers (PC7), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	255.0	222.08	75.39	297.47	-	-	-
1	191.7	153.47	56.10	209.56	38.26	56.5	0.0
2	136.8	335.09	40.04	375.12	-127.30	0.0	27.2

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.32 DC-DC, <9V Input Battery Chargers (PC8), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	0.9	13.40	0.36	13.75	-	-	-
1	0.7	7.40	0.26	7.67	3.04	50.0	0.0
2	0.2	13.10	0.09	13.19	-1.93	10.0	0.0
3	0.2	13.48	0.06	13.54	-2.27	0.0	24.9

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.33 DC-DC, ≥9V Input Battery Chargers (PC9), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	0.8	5.41	0.84	6.25	-	-	-
1	0.3	6.90	0.26	7.16	-0.20	74.8	14.5
2	0.1	7.36	0.14	7.50	-0.45	24.9	17.6

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.7.34 Low Energy, AC Out Battery Chargers (PC10), Low Usage

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	19.3	5.94	13.29	19.22	-	-	-
1	6.1	7.63	4.23	11.85	6.41	13.0	1.3
2	4.0	8.09	2.78	10.87	7.26	13.0	1.4
3	1.5	8.65	1.03	9.68	8.30	13.0	1.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

8B.8 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS USING ALTERNATIVE ENERGY PRICE SCENARIOS

This section presents LCC and PBP results using alternative energy price scenarios from Energy Information Administration (EIA)'s *Annual Energy Outlook 2010* (AEO 2010).[i] The other scenarios considered were a high-growth, low-growth, and carbon cap and trade scenario. Figure 8B.1 and Figure 8B.2 show the price forecasts from AEO 2010 for electricity in the residential sector and commercial sector, respectively, for the three scenarios considered and the reference case. The results in this section are based on a weighted combination of the residential and commercial sectors for each representative unit.

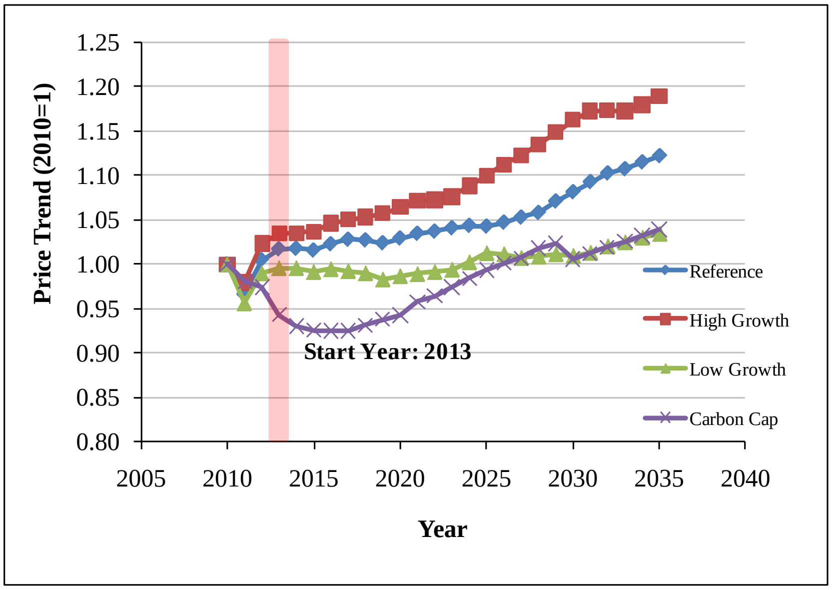


Figure 8B.1 Residential Electricity Price Forecast

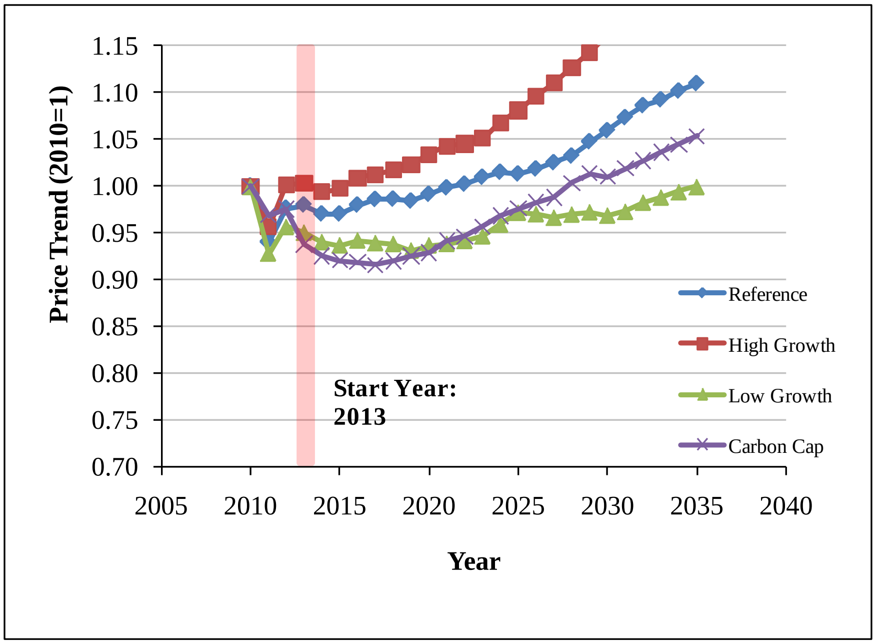


Figure 8B.2 Commercial Electricity Price Forecast

B.8.1 Non-Class A External Power Supply Results Using Alternative Energy Price Scenarios

B.8.1.1 Non-Class A External Power Supply Results Using AEO 2010 High-Growth Price Scenario

Table 8B.8.1 and Table 8B.8.2 present the LCC and PBP results for the two Non-Class A EPS representative units using the high-growth electricity price scenario from AEO 2010.

Table 8B.8.1 203W Multiple Voltage Non-Class A External Power Supplies, AEO 2010 High-Growth

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	82.4	12.330	0.00	61.85	61.85	-	-	-
1	86.4	0.400	3.81	16.61	20.42	2.07	95.0	0.4
2	86.4	0.300	4.13	16.27	20.40	2.09	0.0	3.9
3	88.5	0.300	11.97	13.55	25.52	-3.03	0.0	11.1

† Based on an incremental MSP over the baseline.

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.2 345W High-Power Non-Class A External Power Supplies, AEO 2010 High-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	62.4	15.430	176.92	210.85	387.77	-	-	-
1	81.3	6.010	139.38	81.01	220.39	83.69	50.0	0.0
2	84.6	0.500	139.38	39.88	179.26	124.82	0.0	0.0
3	87.5	0.500	143.08	31.91	174.99	129.08	0.0	0.0
4	92.0	0.266	191.90	19.21	211.11	92.96	0.0	3.6

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.1.2 Non-Class A External Power Supply Results Using AEO 2010 Low-Growth Price Scenario

Table 8B.8.3 and Table 8B.8.4 present the LCC and PBP results for the two Non-Class A EPS representative units using the low-growth electricity price scenario from AEO 2010.

Table 8B.8.3 203W Multiple Voltage Non-Class A External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	82.4	12.330	0.00	59.06	59.06	-	-	-
1	86.4	0.400	3.81	15.86	19.67	1.97	95.0	0.4
2	86.4	0.300	4.13	15.54	19.66	1.97	0.0	4.1
3	88.5	0.300	11.97	12.94	24.91	-3.27	0.0	11.5

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.4 345W High-Power Non-Class A External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	62.4	15.430	176.92	198.84	375.76	-	-	-
1	81.3	6.010	139.38	76.39	215.77	79.99	50.0	0.0
2	84.6	0.500	139.38	37.61	176.99	118.78	0.0	0.0
3	87.5	0.500	143.08	30.10	173.18	122.59	0.0	0.0
4	92.0	0.266	191.90	18.11	210.02	85.75	0.0	3.8

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.1.3 Non-Class A External Power Supply Results Using Carbon Cap and Trade Price Scenario

Table 8B.8.5 and Table 8B.8.6 present the LCC and PBP results for the two Non-Class A EPS representative units using the carbon cap and trade electricity price scenario from the Lieberman-Warner Climate Security Act of 2007.[ii]

Table 8B.8.5 203W Multiple Voltage Non-Class A External Power Supplies, Carbon Cap and Trade Scenario

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	82.4	12.330	0.00	63.57	63.57	-	-	-
1	86.4	0.400	3.81	17.07	20.88	2.13	95.0	0.3
2	86.4	0.300	4.13	16.73	20.85	2.16	0.0	3.7
3	88.5	0.300	11.97	13.93	25.90	-2.89	0.0	10.6

† Based on an incremental MSP over the baseline.

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.6 345W High-Power Non-Class A External Power Supplies, Carbon Cap and Trade Scenario

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	62.4	15.430	176.92	216.19	393.11	-	-	-
1	81.3	6.010	139.38	83.06	222.44	85.34	50.0	0.0
2	84.6	0.500	139.38	40.89	180.27	127.50	0.0	0.0
3	87.5	0.500	143.08	32.72	175.80	131.97	0.0	0.0
4	92.0	0.266	191.90	19.69	211.60	96.18	0.0	3.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.2 Direct Operation External Power Supply Results Using Alternative Energy Price Scenarios

B.8.2.1 Direct Operation External Power Supply Results Using AEO 2010 High-Growth Price Scenario

Table 8B.8.7 through Table 8B.8.10 present the LCC and PBP results for the four Direct Operation EPS representative units using the high-growth electricity price scenario from AEO 2010.

Table 8B.8.7 2.5W External Power Supplies, AEO 2010 High-Growth

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	Avg. Operating Cost *2010$*	Avg. LCC† *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	58.3	0.500	0.00	1.58	1.58	-	-	-
1	67.9	0.300	0.22	1.02	1.25	0.15	57.6	1.6
2	71.0	0.130	0.48	0.81	1.29	0.11	8.3	3.7
3	73.5	0.100	0.65	0.70	1.36	0.05	2.2	4.4
4	74.8	0.039	0.75	0.63	1.38	0.03	0.0	4.4

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.8 18W External Power Supplies, AEO 2010 High-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	76.0	0.500	0.00	5.89	5.89	-	-	-
1	80.3	0.300	0.00	4.50	4.50	0.28	80.6	0.0
2	83.0	0.200	0.24	3.70	3.94	0.68	28.4	1.0
3	85.4	0.100	0.90	3.02	3.91	0.70	10.5	2.5
4	91.1	0.039	4.06	1.71	5.78	-1.16	0.0	6.1

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.9 60W External Power Supplies, AEO 2010 High-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	85.0	0.500	0.00	4.89	4.89	-	-	-
1	87.0	0.500	0.00	4.31	4.31	0.09	81.4	0.0
2	87.0	0.200	1.19	3.65	4.84	-0.32	18.3	5.9
3	88.0	0.073	1.86	3.09	4.95	-0.43	1.4	5.1
4	92.2	0.050	3.93	1.93	5.86	-1.34	0.0	5.8

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.10 120W External Power Supplies, AEO 2010 High-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	85.0	0.500	0.00	6.81	6.81	-	-	-
1	87.0	0.500	0.00	5.91	5.91	0.23	74.2	0.0
2	88.0	0.230	0.44	4.98	5.42	0.62	21.2	1.3
3	88.4	0.210	0.63	4.77	5.40	0.64	3.0	1.8
4	93.5	0.089	8.98	2.48	11.46	-5.42	0.0	8.4

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.2.2 Direct Operation External Power Supply Results Using AEO 2010 Low-Growth Price Scenario

Table 8B.8.11 through Table 8B.8.14 present the LCC and PBP results for the four Direct Operation EPS representative units using the low-growth electricity price scenario from AEO 2010.

Table 8B.8.11 2.5W External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			**Life-Cycle Cost Savings**		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	58.3	0.500	0.00	1.51	1.51	-	-	-
1	67.9	0.300	0.22	0.97	1.20	0.14	57.6	1.7
2	71.0	0.130	0.48	0.77	1.25	0.09	8.3	3.8
3	73.5	0.100	0.65	0.67	1.32	0.02	2.2	4.6
4	74.8	0.039	0.75	0.60	1.35	0.00	0.0	4.6

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.12 18W External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			**Life-Cycle Cost Savings**		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	76.0	0.500	0.00	5.62	5.62	-	-	-
1	80.3	0.300	0.00	4.29	4.29	0.27	80.6	0.0
2	83.0	0.200	0.24	3.53	3.77	0.64	28.4	1.0
3	85.4	0.100	0.90	2.88	3.78	0.63	10.5	2.6
4	91.1	0.039	4.06	1.63	5.70	-1.29	0.0	6.4

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.13 60W External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	85.0	0.500	0.00	4.65	4.65	-	-	-
1	87.0	0.500	0.00	4.10	4.10	0.09	81.4	0.0
2	87.0	0.200	1.19	3.47	4.66	-0.35	18.3	6.2
3	88.0	0.073	1.86	2.94	4.80	-0.49	1.4	5.3
4	92.2	0.050	3.93	1.83	5.77	-1.46	0.0	6.1

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.14 120W External Power Supplies, AEO 2010 Low-Growth

			Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**Efficiency Level** *%*	**No Load Power** *W*	**Avg. Installed Price†** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	85.0	0.500	0.00	6.47	6.47	-	-	-
1	87.0	0.500	0.00	5.61	5.61	0.22	74.2	0.0
2	88.0	0.230	0.44	4.73	5.17	0.57	21.2	1.3
3	88.4	0.210	0.63	4.52	5.16	0.58	3.0	1.9
4	93.5	0.089	8.98	2.35	11.34	-5.60	0.0	8.9

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.2.3 Direct Operation External Power Supply Results Using Carbon Cap and Trade Price Scenario

Table 8B.8.15 through Table 8B.8.18 present the LCC and PBP results for the four Direct Operation EPS representative units using the carbon cap and trade electricity price scenario from the Lieberman-Warner Climate Security Act of 2007.[ii]

Table 8B.8.15 2.5W External Power Supplies, Carbon Cap and Trade Scenario

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	58.3	0.500	0.00	1.63	1.63	-	-	-
1	67.9	0.300	0.22	1.06	1.28	0.16	57.6	1.6
2	71.0	0.130	0.48	0.84	1.32	0.12	8.3	3.5
3	73.5	0.100	0.65	0.73	1.38	0.07	2.2	4.2
4	74.8	0.039	0.75	0.65	1.40	0.05	0.0	4.2

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.16 18W External Power Supplies, Carbon Cap and Trade Scenario

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	76.0	0.500	0.00	6.09	6.09	-	-	-
1	80.3	0.300	0.00	4.65	4.65	0.29	80.6	0.0
2	83.0	0.200	0.24	3.83	4.07	0.71	28.4	0.9
3	85.4	0.100	0.90	3.12	4.02	0.75	10.5	2.3
4	91.1	0.039	4.06	1.77	5.84	-1.07	0.0	5.8

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.17 60W External Power Supplies, Carbon Cap and Trade Scenario

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
			Avg. Installed Price† *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC†** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	85.0	0.500	0.00	5.11	5.11	-	-	-
1	87.0	0.500	0.00	4.50	4.50	0.10	81.4	0.0
2	87.0	0.200	1.19	3.81	5.00	-0.29	18.3	5.5
3	88.0	0.073	1.86	3.23	5.09	-0.38	1.4	4.8
4	92.2	0.050	3.93	2.01	5.95	-1.24	0.0	5.5

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.18 120W External Power Supplies, Carbon Cap and Trade Scenario

CSL	Efficiency Level *%*	No Load Power *W*	Life-Cycle Cost Avg. Installed Price† *2010$*	 Avg. Operating Cost *2010$*	 Avg. LCC† *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	 Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	85.0	0.500	0.00	7.21	7.21	-	-	-
1	87.0	0.500	0.00	6.25	6.25	0.25	74.2	0.0
2	88.0	0.230	0.44	5.27	5.71	0.67	21.2	1.2
3	88.4	0.210	0.63	5.04	5.68	0.71	3.0	1.6
4	93.5	0.089	8.98	2.62	11.61	-5.22	0.0	7.9

† Based on an incremental MSP over the baseline.

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.3 Battery Charger Results Using Alternative Energy Price Scenarios

B.8.3.1 Battery Charger Results Using AEO 2010 High-Growth Price Scenario

Table 8B.8.19 through Table 8B.8.28 present the LCC and PBP results for the BC representative units using the high-growth electricity price scenario from AEO 2010.

Table 8B.8.19 Low Energy, Inductive Battery Chargers (PC1), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	 Avg. Operating Cost *2010$*	 Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	 Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	8.7	4.39	4.41	8.80	-	-	-
1	6.1	4.72	3.08	7.80	0.78	22.2	1.2
2	3.0	5.38	1.54	6.91	1.57	11.1	1.7
3	1.3	10.63	0.65	11.28	-2.80	0.0	8.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.20 Low Energy, Low Voltage Battery Chargers (PC2), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	1.42	3.18	4.59	-	-	-
1	6.5	1.55	2.40	3.95	0.16	82.0	0.5
2	2.9	3.68	1.20	4.88	-0.11	60.1	5.1
3	1.0	6.25	0.35	6.60	-1.77	2.9	8.3
4	0.8	9.07	0.25	9.33	-4.50	0.0	16.6

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.21 Low Energy, Medium Voltage Battery Chargers (PC3), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	11.9	1.79	6.07	7.85	-	-	-
1	4.7	3.51	2.40	5.92	0.36	82.8	3.9
2	0.8	8.51	0.40	8.91	-2.07	20.9	21.5
3	0.8	8.56	0.38	8.94	-2.10	0.0	21.1

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.22 Low Energy, High Voltage Battery Chargers (PC4), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	37.7	8.04	14.26	22.30	-	-	-
1	9.9	12.24	3.72	15.96	0.44	90.7	3.0
2	4.6	20.65	1.68	22.33	-2.69	51.5	13.5
3	3.0	28.61	1.12	29.73	-10.09	0.0	36.7

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.23 Medium Energy, Low Voltage Battery Chargers (PC5), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	84.6	46.61	56.81	103.41	-	-	-
1	56.1	51.40	37.46	88.86	9.98	72.0	1.7
2	29.3	39.57	19.41	58.98	34.44	20.1	0.0
3	15.4	207.82	9.88	217.70	-103.73	13.0	52.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.24 Medium Energy, High Voltage Battery Chargers (PC6), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	120.6	45.37	99.77	145.14	-	-	-
1	81.7	50.13	68.38	118.51	10.26	64.6	1.2
2	38.3	38.52	31.33	69.85	41.69	35.2	0.0
3	16.8	205.10	10.89	215.99	-85.41	13.0	20.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.25 High Energy Battery Chargers (PC7), AEO 2010 High-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	255.0	222.08	77.45	299.53	-	-	-
1	191.7	153.47	57.63	211.10	38.49	56.5	0.0
2	136.8	335.09	41.13	376.22	-126.63	0.0	26.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.26 DC-DC, <9V Input Battery Chargers (PC8), AEO 2010 High-Growth

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	0.9	13.40	0.37	13.77	-	-	-
1	0.7	7.40	0.27	7.68	3.05	50.0	0.0
2	0.2	13.10	0.10	13.20	-1.93	10.0	0.0
3	0.2	13.48	0.08	13.55	-2.28	0.0	24.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.27 DC-DC, ≥9V Input Battery Chargers (PC9), AEO 2010 High-Growth

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	0.8	5.41	1.54	6.95	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	74.8	7.2
2	0.1	7.36	0.26	7.62	-0.25	24.9	8.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.28 Low Energy, AC Out Battery Chargers (PC10), AEO 2010 High-Growth

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	19.3	5.94	13.61	19.54	-	-	-
1	6.1	7.63	4.33	11.96	6.59	13.0	1.2
2	4.0	8.09	2.84	10.93	7.48	13.0	1.4
3	1.5	8.65	1.05	9.70	8.55	13.0	1.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.3.2 Battery Charger Results Using AEO 2010 Low-Growth Price Scenario

Table 8B.8.29 through Table 8B.8.38 present the LCC and PBP results for the BC representative units using the low-growth electricity price scenario from AEO 2010.

Table 8B.8.29 Low Energy, Inductive Battery Chargers (PC1), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	4.39	4.21	8.60	-	-	-
1	6.1	4.72	2.94	7.66	0.73	22.2	1.3
2	3.0	5.38	1.47	6.84	1.46	11.1	1.7
3	1.3	10.63	0.62	11.25	-2.95	0.0	8.7

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.30 Low Energy, Low Voltage Battery Chargers (PC2), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	1.42	3.03	4.45	-	-	-
1	6.5	1.55	2.29	3.84	0.15	82.0	0.5
2	2.9	3.68	1.14	4.83	-0.14	60.1	5.4
3	1.0	6.25	0.33	6.58	-1.85	2.9	8.7
4	0.8	9.07	0.24	9.32	-4.58	0.0	17.2

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.31 Low Energy, Medium Voltage Battery Chargers (PC3), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	11.9	1.79	5.78	7.57	-	-	-
1	4.7	3.51	2.29	5.80	0.33	82.8	4.0
2	0.8	8.51	0.38	8.89	-2.17	20.9	22.4
3	0.8	8.56	0.36	8.93	-2.21	0.0	22.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.32 Low Energy, High Voltage Battery Chargers (PC4), AEO 2010 Low-Growth

CSL	**UEC** *kWh*	**Life-Cycle Cost**			**Life-Cycle Cost Savings**		**Median Payback Period** *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	37.7	8.04	13.56	21.60	-	-	-
1	9.9	12.24	3.53	15.77	0.40	90.7	3.1
2	4.6	20.65	1.59	22.25	-2.78	51.5	14.2
3	3.0	28.61	1.06	29.67	-10.20	0.0	38.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.33 Medium Energy, Low Voltage Battery Chargers (PC5), AEO 2010 Low-Growth

CSL	**UEC** *kWh*	**Life-Cycle Cost**			**Life-Cycle Cost Savings**		**Median Payback Period** *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	84.6	46.61	53.81	100.42	-	-	-
1	56.1	51.40	35.48	86.89	9.35	72.0	1.8
2	29.3	39.57	18.39	57.96	33.02	20.1	0.0
3	15.4	207.82	9.37	217.19	-105.59	13.0	54.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.34 Medium Energy, High Voltage Battery Chargers (PC6), AEO 2010 Low-Growth

CSL	**UEC** *kWh*	**Life-Cycle Cost**			**Life-Cycle Cost Savings**		**Median Payback Period** *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	120.6	45.37	94.26	139.63	-	-	-
1	81.7	50.13	64.59	114.72	9.59	64.6	1.3
2	38.3	38.52	29.61	68.13	39.68	35.2	0.0
3	16.8	205.10	10.27	215.38	-88.38	13.0	21.2

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.35 High Energy Battery Chargers (PC7), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	255.0	222.08	72.98	295.06	-	-	-
1	191.7	153.47	54.30	207.77	37.99	56.5	0.0
2	136.8	335.09	38.75	373.84	-128.08	0.0	28.1

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.36 DC-DC, <9V Input Battery Chargers (PC8), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	0.9	13.40	0.36	13.75	-	-	-
1	0.7	7.40	0.26	7.66	3.04	50.0	0.0
2	0.2	13.10	0.09	13.20	-1.94	10.0	0.0
3	0.2	13.48	0.07	13.55	-2.29	0.0	25.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.37 DC-DC, ≥9V Input Battery Chargers (PC9), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	0.8	5.41	1.54	6.95	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	74.8	7.2
2	0.1	7.36	0.26	7.62	-0.25	24.9	8.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.38 Low Energy, AC Out Battery Chargers (PC10), AEO 2010 Low-Growth

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	19.3	5.94	12.91	18.84	-	-	-
1	6.1	7.63	4.11	11.73	6.18	13.0	1.3
2	4.0	8.09	2.70	10.79	7.00	13.0	1.4
3	1.5	8.65	1.00	9.65	7.99	13.0	1.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

B.8.3.3 Battery Charger Results Using Carbon Cap and Trade Price Scenario

Table 8B.8.39 through Table 8B.8.48 present the LCC and PBP results for the BC representative units using the carbon cap and trade electricity price scenario from the Lieberman-Warner Climate Security Act of 2007.

Table 8B.8.39 Low Energy, Inductive Battery Chargers (PC1), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	4.39	4.53	8.92	-	-	-
1	6.1	4.72	3.17	7.89	0.81	22.2	1.2
2	3.0	5.38	1.58	6.96	1.63	11.1	1.6
3	1.3	10.63	0.67	11.30	-2.71	0.0	7.9

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.40 Low Energy, Low Voltage Battery Chargers (PC2), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	1.42	3.30	4.72	-	-	-
1	6.5	1.55	2.50	4.05	0.17	82.0	0.5
2	2.9	3.68	1.25	4.93	-0.08	60.1	4.9
3	1.0	6.25	0.36	6.61	-1.71	2.9	8.0
4	0.8	9.07	0.27	9.34	-4.44	0.0	15.6

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.41 Low Energy, Medium Voltage Battery Chargers (PC3), Carbon Cap and Trade Scenario)

CSL	UEC *kWh*	Life-Cycle Cost: Avg. Installed Price *2010$*	Life-Cycle Cost: Avg. Operating Cost *2010$*	Life-Cycle Cost: Avg. LCC *2010$*	Life-Cycle Cost Savings: Wtd. Avg. Savings *2010$*	Life-Cycle Cost Savings: Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	11.9	1.79	6.25	8.04	-	-	-
1	4.7	3.51	2.48	5.99	0.38	82.8	3.7
2	0.8	8.51	0.41	8.92	-2.00	20.9	20.5
3	0.8	8.56	0.39	8.95	-2.04	0.0	20.2

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.42 Low Energy, High Voltage Battery Chargers (PC4), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost: Avg. Installed Price *2010$*	Life-Cycle Cost: Avg. Operating Cost *2010$*	Life-Cycle Cost: Avg. LCC *2010$*	Life-Cycle Cost Savings: Wtd. Avg. Savings *2010$*	Life-Cycle Cost Savings: Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	37.7	8.04	14.96	23.00	-	-	-
1	9.9	12.24	3.90	16.14	0.47	90.7	2.8
2	4.6	20.65	1.76	22.42	-2.62	51.5	12.7
3	3.0	28.61	1.18	29.78	-9.98	0.0	33.6

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.43 Medium Energy, Low Voltage Battery Chargers (PC5), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost: Avg. Installed Price *2010$*	Life-Cycle Cost: Avg. Operating Cost *2010$*	Life-Cycle Cost: Avg. LCC *2010$*	Life-Cycle Cost Savings: Wtd. Avg. Savings *2010$*	Life-Cycle Cost Savings: Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	84.6	46.61	58.34	104.95	-	-	-
1	56.1	51.40	38.47	89.87	10.27	72.0	1.6
2	29.3	39.57	19.94	59.51	35.14	20.1	0.0
3	15.4	207.82	10.15	217.97	-102.81	13.0	50.0

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.44 Medium Energy, High Voltage Battery Chargers (PC6), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	120.6	45.37	102.28	147.66	-	-	-
1	81.7	50.13	70.11	120.23	10.56	64.6	1.2
2	38.3	38.52	32.13	70.64	42.59	35.2	0.0
3	16.8	205.10	11.16	216.26	-84.05	13.0	19.5

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.45 High Energy Battery Chargers (PC7), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	255.0	222.08	83.56	305.64	-	-	-
1	191.7	153.47	62.24	215.70	39.14	56.5	0.0
2	136.8	335.09	44.42	379.50	-124.66	0.0	24.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.46 DC-DC, <9V Input Battery Chargers (PC8), Carbon Cap and Trade Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	0.9	13.40	0.38	13.78	-	-	-
1	0.7	7.40	0.28	7.68	3.05	50.0	0.0
2	0.2	13.10	0.10	13.21	-1.92	10.0	0.0
3	0.2	13.48	0.08	13.56	-2.27	0.0	23.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.47 DC-DC, ≥9V Input Battery Chargers (PC9), Carbon Cap and Trade Scenario

		Life-Cycle Cost			**Life-Cycle Cost Savings**		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	0.8	5.41	1.54	6.95	-	-	-
1	0.3	6.90	0.49	7.40	-0.09	74.8	7.2
2	0.1	7.36	0.26	7.62	-0.25	24.9	8.8

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.8.48 Low Energy, AC Out Battery Chargers (PC10), Carbon Cap and Trade Scenario

		Life-Cycle Cost			**Life-Cycle Cost Savings**		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	19.3	5.94	13.94	19.88	-	-	-
1	6.1	7.63	4.44	12.06	6.79	13.0	1.2
2	4.0	8.09	2.92	11.00	7.71	13.0	1.3
3	1.5	8.65	1.08	9.73	8.82	13.0	1.4

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

8B.9 LIFE-CYCLE COSTS AND PAYPACK PERIOD RESULTS FOR BATTERY CHARGERS IN ALTERNATIVE BASE CASE SCENARIO

On January 12th, 2012, the California Energy Commission (CEC) established energy conservation standards for battery chargers in the State of California. The majority of these standards go into effect on February 1st, 2013 and will likely have an effect on DOE's base case efficiency distributions for battery chargers. In the reference case, DOE has assumed that the effects of these standards will only be felt in California. The result of these standards caused DOE to make adjustments to its efficiency distributions and under the reference scenario, as described in TSD chapter 3, only 13 percent of shipments are affected in the base case. The 13 percent corresponds to the percentage of national gross domestic product attributable to the California economy. In an effort to show the breadth of the potential affects from the CEC battery charger standards, DOE has created a sensitivity analysis in which it models an alternative base case efficiency distribution. In this alternative base case, DOE assumes that all shipments of battery chargers in the nation are affected by the California standards and that all products shipped meet the CEC regulations. This has the effect of substantially changing the base case efficiency distribution, presented in Table 8B.9.1, and decreasing the average LCC savings for all battery charger product classes whose California standards are not equivalent to what DOE considers the baseline efficiency level.

Table 8B.9.1 Base Case Efficiency Distribution, Alternative Base Case Scenario

Product Class	CSL0	CSL1	CSL2	CSL3
1	77.8%	11.1%	11.1%	0.0%
2	0.0%	0.0%	96.9%	3.1%
3	0.0%	0.0%	100.0%	0.0%
4	0.0%	0.0%	100.0%	0.0%
5	0.0%	0.0%	0.0%	100.0%
6	0.0%	0.0%	0.0%	100.0%
7	0.0%	100.0%	0.0%	0.0%
8	50.0%	40.0%	10.0%	0.0%
9	25.1%	50.0%	24.9%	0.0%
10	0.0%	0.0%	0.0%	100.0%

Table 8B.9.2 through Table 8B.9.11 present the LCC and PBP results for DOE's battery charger product classes under this alternative base case sensitivity analysis.

Table 8B.9.2 Low Energy, Inductive Battery Chargers (PC1), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	
0	8.7	4.39	4.32	8.71	-	-	-
1	6.1	4.72	3.02	7.74	0.76	22.2	1.1
2	3.0	5.38	1.50	6.88	1.52	11.1	1.6
3	1.3	10.63	0.64	11.27	-2.87	0.0	10.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.3 Low Energy, Low Voltage Battery Chargers (PC2), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	8.7	1.42	3.10	4.51	-	-	-
1	6.5	1.55	2.34	3.89	0.00	100.0	0.0
2	2.9	3.68	1.17	4.85	0.00	100.0	0.0
3	1.0	6.25	0.34	6.59	-1.68	3.4	9.4
4	0.8	9.07	0.25	9.32	-4.41	0.0	18.9

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.4 Low Energy, Medium Voltage Battery Chargers (PC3), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	11.9	1.79	5.93	7.72	-	-	-
1	4.7	3.51	2.35	5.86	0.00	100.0	0.0
2	0.8	8.51	0.39	8.90	0.00	100.0	0.0
3	0.8	8.56	0.37	8.93	-0.03	0.0	20.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.5 Low Energy, High Voltage Battery Chargers (PC4), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost Avg. Installed Price *2010$*	Avg. Operating Cost *2010$*	Avg. LCC *2010$*	Life-Cycle Cost Savings Wtd. Avg. Savings *2010$*	Consumers with No Impact* *%*	Median Payback Period *yrs.*
0	37.7	7.66	13.03	20.69	-	-	-
1	9.9	11.82	3.33	15.15	0.00	100.0	0.0
2	4.6	20.16	1.58	21.73	0.00	100.0	0.0
3	3.0	28.03	1.02	29.05	-7.32	0.0	50.1

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.6 Medium Energy, Low Voltage Battery Chargers (PC5), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	84.6	46.60	19.82	66.43	-	-	-
1	56.1	51.40	13.34	64.74	0.00	100.0	0.0
2	29.3	39.56	7.08	46.64	0.00	100.0	0.0
3	15.4	207.80	4.00	211.81	0.00	100.0	0.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.7 Medium Energy, High Voltage Battery Chargers (PC6), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	120.6	45.37	97.28	142.65	-	-	-
1	81.7	50.13	66.67	116.80	0.00	100.0	0.0
2	38.3	38.52	30.56	69.08	0.00	100.0	0.0
3	16.8	205.10	10.61	215.71	0.00	100.0	0.0

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.8 High Energy Battery Chargers (PC7), Alternative Base Case Scenario

CSL	UEC *kWh*	Life-Cycle Cost			Life-Cycle Cost Savings		Median Payback Period *yrs.*
		Avg. Installed Price *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	
0	255.0	222.08	75.31	297.40	-	-	-
1	191.7	153.47	56.05	209.52	0.00	100.0	0.0
2	136.8	335.09	40.01	375.09	-165.57	0.0	36.3

* "No impact" means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.9 DC-DC, <9V Input Battery Chargers (PC8), Alternative Base Case Scenario

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	0.9	13.40	0.37	13.76	-	-	-
1	0.7	7.40	0.27	7.67	3.05	50.0	0.0
2	0.2	13.10	0.10	13.20	-1.93	10.0	0.0
3	0.2	13.48	0.08	13.55	-2.28	0.0	26.1

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.10 DC-DC, ≥9V Input Battery Chargers (PC9), Alternative Base Case Scenario

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	0.8	5.41	1.55	6.96	-	-	-
1	0.3	6.90	0.50	7.40	-0.09	74.9	7.2
2	0.1	7.36	0.26	7.62	-0.25	24.9	8.4

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

Table 8B.9.11 Low Energy, AC Out Battery Chargers (PC10), Alternative Base Case Scenario

		Life-Cycle Cost			Life-Cycle Cost Savings		
CSL	**UEC** *kWh*	**Avg. Installed Price** *2010$*	**Avg. Operating Cost** *2010$*	**Avg. LCC** *2010$*	**Wtd. Avg. Savings** *2010$*	**Consumers with No Impact*** *%*	**Median Payback Period** *yrs.*
0	19.3	5.94	13.29	19.22	-	-	-
1	6.1	7.63	4.23	11.85	0.00	100.0	0.0
2	4.0	8.09	2.78	10.87	0.00	100.0	0.0
3	1.5	8.65	1.03	9.68	0.00	100.0	0.0

* “No impact” means that the base case forecast product assigned to the consumer has greater efficiency than the level indicated, so the consumer is not affected.

---

[i] U.S. Department of Energy. Energy Information Administration. Annual Energy Outlook 2010. March, 2010. Washington, D.C. http://www.eia.doe.gov/oiaf/aeo/.

[ii] U.S. Department of Energy. Energy Information Administration. Energy Market and Economic Impacts of S.2191, The Lieberman-Warner Climate Security Act of 2007. April 2008. Washington, D.C. http://www.eia.doe.gov/oiaf/servicerpt/s2191/excel/s2191.xls.

APPENDIX 8C. END-USE APPLICATION INPUTS FOR THE LIFE-CYCLE COST ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 8C. END-USE APPLICATION INPUTS FOR THE LIFE-CYCLE COST ANALYSIS

8C.1 INTRODUCTION

There are a number of end-use applications ("applications") encompassed by each representative unit and product class ("representative unit") examined in the analysis. This can create a wide range of life-cycle cost (LCC) and payback period (PBP) results within each representative unit. This is because many of the same external power supply (EPS) or battery charger (BC) specifications can be used for a variety of applications. Since many of the inputs to the life-cycle cost (LCC) model are dependent on the particular application, such as product lifetime, DOE considers an array of popular applications when evaluating each representative unit.

8C.2 END-USE APPLICATION SELECTION METHODOLOGY

DOE compiled its list of relevant applications for the LCC analysis based on the total shipments of an application within a representative unit's output power or battery energy and voltage range for EPSs and BCs, respectively. DOE defines the battery energy and voltage range similarly to the product class delineations, while it defines the output power range as the midpoint between two representative units' values for output power. For example, given three Direct Operation EPS representative units at 2.5, 18, and 60 Watts (W) of output power, the 18W unit would consider applications that have an output power between 10 to 39W. This is because 10W is the midpoint between 2.5W and 18W, and 39W is the midpoint between 18W and 60W. Using these range definitions, DOE classifies the relevant applications for each representative unit and calculates the total shipments for each application.

DOE then collected all the relevant information needed as inputs for each of these applications. This data includes shipments, lifetime, markups, unit energy consumption (UEC), and market share at each CSL. These inputs are explained in more detail in chapters 6, 7, and 10.

8C.3 SUMMARIZED END-USE APPLICATION INPUTS

8C.3.1 Non-Class A External Power Supplies

Table 8C.3.1 and Table 8C.3.2 summarize DOE's findings for the applications associated with Non-Class A EPSs. For Non-Class A EPSs, DOE only noted one application in each product class. Therefore, the LCC results presented in chapter 8 of the Technical Support Document (TSD) pertain solely to that application. For further detail on application data, including the calculation of UECs, please see chapter 7 of the TSD.

Table 8C.3.1 End-Use Application Inputs for 203 Watt Multiple Voltage Non-Class A External Power Supplies

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Video Game Consoles	Res.	7,677	5.0	227 // 145	0	123.4	5.0
					1	33.1	95.0
					2	32.5	0.0
					3	27.0	0.0
					4	N/A	N/A

Table 8C.3.2 End-Use Application Inputs for 345 Watt High-Power Non-Class A External Power Supplies

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Amateur Radios	Res.	3	10.0	124 // 124	0	234.0	50.0
					1	89.9	50.0
					2	44.3	0.0
					3	35.4	0.0
					4	21.3	0.0

8C.3.2 Direct Operation External Power Supplies

Table 8C.3.3 through Table 8C.3.6 summarizes DOE's findings for the applications associated with Direct Operation EPSs. Each representative unit contains multiple applications so the representative units are shown separately. While each representative unit may contain 10 or more relevant applications, this appendix only shows data for the top nine applications for each representative unit. These nine applications comprise over 82-percent of total shipments for a representative unit. For further detail on application data, including the calculation of UECs, please see chapter 7 of the TSD. Detail on all applications can be found in the LCC spreadsheet model.

Table 8C.3.3 End-Use Application Inputs for 2.5 Watt Direct Operation External Power Supplies

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
Answering Machines	Res.	14,043	5.3	206 // 132	0	4.6	46.4
					1	3.0	46.4
					2	2.6	7.1
					3	2.3	0.0
					4	2.1	0.0
Cordless Phones	Res.	10,980	5.3	206 // 132	0	4.6	46.4
					1	3.0	46.4
					2	2.6	7.1
					3	2.3	0.0
					4	2.1	0.0
Mobile Phones	Res.	8,482	4.0	214 // 146	0	2.6	45.8
					1	1.6	54.2
					2	1.1	0.0
					3	0.9	0.0
					4	0.7	0.0
Portable Video Game Systems	Res.	6,482	3.0	227 // 145	0	2.9	40.0
					1	1.8	50.0
					2	0.8	4.0
					3	0.7	6.0
					4	0.3	0.0
Beard and Moustache Trimmers	Res.	5,288	4.5	200 // 123	0	0.2	30.2
					1	0.1	52.6
					2	0.1	12.9
					3	0.1	4.3
					4	0.1	0.0
Smartphone	Res.	3,499	4.0	214 // 146	0	2.7	40.0
					1	1.7	50.0
					2	1.1	4.0
					3	1.0	6.0
					4	0.8	0.0
Baby Monitors	Res.	3,400	4.0	217 // 133	0	4.1	40.0
					1	2.6	50.0
					2	1.9	4.0
					3	1.7	6.0
					4	1.4	0.0
Answering Machines	Comm.	2,876	5.3	206 // 132	0	4.6	46.4
					1	3.0	46.4
					2	2.6	7.1
					3	2.3	0.0
					4	2.1	0.0
Cordless Phones	Comm.	2,249	5.3	206 // 132	0	4.6	46.4
					1	3.0	46.4
					2	2.6	7.1
					3	2.3	0.0
					4	2.1	0.0

Table 8C.3.4 End-Use Application Inputs for 18 Watt Direct Operation External Power Supplies

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
LAN Equipment	Res.	15,464	4.0	189 // 131	0	22.6	12.5
					1	17.6	45.8
					2	14.7	16.7
					3	12.2	25.0
					4	7.0	0.0
Digital Picture Frames	Res.	9,133	5.0	214 // 126	0	29.9	28.6
					1	23.2	57.1
					2	19.4	14.3
					3	16.1	0.0
					4	9.3	0.0
MP3 Speaker Docks	Res.	7,853	4.0	211 // 134	0	0.6	21.2
					1	0.4	55.8
					2	0.4	19.2
					3	0.3	3.8
					4	0.2	0.0
Media Tablets	Res.	6,302	4.0	189 // 131	0	5.2	21.2
					1	3.7	55.8
					2	2.9	19.2
					3	2.1	3.8
					4	1.2	0.0
VoIP Adapters	Res.	5,919	5.0	206 // 132	0	6.1	14.3
					1	4.0	57.1
					2	3.0	14.3
					3	2.0	14.3
					4	1.0	0.0
Portable DVD Players	Res.	3,703	4.0	217 // 133	0	1.8	21.4
					1	1.3	35.7
					2	1.0	28.6
					3	0.8	14.3
					4	0.4	0.0
Wireless Charging Stations	Res.	3,496	6.8	217 // 133	0	5.2	21.2
					1	3.7	55.8
					2	2.9	19.2
					3	2.1	3.8
					4	1.2	0.0
LAN Equipment	Comm.	3,167	4.0	189 // 131	0	22.6	12.5
					1	17.6	45.8
					2	14.7	16.7
					3	12.2	25.0
					4	7.0	0.0
Computer Speakers	Comm.	2,623	5.0	189 // 131	0	14.2	21.2
					1	10.6	55.8
					2	8.6	19.2
					3	6.8	3.8
					4	3.8	0.0

Table 8C.3.5 End-Use Application Inputs for 60 Watt Direct Operation External Power Supplies

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Notebooks	Comm.	11,569	3.7	189 // 131	0	12.0	25.8
					1	10.6	53.0
					2	8.9	18.2
					3	7.5	3.0
					4	4.7	0.0
Video Game Consoles	Res.	11,515	5.0	227 // 145	0	13.4	5.0
					1	11.9	95.0
					2	9.9	0.0
					3	8.3	0.0
					4	5.2	0.0
Notebooks	Res.	9,466	3.7	189 // 131	0	10.9	25.8
					1	9.7	53.0
					2	8.1	18.2
					3	6.8	3.0
					4	4.3	0.0
Netbooks	Comm.	4,772	3.7	189 // 131	0	8.9	23.7
					1	7.9	50.0
					2	6.5	26.3
					3	5.4	0.0
					4	3.4	0.0
Netbooks	Res.	3,904	3.7	189 // 131	0	8.9	23.7
					1	7.9	50.0
					2	6.5	26.3
					3	5.4	0.0
					4	3.4	0.0
Ink Jet Imaging Equipment	Res.	3,390	5.0	199 // 131	0	13.7	8.3
					1	12.0	58.3
					2	10.5	33.3
					3	9.1	0.0
					4	5.7	0.0
LED Monitors	Comm.	1,306	4.0	189 // 131	0	25.1	21.2
					1	21.6	51.9
					2	20.3	26.9
					3	18.0	0.0
					4	11.2	0.0
Ink Jet Imaging Equipment	Comm.	694	5.0	199 // 131	0	15.5	8.3
					1	13.4	58.3
					2	12.4	33.3
					3	10.9	0.0
					4	6.8	0.0
LED Monitors	Res.	643	4.0	189 // 131	0	15.9	21.2
					1	14.0	51.9
					2	12.0	26.9
					3	10.3	0.0
					4	6.4	0.0

Table 8C.3.6 End-Use Application Inputs for 120 Watt Direct Operation External Power Supplies

Application	Sector	Shipments *in 1,000's*	Lifetime *yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Notebooks	Comm.	3,856	3.7	189 // 131	0	21.2	25.8
					1	18.4	53.0
					2	15.5	18.2
					3	14.8	3.0
					4	7.7	0.0
Notebooks	Res.	3,155	3.7	189 // 131	0	19.3	25.8
					1	16.7	53.0
					2	14.1	18.2
					3	13.4	3.0
					4	7.0	0.0
Portable O2 Concentrators	Res.	9	11.0	253 // 148	0	2.0	28.6
					1	1.7	57.1
					2	1.5	7.1
					3	1.5	7.1
					4	0.8	0.0

8C.3.3 Battery Chargers

Table 8C.3.7 through Table 8C.3.16 summarizes DOE's findings for the applications associated with BCs. Each representative unit contains multiple applications so the representative units are shown separately. While each representative unit may contain 10 or more relevant applications, this appendix only shows data for the top 10 applications for each representative unit. With the exception of PC2 (Low Energy, Low Voltage BCs), these 10 applications comprise between 94- to 100-percent of total shipments for a representative unit. For further detail on application data, including the calculation of UECs, please see chapter 7 of the TSD. Detail on all applications can be found in the LCC spreadsheet model.

Table 8C.3.7 End-Use Application Inputs for Low Energy, Inductive Battery Chargers (PC1)

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Rechargeable Toothbrushes	Res.	15,000	5.0	200 // 123	0	8.7	77.8
					1	6.1	11.1
					2	3.0	11.1
					3	1.3	0.0
Rechargeable Water Jets	Res.	100	5.0	200 // 123	0	8.7	77.8
					1	6.1	11.1
					2	3.0	11.1
					3	1.3	0.0

Table 8C.3.8 End-Use Application Inputs for Low Energy, Low Voltage Battery Chargers (PC2)

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
Mobile Phones	Res.	67,852	2.0	214 // 146	0	10.8	0.0
					1	7.8	23.7
					2	3.9	76.3
					3	1.1	0.0
					4	1.0	0.0
Smartphone	Res.	34,989	2.0	214 // 146	0	11.7	0.0
					1	8.5	23.7
					2	4.4	76.3
					3	1.2	0.0
					4	1.1	0.0
Digital Cameras	Res.	20,023	6.0	214 // 126	0	1.0	30.7
					1	0.8	20.5
					2	0.4	41.5
					3	0.1	7.4
					4	0.1	0.0
Answering Machines	Res.	14,043	5.3	206 // 132	0	13.6	60.5
					1	10.7	18.9
					2	5.7	20.6
					3	1.7	0.0
					4	1.1	0.0
Cordless Phones	Res.	10,980	5.3	206 // 132	0	13.6	60.5
					1	10.7	18.9
					2	5.7	20.6
					3	1.7	0.0
					4	1.1	0.0
Bluetooth Headsets	Res.	10,634	5.0	214 // 146	0	7.7	30.7
					1	6.2	20.5
					2	3.4	41.5
					3	1.0	7.4
					4	0.6	0.0
Portable Video Game Systems	Res.	10,386	3.0	227 // 145	0	6.6	30.7
					1	4.4	20.5
					2	2.1	41.5
					3	0.8	7.4
					4	0.6	0.0
Shavers	Res.	8,656	4.1	200 // 123	0	9.5	0.0
					1	7.3	0.0
					2	3.1	75.0
					3	0.9	25.0
					4	0.4	0.0
Mobile Phones	Comm.	7,539	2.0	214 // 146	0	9.9	0.0
					1	7.4	23.7
					2	3.9	76.3
					3	1.0	0.0
					4	0.9	0.0

Table 8C.3.9 End-Use Application Inputs for Low Energy, Medium Voltage Battery Chargers (PC3)

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
Camcorders	Res.	4,700	4.9	214 // 126	0	0.9	18.5
					1	0.3	60.6
					2	0.1	20.9
					3	0.1	0.0
Toy Ride-On Vehicles	Res.	4,045	4.0	235 // 139	0	6.7	18.5
					1	2.6	60.6
					2	0.5	20.9
					3	0.4	0.0
Portable DVD Players	Res.	3,703	4.0	217 // 133	0	6.7	0.0
					1	2.7	87.0
					2	0.4	13.0
					3	0.4	0.0
DIY Power Tools	Res.	2,221	5.9	214 // 134	0	21.5	17.4
					1	8.6	52.2
					2	1.3	30.4
					3	1.3	0.0
RC Toys	Res.	2,100	2.0	227 // 145	0	1.9	18.5
					1	0.8	60.6
					2	0.3	20.9
					3	0.2	0.0
DIY Power Tools	Res.	1,490	5.9	214 // 134	0	8.8	40.2
					1	3.3	43.5
					2	0.7	16.3
					3	0.6	0.0
Handheld Vacuums	Res.	1,320	6.0	200 // 130	0	40.1	14.5
					1	16.0	58.0
					2	2.5	27.5
					3	2.4	0.0
LAN Equipment	Res.	1,064	4.0	189 // 131	0	39.8	18.5
					1	16.0	60.6
					2	2.3	20.9
					3	2.3	0.0
Stick Vacuums	Res.	863	6.0	200 // 130	0	40.1	21.3
					1	16.0	46.2
					2	2.5	32.5
					3	2.4	0.0
DIY Power Tools	Comm.	263	5.9	214 // 134	0	26.7	40.2
					1	9.6	43.5
					2	3.0	16.3
					3	2.5	0.0

Table 8C.3.10 End-Use Application Inputs for Low Energy, High Voltage Battery Chargers (PC4)

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Notebooks	Comm.	15,425	3.7	189 // 131	0	43.9	0.0
					1	11.2	32.6
					2	5.3	67.4
					3	3.4	0.0
Notebooks	Res.	12,621	3.7	189 // 131	0	46.4	0.0
					1	12.0	32.6
					2	4.8	67.4
					3	3.5	0.0
Professional Power Tools	Res.	7,597	1.5	214 // 134	0	19.0	18.3
					1	5.3	50.4
					2	2.5	31.3
					3	1.6	0.0
Netbooks	Comm.	4,772	3.7	189 // 131	0	41.3	0.0
					1	10.7	32.6
					2	5.4	67.4
					3	3.3	0.0
DIY Power Tools	Res.	4,470	5.9	214 // 134	0	10.9	40.2
					1	3.1	43.5
					2	1.4	16.3
					3	1.0	0.0
Professional Power Tools	Comm.	4,091	1.5	214 // 134	0	32.6	18.3
					1	10.8	50.4
					2	6.5	31.3
					3	3.7	0.0
Netbooks	Res.	3,904	3.7	189 // 131	0	42.9	0.0
					1	11.0	32.6
					2	5.3	67.4
					3	3.4	0.0
Handheld Vacuums	Res.	2,680	6.0	200 // 130	0	52.4	14.5
					1	12.9	58.0
					2	5.1	27.5
					3	3.7	0.0
Stick Vacuums	Res.	1,752	6.0	200 // 130	0	52.4	21.3
					1	12.9	46.2
					2	5.1	32.5
					3	3.7	0.0
Robotic Vacuums	Res.	1,000	6.0	200 // 130	0	52.8	21.3
					1	13.4	46.2
					2	5.9	32.5
					3	4.0	0.0

Table 8C.3.11 End-Use Application Inputs for Medium Energy, Low Voltage Battery Chargers (PC5)

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Toy Ride-On Vehicles	Res.	4,045	4.0	235 // 139	0	49.1	18.5
					1	33.0	60.6
					2	17.5	7.9
					3	9.9	13.0
Marine/Automotive/RV Chargers	Res.	500	10.0	235 // 139	0	198.5	78.3
					1	116.2	4.4
					2	72.1	4.4
					3	7.5	13.0
Mobility Scooters	Res.	192	9.7	235 // 139	0	358.9	72.5
					1	255.9	14.5
					2	111.7	0.0
					3	97.1	13.0
Wheelchairs	Res.	125	9.7	235 // 139	0	358.9	72.5
					1	255.9	14.5
					2	111.7	0.0
					3	97.1	13.0
Portable O2 Concentrators*	Res.	5	11.0	253 // 148	0	50.5	77.3
					1	41.1	6.4
					2	14.8	3.2
					3	19.8	13.0

* Note: For Portable O2 Concentrators, the UEC at CSL 3 is greater than the UEC at CSL 2 because of the unique usage profile for this application. This application's usage profile indicates a large amount of time in no-battery (unplugged) mode compared to the other modes. When this usage profile is paired with the specifications from the engineering analysis, the UEC increases at CSL 3 relative to CSL 2.

Table 8C.3.12 End-Use Application Inputs for Medium Energy, High Voltage Battery Chargers (PC6)

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
Electric Scooters	Res.	250	9.7	235 // 139	0	128.2	43.5
					1	89.7	17.4
					2	39.3	26.1
					3	21.3	13.0
Lawn Mowers	Res.	182	6.0	214 // 134	0	97.1	9.7
					1	57.0	58.0
					2	35.0	19.3
					3	2.7	13.0
Motorized Bicycles	Res.	150	9.7	235 // 139	0	128.2	43.5
					1	89.7	17.4
					2	39.3	26.1
					3	21.3	13.0
Wheelchairs	Res.	42	9.7	235 // 139	0	151.0	72.5
					1	113.5	14.5
					2	43.2	0.0
					3	34.9	13.0

Table 8C.3.13 End-Use Application Inputs for High Energy Battery Chargers (PC7)

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
Golf Carts	Comm.	188	3.5	235 // 139	0	276.2	43.5
					1	209.6	56.5
					2	149.4	0.0
					3	N/A	N/A
Golf Carts	Res.	22	6.5	235 // 139	0	76.6	43.5
					1	41.5	56.5
					2	30.2	0.0
					3	N/A	N/A

Table 8C.3.14 End-Use Application Inputs for DC-DC, <9V Input Battery Chargers (PC8)

Application	**Sector**	**Shipments** *in 1,000's*	**Lifetime** *Yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
MP3 Players	Res.	36,091	4.0	211 // 134	0	1.0	50.0
					1	0.8	40.0
					2	0.3	10.0
					3	0.2	0.0
Mobile Phones	Res.	16,963	4.0	214 // 146	0	0.9	50.0
					1	0.7	40.0
					2	0.3	10.0
					3	0.2	0.0
Digital Cameras*	Res.	5,006	6.0	214 // 126	0	0.1	50.0
					1	0.1	40.0
					2	0.0	10.0
					3	0.0	0.0
Mobile Phones	Comm.	1,885	4.0	214 // 146	0	0.9	50.0
					1	0.7	40.0
					2	0.3	10.0
					3	0.2	0.0
Camcorders*	Res.	1,567	4.9	214 // 126	0	0.0	50.0
					1	0.0	40.0
					2	0.0	10.0
					3	0.0	0.0
Bluetooth Headsets	Res.	1,182	5.0	214 // 146	0	1.6	50.0
					1	1.2	40.0
					2	0.4	10.0
					3	0.3	0.0
Personal Digital Assistants	Res.	1,103	4.5	189 // 131	0	0.5	50.0
					1	0.4	40.0
					2	0.1	10.0
					3	0.1	0.0
Personal Digital Assistants	Comm.	473	4.5	189 // 131	0	0.5	50.0
					1	0.4	40.0
					2	0.1	10.0
					3	0.1	0.0
E-Books	Res.	440	4.9	217 // 133	0	0.5	50.0
					1	0.4	40.0
					2	0.1	10.0
					3	0.1	0.0
Digital Cameras	Comm.	263	6.0	214 // 126	0	1.0	50.0
					1	0.8	40.0
					2	0.3	10.0
					3	0.2	0.0

* Note: Some applications have a UEC that is less than 0.0. These UECs appear as 0.0, but are not zero.

Table 8C.3.15 End-Use Application Inputs for DC-DC, ≥9V Input Battery Chargers (PC9)

Application	Sector	Shipments *in 1,000's*	Lifetime *Yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
In-Vehicle GPS	Res.	9,484	4.9	260 // 169	0	0.8	25.0
					1	0.3	50.0
					2	0.1	25.0
					3	N/A	N/A
Flashlights/Lanterns	Res.	50	10.0	217 // 133	0	7.9	46.2
					1	1.0	50.0
					2	0.7	3.8
					3	N/A	N/A
Medical Nebulizers	Res.	45	11.0	253 // 148	0	0.8	24.5
					1	0.3	53.1
					2	0.1	22.4
					3	N/A	N/A
Portable O2 Concentrators	Res.	5	11.0	253 // 148	0	0.8	88.9
					1	0.3	7.4
					2	0.1	3.7
					3	N/A	N/A

Table 8C.3.16 End-Use Application Inputs for Low Energy, AC Out Battery Chargers (PC10)

Application	Sector	Shipments *in 1,000's*	Lifetime *yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Uninterruptible Power Supplies	Res.	5,064	7.3	201 // 135	0	19.3	87.0
					1	6.1	0.0
					2	4.0	0.0
					3	1.5	13.0
Uninterruptible Power Supplies	Comm.	2,936	7.3	201 // 135	0	19.3	87.0
					1	6.1	0.0
					2	4.0	0.0
					3	1.5	13.0

8C.4 END-USE APPLICATION SAMPLING

DOE uses the list of relevant applications for each representative unit to approximate the input variables for that unit. To do this, DOE weights each application within a given representative unit by that application's shipments as a percentage of the total shipments for the representative unit. DOE then uses these weighted inputs for the LCC calculations. DOE believes an application's shipments are an accurate index of consumer purchases relative to other applications within a year. While some of DOE's analyses focus on an application's install base to approximate the level of ownership for a given product, DOE finds that shipments better reflect consumer purchasing events within a year, which is the object of concern in the LCC and PBP analysis. DOE also considers application-specific LCC results as a subgroup analysis, detailed in chapter 11.

In the Monte Carlo simulation analysis, DOE samples an application from each representative unit for each trial that is run. The applications are sampled based on their shipment-weighted probabilities. All of the application's input variables are used when it is selected in a trial. These input variables include lifetime, markups, UEC, and market share at each CSL. The resulting LCC findings are thus made up of multiple trials that account for discrete input sets for each application, which are then averaged over the number of trials conducted.

In the sample calculation, however, DOE utilizes only one set of inputs per representative unit. These inputs are generated by using a shipment-weighted average across applications for each of the input types. Thus, the resulting inputs account for each of the applications in proportion to the application's weighting. Table 8C.4.1 through Table 8C.4.3 shows the shipment-weighted results for each input.

Table 8C.4.1 Shipment-Weighted Inputs for Non-Class A External Power Supply Representative Units

Representative Unit	**Lifetime** *yrs*	**Markups (Baseline // Incremental)** *%*	**CSL**	**Unit Energy Consumption** *kWh/yr*	**Market Share** *%*
203 Watt Multiple Voltage	5.0	227 // 145	0	123.4	5.0
			1	33.1	95.0
			2	32.5	0.0
			3	27.0	0.0
			4	N/A	N/A
345 Watt High-Power	10.0	124 // 124	0	234.0	50.0
			1	89.9	50.0
			2	44.3	0.0
			3	35.4	0.0
			4	21.3	0.0

Table 8C.4.2 Shipment-Weighted Inputs for Direct Operation External Power Supply Representative Units

Representative Unit	Lifetime *yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
2.5 Watt Regular AC/DC	4.7	210 // 135	0	3.4	42.4
			1	2.2	49.3
			2	1.7	6.1
			3	1.5	2.2
			4	1.3	0.0
18 Watt Regular AC/DC	4.6	202 // 131	0	13.1	19.4
			1	10.0	52.3
			2	8.3	17.9
			3	6.8	10.5
			4	3.8	0.0
60 Watt Regular AC/DC	4.2	199 // 134	0	12.2	18.6
			1	10.8	63.1
			2	9.1	17.0
			3	7.7	1.4
			4	4.8	0.0
120 Watt Regular AC/DC	3.7	189 // 131	0	20.3	25.8
			1	17.6	53.0
			2	14.8	18.2
			3	14.2	3.0
			4	7.4	0.0

Table 8C.4.3 Shipment-Weighted Inputs for Battery Charger Representative Units

Representative Unit	Lifetime *yrs*	Markups (Baseline // Incremental) *%*	CSL	Unit Energy Consumption *kWh/yr*	Market Share *%*
Low Energy, Inductive (PC1)	5.0	200 // 123	0	8.7	77.8
			1	6.1	11.1
			2	3.0	11.1
			3	1.3	0.0
Low Energy, Low Voltage (PC2)	3.6	213 // 140	0	9.4	17.9
			1	7.0	22.3
			2	3.5	56.6
			3	1.0	3.1
			4	0.8	0.0
Low Energy, Medium Voltage (PC3)	4.6	216 // 133	0	11.9	17.0
			1	4.7	61.8
			2	0.8	21.2
			3	0.8	0.0
Low Energy, High Voltage (PC4)	3.8	198 // 132	0	37.7	9.2
			1	9.9	39.3
			2	4.6	51.5
			3	3.0	0.0
Medium Energy, Low Voltage (PC5)	5.0	235 // 139	0	84.6	28.2
			1	56.1	51.8
			2	29.3	7.0
			3	15.3	13.0
Medium Energy, High Voltage (PC6)	8.6	229 // 137	0	120.6	35.5
			1	81.7	29.1
			2	38.3	22.4
			3	16.8	13.0
High Energy (PC7)	3.8	235 // 139	0	255.0	43.5
			1	191.7	56.5
			2	136.8	0.0
			3	N/A	N/A
DC-DC, <9V Input (PC8)	4.2	212 // 137	0	0.9	50.0
			1	0.7	40.0
			2	0.2	10.0
			3	0.2	0.0
DC-DC, ≥9V Input (PC9)	5.0	260 // 169	0	0.8	25.1
			1	0.3	50.0
			2	0.1	24.9
			3	N/A	N/A
Low Energy, AC Out (PC10)	7.3	201 // 135	0	19.3	87.0
			1	6.1	0.0
			2	4.0	0.0
			3	1.5	13.0

APPENDIX 8D. RESIDENTIAL DISCOUNT RATE DISTRIBUTIONS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 8D. RESIDENTIAL DISCOUNT RATE DISTRIBUTIONS

8D.1 INTRODUCTION

As discussed in Chapter 8, DOE characterized real interest rates associated with household debt and assets with probability distributions to develop a residential discount rate. The sections below provide the probability distributions.

8D.2 DISTRIBUTION OF REAL INTEREST RATES FOR CONSUMER DEBT CLASSES

Table 8D.2.1 presents weighted distributions of the real effective interest rates for various household debt classes. As reported in Chapter 8, DOE used data from the Federal Reserve Board's *Survey of Consumer Finances (SCF)* in 1989, 1992, 1995, 1998, 2001, 2004, and 2007 to generate the probability distributions for household debt. The weights associated with each binned rate correspond to the share of each value among the surveyed households. DOE calculated the rates shown in Table 8D.2.1 by developing a similar table from each of the seven *SCF* surveys. DOE used each year's respective weighting for the bins and then averaged across the seven *SCF* surveys to derive the values shown in Table 8D.2.1.

Table 8D.2.1 Household Debt: Real Interest Rate Distributions

Rate %	Home Equity %	Credit Card %	Installment Loans %	Other Residence %	Other Line of Credit %
0.0	2.3	5.2	37.1	1.4	1.9
0.5	6.2	1.0	1.4	1.5	2.8
1.5	7.9	1.5	2.5	4.6	3.0
2.5	12.1	2.3	4.3	13.1	4.4
3.5	22.8	3.3	3.8	18.0	5.0
4.5	24.2	4.2	4.5	20.7	12.3
5.5	15.9	5.9	5.3	18.3	11.3
6.5	3.8	6.6	6.6	11.8	8.9
7.5	2.9	3.1	2.6	4.8	5.1
8.5	0.4	6.4	3.6	3.0	10.8
9.5	0.8	5.8	2.8	0.8	6.9
10.5	0.0	5.9	2.8	0.4	4.9
11.5	0.2	5.7	1.4	0.5	6.3
12.5	0.2	4.8	2.5	0.4	4.4
13.5	0.0	4.8	1.9	0.1	1.1
14.5	0.1	12.3	4.6	0.4	4.2
15.5		9.0	2.9	0.2	2.7
16.5		3.4	1.5	0.1	0.7
17.5		3.9	2.1	0.1	0.3
18.5		1.9	1.5		1.2
19.5		1.1	0.7		0.7
20.5		0.7	0.9		0.0
21.5		0.3	1.0		0.6
22.5		0.2	0.4		0.3
23.5		0.1	0.1		0.0
24.5		0.3	0.7		0.1
25.5		0.1	0.0		
26.5			0.0		
27.5			0.1		
28.5			0.1		
29.5			0.0		
30.5			0.0		
31.5			0.0		
32.5			0.0		
33.5			0.0		
34.5			0.0		
35.5			0.1		
36.5			0.0		
37.5			0.0		
38.5			0.0		
39.5			0.4		

8D.3 DISTRIBUTION OF REAL INTEREST RATES FOR FINANCIAL ASSETS

Table 8D.3.1 presents the time series of real effective interest rates associated with various household asset types. As reported in Chapter 8, DOE used data from various sources to generate the probability distributions for each of the asset types identified in Table 8D.3.1. For each asset, the average, minimum, maximum, and standard deviation are provided. DOE developed probability distributions based on the average value and standard deviation. Because the use of the standard deviations yields distributions with negative values, DOE truncated the lower end of the normal distribution at a discount rate of zero. DOE also truncated the higher end of the normal distribution in equal proportion to the truncation at the lower end to maintain the average values above in Table 8D.3.1.

Table 8D.3.1 Household Assets: Time-Series of Real Interest Rates

Year	Savings Accounts %	CDs 6 Months %	Treasury Savings Bonds %	Corp AAA Bonds %	Stocks S&P 500 %	Mutual Funds %
1980	-	-0.5	-2.3	-1.4	16.1	10.3
1981	-	5.0	3.7	3.5	-13.6	-7.9
1982	-	6.0	8.0	7.2	13.4	11.3
1983	-	5.9	8.3	8.6	18.5	15.2
1984	5.5	6.1	7.9	8.0	1.8	3.9
1985	5.3	4.5	7.5	7.5	26.7	20.3
1986	6.0	4.6	7.2	7.0	16.3	13.2
1987	3.3	3.2	5.7	5.5	2.1	3.2
1988	3.1	3.6	5.3	5.4	11.9	9.7
1989	3.0	4.1	4.0	4.2	25.4	18.4
1990	2.4	2.6	3.5	3.7	-8.0	-4.1
1991	2.7	1.6	4.2	4.4	25.0	18.1
1992	2.1	0.7	4.9	5.0	4.4	4.6
1993	1.1	0.3	3.9	4.1	6.8	5.9
1994	1.3	2.3	5.1	5.3	-1.2	1.0
1995	2.2	3.1	4.5	4.6	33.4	23.8
1996	2.0	2.4	4.2	4.3	20.3	14.9
1997	2.7	3.4	4.6	4.9	28.9	20.9
1998	3.4	3.8	4.8	4.9	26.4	19.2
1999	2.3	3.2	4.6	4.7	18.3	13.8
2000	1.7	3.1	3.8	4.1	-12.0	-6.6
2001	1.8	0.8	3.5	4.1	-14.3	-8.2
2002	1.3	0.2	4.6	4.8	-23.2	-13.8
2003	-0.2	-1.1	3.4	3.3	25.5	18.1
2004	-0.7	-0.9	3.0	2.9	7.9	6.2
2005	-0.2	0.3	2.0	1.8	1.4	1.5
2006	1.1	2.0	2.1	2.3	12.0	8.8
2007	2.0	2.3	2.5	2.6	2.6	2.6
2008	0.2	-0.7	2.1	1.7	-38.9	-25.4
2009	3.6	1.2	6.1	5.7	26.4	19.5
Average	2.3	2.4	4.4	4.5	7.2	6.6
Minimum	-0.7	-1.1	-2.3	-1.4	-38.9	-25.4
Maximum	6.0	6.1	8.3	8.6	33.4	23.8
Std. Dev.	1.7	2.1	2.2	2.0	17.2	11.7

APPENDIX 9A SHIPMENTS SENSITIVITY ANALYSIS

9A.1 Price Elasticity Sensitivity

This appendix contains the results of the shipments sensitivity analysis for battery chargers.[a] DOE assumes that the price elasticity of demand for all BC applications is equal to -1, meaning that a given percentage increase in the final product price would be accompanied by that same percentage decrease in shipments. Table 9A.1 shows the decrease in demand for BCs in the sensitivity case by product class. Table 9A.2 shows the decrease in demand for individual BC applications, as well as DOE's assumptions about the average price of each application.

Table 9A.1 Decrease in Demand for BCs in 2013 by Product Class

Product Class	Shipments in the Absence of Standards (units)	Weighted-Average Price Increase Due to Standards	Percent of Shipments Affected by Standards	Decrease in Demand Due to Standards (units)	Decrease in Demand Due to Standards (%)
1	15,553,000	$0.92	89%	159,854	1.03%
2	256,488,228	$0.13	21%	119,462	0.05%
3	23,752,295	$1.61	17%	75,342	0.32%
4	62,753,452	$3.92	9%	208,301	0.33%
5	5,012,255	$0.00	93%	0	0.00%
6	642,367	$0.00	78%	0	0.00%
7	216,939	$0.00	44%	0	0.00%
8	67,166,135	$0.00	50%	0	0.00%
9	9,870,748	$0.00	0%	0	0.00%
10	8,240,000	$2.53	100%	48,593	0.59%

---

[a] DOE received comments on its preliminary analysis that standards that cause significant increases in the prices of end-use products may lead to a reduction in shipments as consumers forgo purchasing the more expensive end-use products. (AHAM, No. 42 at pp. 14-15; PTI, No. 45 at p. 12) DOE conducted a sensitivity analysis on BCs to demonstrate that the proposed standards would most likely have a negligible effect on product shipments.

Table 9A.2 Decrease in Demand for BC Applications due to Standards

BC Application	Average application price	Shipments in 2013 in the Absence of Standards (units)	Decrease in Demand Due to Standards (units)	Decrease in Demand Due to Standards (%)
Wireless Speakers	$126.40	234,953	541	0.23%
MP3 Speaker Docks	$84.12	1,427,426	777	0.05%
Wireless Headphones	$55.76	515,000	423	0.08%
MP3 Players	$116.52	41,304,030	1,854	< 0.01%
Personal Digital Assistants	$244.10	1,802,500	33	< 0.01%
Netbooks	$297.35	8,935,971	No change (1)	
Notebooks	$542.14	28,887,380	No change (1)	
Media Tablets	$388.62	7,592,394	No change (1)	
Uninterruptible Power Supplies	$429.45	8,240,000	48,593	0.59%
Portable Printers	$187.82	987,277	3,211	0.33%
E-Books	$241.25	2,266,000	343	0.02%
Mobile Internet Hotspots	$269.99	1,474,955	244	0.02%
LAN Equipment	$99.16	1,320,923	3,878	0.29%
In-Vehicle GPS	$129.93	13,024,350	829	0.01%
Handheld GPS	$187.01	155,891	39	0.02%
Bluetooth Headsets	$70.08	14,317,000	9,188	0.06%
Consumer Two-Way Radios	$53.29	11,371,200	10,663	0.09%
Mobile Phones	$180.09	97,066,170	No change (1)	
Smartphone	$486.49	42,397,890	No change (1)	
Cordless Phones	$22.14	13,625,870	4,278	0.32%
Answering Machines	$44.76	17,426,570	28,016	0.16%

BC Application	Average application price	Shipments in 2013 in the Absence of Standards (units)	Decrease in Demand Due to Standards (units)	Decrease in Demand Due to Standards (%)
Baby Monitors	$104.20	3,502,000	1,535	0.04%
RC Toys	$53.13	2,163,000	13,134	0.61%
Portable Video Game Systems	$162.50	10,697,580	3,264	0.03%
Video Game Consoles	$249.99	4,636,720	920	0.02%
Handheld Vacuums	$85.56	4,120,000	21,739	0.53%
Robotic Vacuums	$265.14	1,030,000	3,204	0.31%
Stick Vacuums	$89.34	2,692,935	19,993	0.74%
Home Security Systems	$128.46	4,345,753	1,550	0.04%
Blenders	$156.49	63,088	120	0.19%
Can Openers	$22.85	293,725	285	0.10%
Mixers	$156.49	59,462	233	0.39%
Camcorders	$231.23	6,455,010	5,869	0.09%
Digital Cameras	$225.15	27,135,968	4,154	0.02%
Portable DVD Players	$126.40	3,813,781	No change (1)	
Air Mattress Pumps	$30.55	257,500	2,505	0.97%
Flashlights/Lanterns	$25.95	103,000	3,156	3.06%
Universal Battery Chargers	$35.98	309,000	3,080	1.00%
Rechargeable Garden Care Products	$96.27	94,245	832	0.88%
Lawn Mowers	$273.62	187,607	No change (2)	
Rechargeable Toothbrushes	$80.41	15,450,000	156,947	1.02%
Rechargeable Water Jets	$28.94	103,000	2,908	2.82%
Beard and Moustache Trimmers	$22.51	2,420,500	4,514	0.19%

BC Application	**Average application price**	**Shipments in 2013 in the Absence of Standards (units)**	**Decrease in Demand Due to Standards (units)**	**Decrease in Demand Due to Standards (%)**
Hair Clippers	$30.93	1,562,478	2,120	0.14%
Shavers	$79.73	8,915,680	3,083	0.03%
Sleep Apnea Machines	$470.49	515,000	1,027	0.20%
Medical Nebulizers	$67.26	463,500	5,821	1.26%
Portable O2 Concentrators	$3,083.40	9,270	No change (2)	
DIY Power Tools (Integral)	$40.43	4,815,250	18,051	0.37%
DIY Power Tools (External)	$93.11	7,222,875	105,765	1.46%
Professional Power Tools	$142.08	12,038,125	61,877	0.51%
Electric Scooters	$166.33	257,500	No change (2)	
Motorized Bicycles	$795.42	154,500	No change (2)	
Golf Carts	$6,135.17	216,939	No change (2)	
Toy Ride-On Vehicles	$117.37	8,332,597	10,960	0.13%
Wheelchairs	$4,017.09	171,039	No change (2)	
Mobility Scooters	$1,025.72	198,042	No change (2)	
Marine/Automotive/RV Chargers	$488.05	515,000	No change (2)	

(1) There were no products affected by the proposed standard. The efficiency of all units in the market already meets or exceeds the proposed standard level.

(2) The proposed standard is expected to lead to a decline in the price of BCs for this application. Thus, it is assumed that there will be no increase in the price of the end-use product as a result of the BC standard.

9A.2 Alternative Base Case Efficiency Sensitivity

On January 12th, 2012, the California Energy Commission (CEC) established energy conservation standards for battery chargers in the State of California. These standards will go into effect on February 1st, 2013 and will have an impact on DOE's base case efficiency distributions for battery chargers. In the reference case, DOE has assumed that these standards will only affect the market in California. In an effort to show the breadth of the potential effects from the CEC battery charger standards, DOE developed an alternative base case efficiency scenario wherein all battery chargers sold in the United States are designed to meet the California standards. The average efficiency distributions of each product class in this sensitivity case are shown below in Table 9A.3. The results of the LCC and NIA sensitivity analyses can be found in Appendices 8A and 10A, respectively.

Table 9A.3 Efficiency Distributions under Full Spillover Scenario

Product Class	CSL 0	CSL 1	CSL 2	CSL3
1	78%	11%	11%	0%
2	0%	0%	97%	3%
3	0%	0%	100%	0%
4	0%	0%	100%	0%
5	0%	0%	0%	100%
6	0%	0%	0%	100%
7	0%	100%	0%	0%
8	50%	40%	10%	0%
10	0%	0%	0%	100%

APPENDIX 10-A NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE UNDER ALTERNATIVE SCENARIOS

TABLE OF CONTENTS

LIST OF TABLES

10-A.1 Introduction

This appendix presents national energy savings (NES) and net present value (NPV) results using inputs from alternative scenarios. The tables in section 10-A.2 show how the cumulative net present value of consumer benefits from standards varies with energy prices. DOE examined three scenarios, which are based on the energy price forecasts in the High Economic Growth, Low Economic Growth, and Reference cases in EIA's *Annual Energy Outlook 2010*. The tables in section 10-A.3 investigate a scenario in which the demand for battery chargers changes in response to standards and show how these changes could affect NES and NPV.

10-A.2 NIA Results by Energy Price Forecast Scenario

Table 10-A.1 and Table 10-A.2 contain NPV results for external power supplies at 3 percent and 7 percent discount rates, respectively. Table 10-A.3 and Table 10-A.4 contain the corresponding NPV results for battery chargers. In each table cell, results are displayed in the following format:

"Reference Case Result"

["Low Economic Growth Case Result" to "High Economic Growth Case Result"]

Table 10-A.10.1 NPV Results for External Power Supplies by Energy Price Forecast Scenario, 3 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	1228 [1068 to 1389]	1138 [886 to 1394]	-3292 [-3751 to -2827]
B, C, D, E	1542 [1338 to 1749]	1525 [1207 to 1849]	-2983 [-3542 to -2415]
X	329 [305 to 353]	330 [303 to 357]	-533 [-589 to -478]
H	9.4 [8.9 to 9.8]	9.7 [9.3 to 10.2]	7.6 [7.0 to 8.1]

Table 10-A.10.2 NPV Results for External Power Supplies by Energy Price Forecast Scenario, 7 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level		
	TSL 1	TSL 2	TSL 3
B	596 [515 to 676]	463 [335 to 590]	-2357 [-2590 to -2126]
B, C, D, E	730 [627 to 831]	613 [453 to 773]	-2301 [-2583 to -2022]
X	178 [166 to 189]	176 [162 to 189]	-364 [-392 to -336]
H	4.8 [4.6 to 5.0]	5.0 [4.8 to 5.2]	3.6 [3.3 to 3.8]

Table 10-A.10.3 NPV Results for Battery Chargers by Energy Price Forecast Scenario, 3 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	294 [275 to 313]	606 [561 to 651]	-781 [-842 to -719]	
2, 3, 4	1255 [1147 to 1364]	-367 [-631 to -99]	-14159 [-14783 to -13526]	-38443 [-39137 to -37738]
5, 6	1628 [1537 to 1722]	4648 [4446 to 4856]	-11123 [-11387 to -10850]	
7	119 [117 to 122]	-493 [-501 to -485]		
8	2780 [2777 to 2784]	-1654 [-1668 to -1640]	-2001 [-2017 to -1985]	
10	1192 [1110 to 1276]	1354 [1259 to 1451]	1550 [1438 to 1663]	

Table 10-A.10.4 NPV Results for Battery Chargers by Energy Price Forecast Scenario, 7 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	157 [147 to 166]	318 [296 to 340]	-527 [-558 to -497]	
2, 3, 4	711 [651 to 771]	-553 [-704 to -403]	-9641 [-9980 to -9305]	-24255 [-24628 to -23886]
5, 6	997 [945 to 1049]	2919 [2804 to 3035]	-8002 [-8152 to -7850]	
7	80 [79 to 82]	-290 [-294 to -287]		
8	1665 [1663 to 1667]	-976 [-984 to -968]	-1183 [-1192 to -1173]	
10	703 [657 to 749]	795 [742 to 849]	907 [844 to 969]	

10-A.3 NIA Results in an Elastic Shipment Scenario

This section displays NES and NPV results for battery chargers when accounting for price elasticity of demand. For the underlying assumptions regarding how demand for battery chargers may change in response to standards, see Appendix 9-A. For comparison with the reference case results, see Chapter 10. Table 10-A.5 contains NES results for battery chargers. Table 10-A.6 and Table 10-A.7 contain the NPV results for battery chargers at 3 percent and 7 percent discount rates, respectively.

Table 10-A.10.5 NES Results for Battery Chargers in an Elastic Shipment Scenario (Quadrillion Btu)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	0.055	0.128	0.176	
2, 3, 4	0.308	0.758	1.794	1.994
5, 6	0.268	0.596	0.781	
7	0.007	0.021		
8	0.010	0.041	0.045	
10	0.229	0.266	0.311	

Table 10-A.10.6 NPV Results for Battery Chargers in an Elastic Shipment Scenario, 3 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	291	599	-773	
2, 3, 4	1,253	-368	-14,136	-38,375
5, 6	1,628	4,648	-11,123	
7	119	-493		
8	2,780	-1,654	-2,001	
10	1,185	1,346	1,540	

Table 10-A.10.7 NPV Results for Battery Chargers in an Elastic Shipment Scenario, 7 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	155	315	-522	
2, 3, 4	663	-435	-8,959	-23,501
5, 6	867	2,539	-6,961	
7	70	-299		
8	1,659	-1,000	-1,208	
10	608	688	784	

10-A.4 NIA Results under a Full Spillover Scenario

On January 12th, 2012, the California Energy Commission (CEC) established energy conservation standards for battery chargers in the State of California. These standards will go into effect on February 1st, 2013 and will have an impact on DOE's base case efficiency distributions for battery chargers. In the reference case, DOE has assumed that these standards will only affect the market in California. In an effort to show the breadth of the potential effects from the CEC battery charger standards, DOE developed an alternative base case efficiency scenario wherein all battery chargers sold in the United States are designed to meet the California standards. The average efficiency distributions of each product class in this sensitivity case are shown below in Table 10-A.10.9. Table 10-A.10.9 through Table 10-A.10.11 show NES and NPV results under this scenario

Table 10-A.10.8 Efficiency Distributions under a Full Spillover Scenario

Product Class	CSL 0	CSL 1	CSL 2	CSL3
1	78%	11%	11%	0%
2	0%	0%	97%	3%
3	0%	0%	100%	0%
4	0%	0%	100%	0%
5	0%	0%	0%	100%
6	0%	0%	0%	100%
7	0%	100%	0%	0%
8	50%	40%	10%	0%
10	0%	0%	0%	100%

Table 10-A.10.9 NES Results for Battery Chargers under a Full Spillover Scenario (Quadrillion Btu)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	0.056	0.130	0.178	
2, 3, 4	0.000	0.000	0.742	0.941
5, 6	0.000	0.000	0.000	
7	0.000	0.013		
8	0.011	0.048	0.053	
10	0.000	0.000	0.000	

Table 10-A.10.10 NPV Results for Battery Chargers under a Full Spillover Scenario, 3 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	294	606	-781	
2, 3, 4	0	0	-8431	-32733
5, 6	0	0	0	
7	0	-615		
8	2791	-1610	-1953	
10	0	0	0	

Table 10-A.10.11 NPV Results for Battery Chargers under a Full Spillover Scenario, 7 Percent Discount Rate (2010$ Million)

Product Class	Trial Standard Level			
	TSL 1	TSL 2	TSL 3	TSL 4
1	157	318	-527	
2, 3, 4	0	0	-5252	-19832
5, 6	0	0	0	
7	0	-371		
8	1665	-976	-1183	
10	0	0	0	

APPENDIX 10-B. NIA SENSITIVITY ANALYSIS FOR ALTERNATIVE PRODUCT PRICE TREND SCENARIOS

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 10-B. NIA SENSITIVITY ANALYSIS FOR ALTERNATIVE PRODUCT PRICE TREND SCENARIOS

10-B.1 INTRODUCTION

DOE used a constant price assumption for the default (reference case) forecast in the NIA described in Chapter 10. In order to investigate the impact of different product price forecasts on the net present value (NPV) for the considered TSLs for battery chargers and external power supplies (EPSs), DOE also considered three alternative price trends for a sensitivity analysis. This appendix describes the alternative price trends and compares NPV results for these scenarios with the default forecast.

10-B.2 ALTERNATIVE BATTERY CHARGER AND EXTERNAL POWER SUPPLY PRICE TREND SCENARIOS

DOE considered three alternative price trends for a sensitivity analysis based on several price indexes forecasted for EIA's *Annual Energy Outlook 2010* (*AEO2010)*. One of these used the "Chained price index--nonresidential investment--other information equipment" index, a second used the "Chained price index--nonresidential capital equipment" index, and the third used the "Chained price index--consumer durable goods" index. Non residential price indexes were used as both battery chargers and EPSs are mainly purchased by original equipment manufacturers and not directly by end-users.

10-B.2.1 Low Price Decline Scenario

DOE examined a forecast based on the "Chained price index--nonresidential investment--other information equipment" index that was forecasted for *AEO2010* out to 2035. This index is one of the most disaggregated categories that include battery chargers and EPSs. To develop an inflation-adjusted index, DOE normalized the above index with the "chained price index—gross domestic product" forecasted for *AEO2010*. To extend the price index beyond 2035, DOE used the average annual growth rate in 2026 to 2035.

10-B.2.2 Medium Price Decline Scenario

DOE applied the same methodology as for the Low Price Decline Scenario (explained above), using a forecast based on the "Chained price index--nonresidential capital equipment" index (includes equipment and software) that was forecasted for *AEO2010* out to 2035.

10-B.2.3 High Price Decline Scenario

Again, DOE applied the same methodology as for the Low Price Decline Scenario (explained above), using a forecast based on the "Chained price index--consumer durable goods" index that was forecasted for *AEO2010* out to 2035.

10-B.2.4 Summary

Table 10-B.2.1 shows the average annual rate of change for the product price index used in each scenario. Figure 10-B.2.1 shows the resulting price trends.

Table 10-B.2.1 Product Price Trend Scenarios

Scenario	**Price Trend**	**Average Annual Rate of Change**
Default	Constant Price	0%
Low Price Decline	*AEO 2010* -" Chained price index--nonresidential investment--other information equipment"	- 2%
Medium Price Decline	*AEO 2010* -" Chained price index--nonresidential capital equipment"	- 3%
High Price Decline	*AEO 2010* - "Chained price index--consumer durable goods"	- 4%

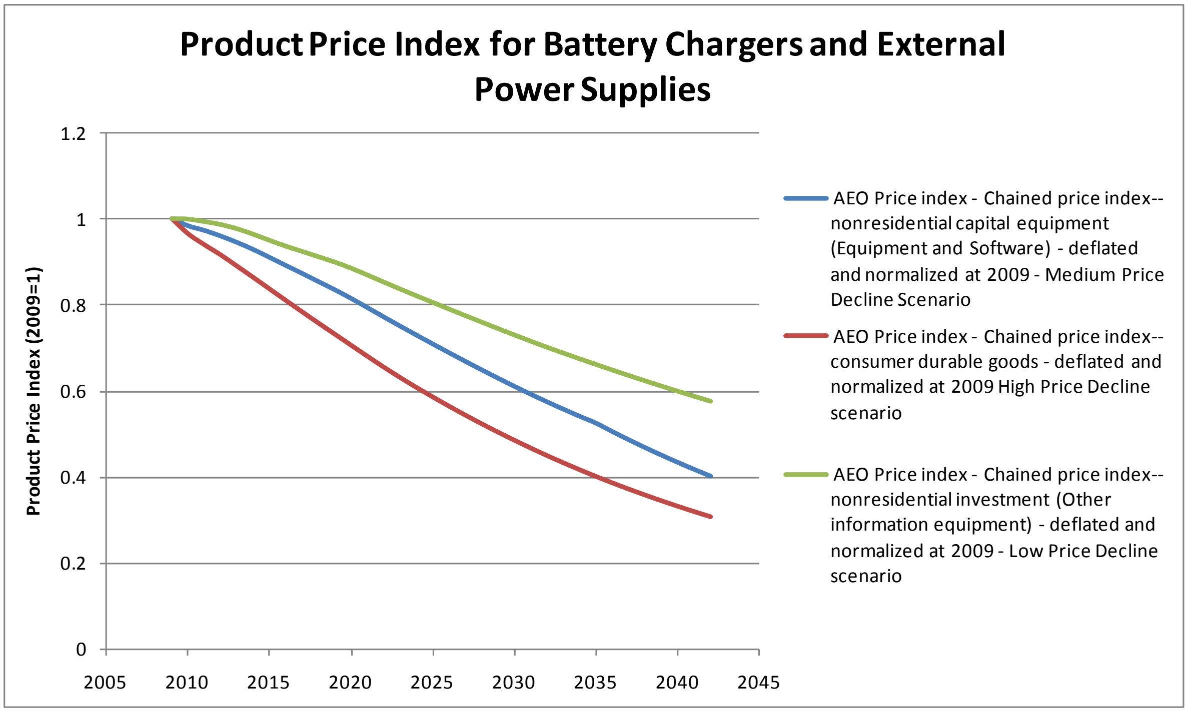


Figure 10-B.2.1 Product Price Trend Scenarios

10-B.3 NPV RESULTS BY PRICE TREND SCENARIO

Results are presented here for each group of battery charger and EPS product classes at each trial standard level. They combine the NPV of consumer benefits using 3 and 7 percent discount rates with the present value of the potential economic benefits resulting from reduced CO_2 and NO_X emissions. For these results, the economic benefits from reduced CO_2 emissions were calculated using a SCC value of $22.3/metric ton in 2010 (in 2010$) for CO_2, increasing at 3 percent per year, and a discount rate of 3 percent. The economic benefits from reduced NO_X emissions were calculated using a value of $2,537/ton (in 2010$), which is the average of the low and high values used in DOE's analysis, and either a 3 percent or 7 percent discount rate. See chapter 16 for information regarding the derivation of these values. The costs and benefits are considered for products shipped in 2013-2042.

The results presented here are annualized values. DOE used a two-step calculation process to convert the time-series of costs and benefits into annualized values. First, DOE calculated a present value in 2011, the year used for discounting the NPV of total consumer costs and savings, for the time-series of costs and benefits using discount rates of three and seven percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE used the discount rate appropriate for each SCC time series. From the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in 2011, which yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

Table 10-B.3.1 External Power Supplies: Annualized Present Value of Consumer Impacts and Monetized Benefits from CO_2 and NO_X Emissions Reductions (million 2010$)

Product Class Group	**TSL**		***7% discount rate***				***3% discount rate***			
			Ref.	**High**	**Med.**	**Low**	**Ref.**	**High**	**Med.**	**Low**
B,C,D,E	1	Incremental Installed Costs	$110.9	$71.6	$83.0	$92.4	$117.4	$69.4	$82.0	$93.4
		Operating Cost Savings	$163.0	$163.0	$163.0	$163.0	$188.2	$188.2	$188.2	$188.2
		Emissions Reductions	$29.6	$29.6	$29.6	$29.6	$29.8	$29.8	$29.8	$29.8
		Net Benefits	$81.7	$120.9	$109.5	$100.2	$100.6	$148.6	$136.0	$124.6
	2	Incremental Installed Costs	$216.1	$139.6	$161.9	$180.1	$228.9	$135.3	$159.9	$182.1
		Operating Cost Savings	$255.5	$255.5	$255.5	$255.5	$294.9	$294.9	$294.9	$294.9
		Emissions Reductions	$46.4	$46.4	$46.4	$46.4	$46.7	$46.7	$46.7	$46.7
		Net Benefits	$85.8	$162.2	$140.0	$121.8	$112.8	$206.4	$181.8	$159.5
	3	Incremental Installed Costs	$650.3	$420.3	$487.2	$542.0	$688.8	$407.1	$481.1	$548.1
		Operating Cost Savings	$452.5	$452.5	$452.5	$452.5	$522.1	$522.1	$522.1	$522.1
		Emissions Reductions	$82.2	$82.2	$82.2	$82.2	$82.8	$82.8	$82.8	$82.8
		Net Benefits	($115.5)	$114.4	$47.6	($7.2)	($83.8)	$197.9	$123.9	$56.8
X	1	Incremental Installed Costs	$1.5	$1.0	$1.1	$1.3	$1.6	$0.9	$1.1	$1.3
		Operating Cost Savings	$15.8	$15.8	$15.8	$15.8	$18.4	$18.4	$18.4	$18.4
		Emissions Reductions	$3.3	$3.3	$3.3	$3.3	$3.3	$3.3	$3.3	$3.3
		Net Benefits	$17.6	$18.2	$18.0	$17.9	$20.1	$20.8	$20.6	$20.4
	2	Incremental Installed Costs	$4.0	$2.6	$3.0	$3.4	$4.3	$2.5	$3.0	$3.4
		Operating Cost Savings	$18.2	$18.2	$18.2	$18.2	$21.1	$21.1	$21.1	$21.1
		Emissions Reductions	$3.8	$3.8	$3.8	$3.8	$3.8	$3.8	$3.8	$3.8
		Net Benefits	$17.9	$19.4	$18.9	$18.6	$20.7	$22.4	$22.0	$21.5
	3	Incremental Installed Costs	$66.5	$43.0	$49.8	$55.4	$70.5	$41.6	$49.2	$56.1
		Operating Cost Savings	$37.2	$37.2	$37.2	$37.2	$43.3	$43.3	$43.3	$43.3
		Emissions Reductions	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8	$7.8
		Net Benefits	($21.5)	$2.0	($4.8)	($10.4)	($19.4)	$9.4	$1.9	($5.0)
H	1	Incremental Installed Costs	($0.1)	($0.0)	($0.0)	($0.0)	($0.1)	($0.0)	($0.0)	($0.0)
		Operating Cost Savings	$0.3	$0.3	$0.3	$0.3	$0.4	$0.4	$0.4	$0.4
		Emissions Reductions	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
		Net Benefits	$0.5	$0.4	$0.4	$0.4	$0.5	$0.5	$0.5	$0.5
	2	Incremental Installed Costs	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)
		Operating Cost Savings	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4
		Emissions Reductions	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
		Net Benefits	$0.5	$0.5	$0.5	$0.5	$0.6	$0.5	$0.6	$0.6
	3	Incremental Installed Costs	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
		Operating Cost Savings	$0.4	$0.4	$0.4	$0.4	$0.5	$0.5	$0.5	$0.5
		Emissions Reductions	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
		Net Benefits	$0.4	$0.4	$0.4	$0.4	$0.5	$0.5	$0.5	$0.5

Parentheses indicate negative (-) values.

Table 10-B.3.2 Battery Chargers: Annualized Present Value of Consumer Impacts and Monetized Benefits from CO_2 and NO_X Emissions Reductions (million 2010$)

Product Class Group	TSL		*7% discount rate*				*3% discount rate*			
			Ref.	**High**	**Med.**	**Low**	**Ref.**	**High**	**Med.**	**Low**
1	1	Incremental Installed Costs	$4.0	$2.6	$3.0	$3.3	$4.2	$2.5	$3.0	$3.4
		Operating Cost Savings	$16.6	$16.6	$16.6	$16.6	$19.2	$19.2	$19.2	$19.2
		Emissions Reductions	$2.9	$2.9	$2.9	$2.9	$3.0	$3.0	$3.0	$3.0
		Net Benefits	$15.6	$17.0	$16.6	$16.2	$18.0	$19.7	$19.2	$18.8
	2	Incremental Installed Costs	$13.2	$8.5	$9.9	$11.0	$13.9	$8.2	$9.7	$11.1
		Operating Cost Savings	$38.8	$38.8	$38.8	$38.8	$44.8	$44.8	$44.8	$44.8
		Emissions Reductions	$6.9	$6.9	$6.9	$6.9	$6.9	$6.9	$6.9	$6.9
		Net Benefits	$32.5	$37.1	$35.8	$34.7	$37.8	$43.5	$42.0	$40.6
	3	Incremental Installed Costs	$95.5	$61.7	$71.5	$79.6	$101.2	$59.8	$70.7	$80.5
		Operating Cost Savings	$53.0	$53.0	$53.0	$53.0	$61.3	$61.3	$61.3	$61.3
		Emissions Reductions	$9.4	$9.4	$9.4	$9.4	$9.4	$9.4	$9.4	$9.4
		Net Benefits	($33.1)	$0.7	($9.2)	($17.2)	($30.4)	$11.0	$0.1	($9.8)
2, 3, 4	1	Incremental Installed Costs	$43.4	$28.0	$32.5	$36.1	$45.9	$27.1	$32.1	$36.5
		Operating Cost Savings	$100.7	$100.7	$100.7	$100.7	$114.8	$114.8	$114.8	$114.8
		Emissions Reductions	$17.9	$17.9	$17.9	$17.9	$18.1	$18.1	$18.1	$18.1
		Net Benefits	$75.3	$90.6	$86.1	$82.5	$86.9	$105.7	$100.8	$96.3
	2	Incremental Installed Costs	$298.5	$192.9	$223.6	$248.7	$316.1	$186.8	$220.8	$251.6
		Operating Cost Savings	$253.9	$253.9	$253.9	$253.9	$289.8	$289.8	$289.8	$289.8
		Emissions Reductions	$45.1	$45.1	$45.1	$45.1	$45.4	$45.4	$45.4	$45.4
		Net Benefits	$0.6	$106.1	$75.4	$50.3	$19.0	$148.3	$114.3	$83.6
	3	Incremental Installed Costs	$1,346.5	$870.3	$1,008.8	$1,122.2	$1,426.3	$842.9	$996.2	$1,135.0
		Operating Cost Savings	$569.6	$569.6	$569.6	$569.6	$650.0	$650.0	$650.0	$650.0
		Emissions Reductions	$101.2	$101.2	$101.2	$101.2	$101.9	$101.9	$101.9	$101.9
		Net Benefits	($675.7)	($199.5)	($338.0)	($451.4)	($674.4)	($91.1)	($244.4)	($383.2)
	4	Incremental Installed Costs	$2,579.4	$1,667.2	$1,932.4	$2,149.7	$2,732.2	$1,614.7	$1,908.4	$2,174.2
		Operating Cost Savings	$624.8	$624.8	$624.8	$624.8	$712.8	$712.8	$712.8	$712.8
		Emissions Reductions	$111.1	$111.1	$111.1	$111.1	$111.8	$111.8	$111.8	$111.8
		Net Benefits	($1,843.5)	($931.3)	($1,196.6)	($1,413.8)	($1,907.6)	($790.1)	($1,083.8)	($1,349.6)
5, 6	1	Incremental Installed Costs	$9.1	$5.9	$6.8	$7.6	$9.6	$5.7	$6.7	$7.7
		Operating Cost Savings	$89.4	$89.4	$89.4	$89.4	$105.1	$105.1	$105.1	$105.1
		Emissions Reductions	$16.1	$16.1	$16.1	$16.1	$16.3	$16.3	$16.3	$16.3
		Net Benefits	$96.5	$99.7	$98.7	$98.0	$111.7	$115.7	$114.6	$113.7
	2	Incremental Installed Costs	($36.7)	($23.7)	($27.5)	($30.6)	($38.9)	($23.0)	($27.1)	($30.9)
		Operating Cost Savings	$198.5	$198.5	$198.5	$198.5	$233.7	$233.7	$233.7	$233.7
		Emissions Reductions	$35.9	$35.9	$35.9	$35.9	$36.2	$36.2	$36.2	$36.2
		Net Benefits	$271.1	$258.1	$261.9	$265.0	$308.7	$292.8	$297.0	$300.8
	3	Incremental Installed Costs	$904.7	$584.7	$677.8	$753.9	$958.3	$566.3	$669.3	$762.5
		Operating Cost Savings	$259.8	$259.8	$259.8	$259.8	$306.0	$306.0	$306.0	$306.0
		Emissions Reductions	$47.0	$47.0	$47.0	$47.0	$47.4	$47.4	$47.4	$47.4
		Net Benefits	($597.9)	($277.9)	($370.9)	($447.1)	($604.9)	($213.0)	($316.0)	($409.2)
7	1	Incremental Installed Costs	($4.4)	($2.9)	($3.3)	($3.7)	($4.7)	($2.8)	($3.3)	($3.7)
		Operating Cost Savings	$2.1	$2.1	$2.1	$2.1	$2.3	$2.3	$2.3	$2.3

Product Class Group	TSL		*7% discount rate*				*3% discount rate*			
			Ref.	**High**	**Med.**	**Low**	**Ref.**	**High**	**Med.**	**Low**
		Emissions Reductions	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4
		Net Benefits	$6.9	$5.3	$5.8	$6.1	$7.4	$5.5	$6.0	$6.4
	2	Incremental Installed Costs	$28.9	$18.7	$21.7	$24.1	$30.6	$18.1	$21.4	$24.4
		Operating Cost Savings	$5.5	$5.5	$5.5	$5.5	$6.2	$6.2	$6.2	$6.2
		Emissions Reductions	$1.1	$1.1	$1.1	$1.1	$1.1	$1.1	$1.1	$1.1
		Net Benefits	($22.3)	($12.1)	($15.1)	($17.5)	($23.3)	($10.8)	($14.1)	($17.1)
8	1	Incremental Installed Costs	($130.8)	($84.5)	($98.0)	($109.0)	($138.5)	($81.9)	($96.8)	($110.2)
		Operating Cost Savings	$3.4	$3.4	$3.4	$3.4	$3.9	$3.9	$3.9	$3.9
		Emissions Reductions	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6
		Net Benefits	$134.8	$88.5	$102.0	$113.0	$143.0	$86.3	$101.2	$114.7
	2	Incremental Installed Costs	$93.1	$60.2	$69.7	$77.6	$98.6	$58.3	$68.9	$78.4
		Operating Cost Savings	$14.4	$14.4	$14.4	$14.4	$16.4	$16.4	$16.4	$16.4
		Emissions Reductions	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5	$2.5
		Net Benefits	($76.2)	($43.2)	($52.8)	($60.7)	($79.6)	($39.3)	($49.9)	($59.5)
	3	Incremental Installed Costs	$111.2	$71.9	$83.3	$92.7	$117.8	$69.6	$82.3	$93.8
		Operating Cost Savings	$15.9	$15.9	$15.9	$15.9	$18.2	$18.2	$18.2	$18.2
		Emissions Reductions	$2.8	$2.8	$2.8	$2.8	$2.8	$2.8	$2.8	$2.8
		Net Benefits	($92.5)	($53.2)	($64.6)	($74.0)	($96.8)	($48.7)	($61.3)	($72.8)
10	1	Incremental Installed Costs	$14.0	$9.1	$10.5	$11.7	$14.9	$8.8	$10.4	$11.8
		Operating Cost Savings	$70.7	$70.7	$70.7	$70.7	$84.8	$84.8	$84.8	$84.8
		Emissions Reductions	$13.6	$13.6	$13.6	$13.6	$13.7	$13.7	$13.7	$13.7
		Net Benefits	$70.2	$75.2	$73.7	$72.6	$83.7	$89.7	$88.1	$86.7
	2	Incremental Installed Costs	$17.9	$11.5	$13.4	$14.9	$18.9	$11.2	$13.2	$15.1
		Operating Cost Savings	$82.0	$82.0	$82.0	$82.0	$98.4	$98.4	$98.4	$98.4
		Emissions Reductions	$15.8	$15.8	$15.8	$15.8	$15.9	$15.9	$15.9	$15.9
		Net Benefits	$79.9	$86.2	$84.4	$82.9	$95.4	$103.1	$101.1	$99.2
	3	Incremental Installed Costs	$22.5	$14.6	$16.9	$18.8	$23.9	$14.1	$16.7	$19.0
		Operating Cost Savings	$95.6	$95.6	$95.6	$95.6	$114.7	$114.7	$114.7	$114.7
		Emissions Reductions	$18.4	$18.4	$18.4	$18.4	$18.6	$18.6	$18.6	$18.6
		Net Benefits	$91.5	$99.5	$97.1	$95.2	$109.4	$119.2	$116.6	$114.3

Parentheses indicate negative (-) values.

APPENDIX 12A MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

12A.1 BATTERY CHARGER MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Spring 2011

As part of the rulemaking process for energy conservation standards for battery chargers (BCs), the Department of Energy (DOE) conducts the manufacturer impact analysis (MIA). In this analysis, DOE uses publicly available information and information provided by manufacturers during interviews to assess possible impacts on manufacturers due to new energy conservation standards.

1-1 SCOPE OF COVERAGE AND PRODUCT CLASSES

Definitions

The term **battery charger** means a device that charges batteries for consumer products, including battery chargers embedded in other consumer products. (42 U.S.C. 6291(32))
The statutory definition of a **consumer product** is any article other than an automobile, as defined in section 32901(a)(3) of title 49, that consumes energy or water and which, to any significant extent, is distributed in commerce for personal use or consumption by individuals. (42 U.S.C. 6291(1))

Product Classes

To establish effective energy conservation standards, DOE divides covered products into classes by the type of energy used, the capacity of the product, and any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42 U.S.C. 6295(q)) DOE then conducts its analysis and considers establishing or amending standards to provide separate standard levels for each product class.

For BCs, DOE examined a number of different performance related features including the following capacity- and utility-related characteristics: output power, battery voltage, battery capacity, battery energy, inductive charging capability, input voltage (line AC or low-voltage DC), and AC output.

The product classes DOE established for the preliminary analysis appear in Table A.1-1.

Table A.1-1 BC Product Classes Used in the Preliminary Analysis

			Product Class		**Example Applications**
			#	**Description**	
AC In, DC Out	< 100 Wh	Inductive Connection	1	Low Energy, Inductive	Toothbrushes
		<4 V	2	Low Energy, Low Voltage	Telephones
		4–10 V	3	Low Energy, Med. Voltage	Cameras and Small Tools
		>10 V	4	Low Energy, High Voltage	Laptops and Large Tools
	100–3000 Wh	<20 V	5	Med. Energy, Low Voltage	Marine Chargers, Wheelchairs
		≥20 V	6	Med. Energy, High Voltage	Electric Bikes, Lawnmowers
	> 3000 Wh		7	High Energy	Golf Cars
DC In, DC Out		<9 V Input	8	Low Energy, Low Voltage DC Input	USB Chargers
		≥9 V Input	9	Low Energy, High Voltage DC Input	Car Chargers
AC In, AC Out		AC Output from Battery	10	Low Energy, AC Output	Uninterruptible Power Supplies

1.1 Please provide any comments that you may have regarding the appropriateness of these product class definitions. Should DOE divide them into additional product classes, combine certain products classes, or consider any other BC characteristics for establishing product classes?

1-2 ENGINEERING ANALYSIS

Overview

In the engineering analysis, DOE develops a relationship between the manufacturer selling price (MSP) and increases in BC efficiency. The efficiency values range from that of a typical BC sold today (*i.e.*, the baseline) to the maximum technologically feasible efficiency level. At each efficiency level examined, DOE determines the consequent MSP, a relationship referred to as a cost-efficiency curve.

DOE structured its BC engineering analysis around two methodologies: (1) test and teardowns, which involve testing products for efficiency and determining cost from a detailed bill of materials derived from tear-downs and (2) the efficiency-level approach, whereby manufacturers provide and explain their costs of achieving increases in energy efficiency at discrete levels of efficiency.

BC Representative Product Classes and Representative Units

As discussed previously, DOE divided BCs into 10 product classes in the preliminary analysis. DOE adopted these divisions after analyzing comments from interested parties and examining market-available BC technologies. After establishing product classes, DOE selected certain classes as "representative" and concentrated its analytical effort on these because they represent a significant majority of units. DOE also believed that because of the high volumes of these classes, they would be more useful when extending the engineering results to the remaining BC product classes.

For each representative product class, DOE then identified the most common battery voltage and energy combinations from a survey of popular battery-operated products in the market, taking into account the distribution of those BC characteristics by application. DOE then selected the BC characteristics of the representative units to correspond to the densest clusters of BC models.

The representative product classes along with the battery energy and voltage combinations that DOE analyzed in the preliminary analysis are depicted in Table A.1-2.

Table A.1-2 The BC Representative Units for each Representative Product Class

			Product Class Number	**Rep. Unit Voltage *V***	**Rep. Unit Energy *Wh***	**Avg. Annual Production Volume *K units***
AC In, DC Out	< 100 Wh	Inductive Connection	1	3.6	1.5	500
		<4 V	2	3.6	3	480
		4–10 V	3	Scaled Product Class		
		>10 V	4	10.8	20	640
	100–3000 Wh	<20 V	5	12	800	50
		≥20 V	6	Scaled Product Class		
	> 3000 Wh		7	48	3,750	150
DC In, DC Out		<9 V Input	8	Scaled Product Class		
		≥9 V Input	9	Scaled Product Class		
AC In, AC Out		AC Output from Battery	10	12	70	1000

2.1 Please comment on the appropriateness of these representative unit values for products with which you have familiarity.

2.2 Please provide a description of BC end-use product applications that you sell or for which you sell components. Do any of those applications use BCs with electrical characteristics similar to the representative values shown above?

2.3 What are the highest volume products (related to this rulemaking) that you sell? Please include output voltage, output power, and application.

BC Efficiency Metrics

DOE is planning on establishing energy conservation standards for battery chargers based on the estimated amount of energy consumption a unit has over a one year period. To establish such standards, DOE needs to understand all of the modes of operation of a battery charger, estimate the time spent in each mode, and determine the energy consumption of units in each mode. DOE defines the combination of the energy consumed in each of these modes over a one year period as unit energy consumption (UEC).

DOE determined that there are 5 modes of operation that a battery charger can be in at any given time: active (or charge) mode, maintenance mode, no-battery (or standby) mode, off mode, and unplugged mode. These 5 modes are defined below:

Active (or charge): The charger is charging a depleted battery, equalizing it cells, or performing functions necessary for bringing the battery to the fully charged state.

Maintenance: The batteries have reached full charge; intended to maintain the fully charged state of the battery, while protecting it from overcharge.

No-Battery (or standby): The battery is removed from the charger following a full charge. The charger (or a part) remains connected to mains.

Off: The charger remains connected to mains, the battery is removed, and all manual on-off switches are turned off.

Unplugged: The charger is disconnected from mains entirely.

DOE is currently updating the test procedure to accommodate the measurement of a proxy for active mode energy consumption. Additionally, the proposed test procedure will return three metrics related to maintenance, standby, and off mode operation. For the fifth mode of operation, unplugged mode, the energy consumption is always 0 because the unit is not connected to a power source and therefore cannot consume energy.

DOE has expressed its intention of weighting these mode-specific metrics using a product-class average usage profile[1] to calculate the unit energy consumption of a BC. To best reflect actual usage would require setting separate standards for each application that uses BCs. Because of the complexity associated with the large number of applications, DOE has elected to group the usage profiles according to the product classes discussed previously. These assumed usage profiles for each product class are shown in Table A.1-3.

---

[1] The calculation of product-class-average usage profiles and the calculation of typical energy consumption are described in detail in the energy use and end-use load characterization (chapter 7).

Table A.1-3 Battery Charger Usage Profiles

Product Class ID	Active + Maintenance	No Battery (Standby)	Unplugged	Off	Charges
	Hours per Day				No. per Day
1	23.9	0.1	0	0	0.26
2	9.7	5.0	9.4	0	0.56
3	5.6	0.2	18.1	0.1	0.22
4	19.8	0.3	6.9	0.1	0.88
5	7.7	0.5	15.8	0	0.55
6	15.4	8.6	0	0	0.46
7	7.7	8.1	8.1	0	0.36
8	6.5	7.5	10.1	0	0.43
9	1.1	0.1	22.8	0	0.15
10	24.0	0	0	0	0

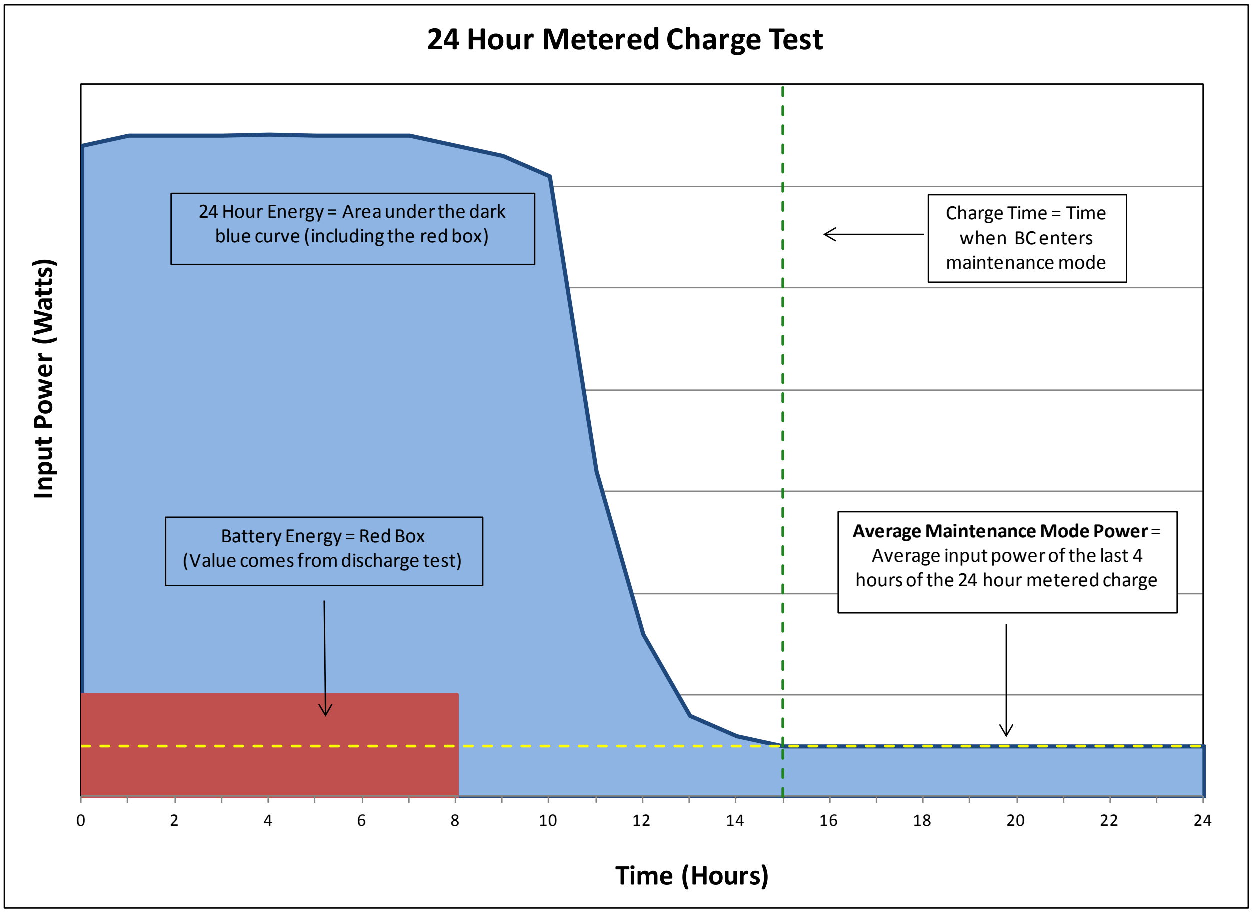
Note: Usage times may not sum to 24 hours due to rounding.

2.4 Do the usage profiles presented in Table A.1-3 seem reasonable for the product classes with which you are familiar? In particular, do the average number of charges and the time spent in active and maintenance mode accurately depict the usage of your product line?

As mentioned, the outputs of DOE's battery charger test procedure provide information on the tested unit's active, maintenance, standby, and off modes of operation. DOE is able to obtain useful information related to these modes of operation through four separate tests: a charge test, a discharge test, a standby mode test, and an off mode test. The standby and off mode tests are simply measurements of average power consumption in each of those modes. The charge and discharge tests are slightly more complicated.

As it is not always possible to determine exactly when a battery charger has finished charging its battery but most batteries finish charging within 24 hours, the DOE test procedure defines a parameter called 24 hour energy. The 24 hour energy of a BC is a direct output of the metered charge test. The test begins with a completely depleted battery. The battery charger is connected and input power is measured for 24 hours (or more if the battery is known to take longer than 19 hours to charge). The measured input power can then be integrated with respect to time to obtain the 24 hour energy consumption. If the battery is known to take 19 hours or less to charge, then the last four hours of the charge test will be purely maintenance mode. There is a one hour buffer to ensure the device has completely shifted into maintenance mode. The average power over this four hour time period is determined and taken as the average maintenance mode power of the BC. Finally, in the discharge test, the actual energy that was put into the battery is determined. This value is called battery energy and is considered "useful" energy that is not counted towards a BC's unit energy consumption. However, the battery energy, along with the 24 hour energy and maintenance mode power, is used to calculate UEC. Figure A.1-1 graphically depicts the relationship between these parameters.

Figure A.1-1 Results of Metered Charge and Discharge Tests



Average Maintenance Mode Power

**This is a theoretical drawing and is not exactly representative of any particular tested product.*

Finally, after conducting the BC tests specified in the DOE test procedure, the unit energy consumption can be calculated. The equation below, which is also presented in the technical support document (TSD) that was published on DOE's website[2], shows how this calculation combines the assumptions about product usage and the results of the test procedure to obtain UEC

*Parameters shown in blue font are direct outputs of the test procedure and those in red font are assumed values estimated by DOE.

- E_{24} = 24 hour energy
- $E_{battery}$ = Measured battery energy
- P_{maint} = Average maintenance mode power
- P_{no} = Average no-battery mode power

---

[2] http://www1.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html

- $P_{unplugged}$ = Average unplugged mode power (always 0)
- P_{off} = Average off mode power
- n = Number of charges per day
- t_{charge} = Time to completely charge a fully discharged battery
- $t_{act\&maint}$ = Time per day spent in active and maintenance mode
- t_{no} = Time per day spent in no-battery mode
- $t_{unplugged}$ = Time per day spent in unplugged mode
- t_{off} = Time per day spent in off mode

The equation above equates to 365 multiplied by the sum of daily active energy consumption (minus battery energy because that is useful energy), daily maintenance mode energy, daily no-battery mode energy, daily unplugged mode energy (which is 0), and daily off mode energy consumption.

When DOE presented its notice of proposed rulemaking (NOPR) for BC test procedures, it proposed shortening the test procedure. This proposal relied on the user's ability to determine the charge time for the unit being tested, which many interested parties said could be difficult, if not impossible to do for some BCs. As a result of these comments, DOE is likely to proceed with a test procedure for BCs that is not shortened and from which the user testing a BC will not explicitly obtain charge time. DOE does wish to use an equation to calculate UEC that relies on an output from the test procedure that does not exist (other than the usage profile assumptions). Therefore, DOE has revised the presentation of its calculation to what is shown below. Even though this equation looks different from the equation above, it actually is equivalent. When the terms in the equation above are multiplied out, the terms that rely on charge time drop out. What is left can be rearranged to give you the equation below.

2.5 Do the above equations for UEC seem reasonable? Please describe any hesitations that you may have with the calculation of UEC.

2.6 For product classes where it is appropriate, DOE plans to establish UEC requirements in terms of battery energy and voltage. In other words, the UEC that a product must be below will be a function of the BC's voltage and energy. Does this seem reasonable for the products with which you are familiar?

2.7 Please express any comments that you may have on DOE's plan to use UEC as the metric for energy conservation standards for BCs.

BC Candidate Standard Levels Analyzed

DOE is evaluating the impacts of various standard levels. Each standard level corresponds to different product efficiency, beginning with a baseline efficiency level that represents the least efficient products on the market. DOE evaluates three efficiency levels higher than the baseline level: an intermediate level, a best-in-market level, and a maximum-technology-feasible level. As BC efficiency improves at each higher candidate standard level (CSL), the unit energy consumption (UEC) for that product decreases.

CSLs are generally based on (1) design options associated with the specific units being analyzed; (2) other voluntary specifications or mandatory standards that cause manufacturers to develop products at particular efficiency levels; and (3) the maximum technologically feasible level[3]. The CSLs examined for the preliminary analysis are expressed in terms of UEC and summarized for each representative unit in Table A.1-4.

Table A.1-4 Candidate Standard Levels for the BC Representative Units

		Annual Energy Consumption by Representative Unit *kWh*					
#	**Efficiency Level**	**Low Energy, Inductive 1.5 Wh, 3.6 V**	**Low Energy, Low Voltage 3 Wh, 3.6 V**	**Low Energy, High Voltage 20 Wh, 10.8 V**	**Med. Energy, Low Voltage 800 Wh, 12 V**	**High Energy 3750 Wh, 48 V**	**Low Energy, AC Output 70 Wh 12 V**
0	Baseline	10.0	10.0	39.4	202.7	290.0	19.6
1	Improved	7.0	6.0	10.5	159.6	250.0	6.4
2	Best-in-Market	3.5	1.2	6.1	100.0	200.0	4.0
3	Maximum Technologically Feasible	1.5	-	-	75.0	150.0	1.5

BC Scaling from Representative Units to Remaining Product Classes

Following the development of engineering results for the representative units, DOE must extend these results to all BCs that were not analyzed. This task is twofold: (1) scaling the representative unit results to BCs that are also in the representative product class, but which differ in battery voltage and energy; and (2) scaling the representative unit results to BCs in product classes not explicitly analyzed.

---

[3] The “max-tech” level represents the most efficient design that is commercialized or has been demonstrated in a prototype with materials or technologies available today. “Max tech” is not constrained by economic justification apart from the requirement that there be more than one unique way to achieve it. It is typically the most expensive design option considered in the engineering analysis.

DOE used a hybrid approach to scaling in the preliminary analysis. When possible, DOE first attempted to use engineering relationships to scale the performance of BC designs at each CSL, dividing the problem by operational mode and BC stage (*i.e.*, power supply, charge controller), such that the final energy consumption of a scaled unit was a function of the expected performance of each stage in each mode, weighted by the average time spent in each mode. In cases where this was not possible, DOE scaled the results based on test results of actual BCs available in the market.

Table A.1-5 shows the representative battery voltage and energy along with annual production volume for the representative units as well as for the scaled product classes.

Table A.1-5 The BC Representative Units for each Representative and Scaled Product Class.

			Product Class Number	**Rep. Unit Voltage *V***	**Rep. Unit Energy *Wh***	**Avg. Annual Production Volume *K units****
AC In, DC Out	< 100 Wh	Inductive Connection	1	3.6	1.5	500
		<4 V	2	3.6	3	480
		4–10 V	3	7.2	10	480
		>10 V	4	10.8	20	640
	100–3000 Wh	<20 V	5	12	800	50
		≥20 V	6	36	384	50
	> 3000 Wh		7	48	3,750	150
DC In, DC Out		<9 V Input	8	3.6	2	480
		≥9 V Input	9	3.6	5	480
AC In, AC Out		AC Output from Battery	10	12	70	1000

* Note: The production volume for product classes 3, 8, 9 uses product class 2 data, and the production volume for product class 6 uses product class 5 data.

2.8 Do the battery voltage and energy seem representative of popular products for the scaled product classes shown in bold above?

Table A.1-6 shows the CSLs for the scaled product classes that DOE developed for the preliminary analysis.

Table A.1-6 Candidate Standard Levels for the Scaled BC Representative Units

		Unit Energy Consumption by Representative Unit ***kWh***			
		Low Energy, Medium Voltage	**Medium Energy, High Voltage**	**Low Energy, Low Voltage DC Input**	**Low Energy, High Voltage DC Input**
#	**Efficiency Level**	**10Wh, 7.2V**	**384Wh, 36V**	**2Wh, 3.6V**	**5Wh, 3.6V**
0	Baseline	10.0	69.3	1.5	1.3
1	Improved	5.4	41.9	0.9	0.8
2	Best-in-Market	1.0	25.0	0.8	0.5
3	Maximum Technologically Feasible	-	18.0	-	-

2.9 Do the CSLs for the scaled product classes shown in Table A.1-6 correspond to your expectations for the given battery energy and voltage characteristics?

Product Performance

DOE is evaluating energy conservations standards for BCs in terms of UEC; however, DOE recognizes that UEC is not a term used in industry. Therefore, in the following sections DOE discusses the CSL in terms of other BC performance characteristics.

2.10 During the preliminary analysis, DOE visited numerous manufacturers to obtain information regarding the performance of battery chargers at various efficiency levels. The tables below show aggregate-manufacturer data that DOE published in its preliminary analysis TSD. Do the performance parameters listed for designs corresponding to each CSL seem reasonable with your expectations for the product classes with which you are familiars?

Table A.1-7 Aggregate Manufacturer Performance Parameters for Product Class 1

CSL	Example Application	Rated Battery Energy *Wh*	Rated Battery Voltage *V*	Est. Time in Active *h*	Est. 24-Hour Charge Energy *Wh*	Est. Active-Only System Eff.	Est. Maint. Power *W*	Est. No-Battery Power *W*	UEC *kWh/yr*
0	Toothbrush	1.5	3.6	24.0	26.7	6%	1.2	0.5	10.0
1	Toothbrush	1.5	3.6	24.0	19.3	8%	0.8	0.4	7.0
2	Toothbrush	1.5	3.6	24.0	10.8	14%	0.4	0.2	3.5
3	Toothbrush	1.5	3.6	24.0	5.9	25%	0.2	0.1	1.5

2.11 Do you offer any products with performance characteristics similar to those shown in the table above? Can you recommend any of your products that DOE should test to verify these numbers when it proceeds with developing the engineering analysis in the Notice of Proposed Rulemaking (NOPR)?

BC Technology Options

Since most consumer BCs contain an AC/DC power conversion stage, similar to that found in an external power supply (EPS), all of the EPS technology options also apply to BCs. The technology options used to decrease EPS no-load power will impact energy consumption of BCs in no-battery and maintenance modes (and off mode, if applicable), while those used to increase EPS conversion efficiency will impact energy consumption in active and maintenance modes.

Technology options specific to BCs that DOE presented in the framework document included:

- Termination
- Elimination/Limitation of Maintenance Current
- Elimination of No-Battery Current
- Phase Control to Limit Input Power
- Improve power supply efficiency
- Reduce power supply no-load power
- Maintenance by periodic topping-off charge
- Switched-mode charge controller
- Automatic battery-connected on-off switch
- Improved electronic/magnetic components beyond the power supply

2.12 What are your design options (e.g. Schottky diodes, improved components, maintenance strategies) for improving BC energy consumption in:

- Active or charge mode;
- Maintenance mode; and
- No-battery or standby mode?

2.13 For your products, does battery energy or voltage affect energy consumption? In other words, for a given product class, would it be reasonable to set standards universal standards (i.e. one mandatory UEC level) for all products regardless of battery energy and voltage?

2.14 What battery chemistries are common for products in the product classes for which you are familiar? Do you believe that the use of certain battery chemistries would prohibit a BC from reaching higher CSLs?

Table A.1-8 Battery Chemistries Available at each CSL

CSL	UEC *kWh/yr*	Est. 24 Hour Energy *Wh*	Est. Maint. Power *W*	Est. No-Battery Power *W*	Battery Chemistries Possible
0	10.0	26.7	1.2	0.5	
1	7.0	19.3	0.8	0.4	
2	3.5	10.8	0.4	0.2	
3	1.5	5.9	0.2	0.1	

2.15 How should DOE account for the energy consumption of secondary functions of a BC, for example, a BC that includes an indicator light that never shuts off?

2.16 Are there any other BC design concerns unique to certain applications?

BC Relationships between Cost and Efficiency

For the preliminary analysis, Navigant Consulting Inc. (NCI), a DOE contractor, entered into non-disclosure agreements and interviewed representatives of several firms that manufacture battery-powered products or BCs for those products. For each representative unit, the interviewers asked manufacturers to describe the technological improvements and associated costs necessary to meet each of the CSLs. NCI aggregated the responses from these interviews and presented DOE with generalized responses free of any proprietary data for use in the analysis.

DOE supplemented the data provided by manufacturers with performance parameters and costs derived from test and teardown data. Following testing, the units corresponding to each commercially available CSL were torn down to (1) evaluate the presence of energy efficient design options and (2) estimate material costs.

Because the BC constitutes a small portion of the circuitry of these products, DOE, through iSuppli (a firm specializing in consumer electronics costs), identified the subset of components in each product enclosure responsible for battery charging, including the battery, charge regulator, and any related power converters and voltage regulators. The function of the latter two sub-circuits was split between the battery charger and other aspects of the application (*e.g.*, powering a notebook computer in addition to charging its battery). Nonetheless, because of the crucial role played by these sub-circuits in the battery charging process, their full cost was included in the BC manufacturing cost estimate.

DOE integrated the results of the BC teardown analysis with the information obtained during manufacturer interviews, to arrive at the relationship between cost and efficiency for the BC representative units. The results of this analysis are presented in the tables below.

Table A.1-9 Cost and Efficiency Relationship for BC Product Class 1: Low Energy, Inductive

CSL	**UEC** *kWh/yr*				**MSP from Interviews** *2009$*	**MSP from Teardowns** *2009$*
0	10.0				$2.05	-
1	7.0				$2.22	-
2	3.5				$2.45	-
3	1.5				$2.60	-

Table A.1-10 Cost and Efficiency Relationship for BC Product Class 2: Low Energy, Low Voltage

CSL	**UEC** *kWh/yr*				**MSP from Interviews** *2009$*	**MSP from Teardowns** *2009$*
0	10.0				$0.62	-
1	6.0				$1.09	$0.62
2	1.2				$11.71	$2.62
3	-				-	-

Table A.1-11 Cost and Efficiency Relationship for BC Product Class 3: Low Energy, Medium Voltage

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	10.0				$3.16	-
1	5.4				$4.96	-
2	1.0				$12.99	-
3	-				-	-

Table A.1-12 Cost and Efficiency Relationship for BC Product Class 4: Low Energy, High Voltage

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	39.4				$3.79	$3.79
1	10.5				$9.52	$6.76
2	6.1				$12.68	$7.44
3	-				-	-

Table A.1-13 Cost and Efficiency Relationship for BC Product Class 5: Med. Energy, Low Voltage

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	202.7				$18.48	$18.48
1	159.6				$27.46	$21.71
2	100.0				$64.14	-
3	75.0				$127.00	-

Table A.1-14 Cost and Efficiency Relationship for BC Product Class 6: Med. Energy, High Voltage

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	69.3				$18.48	-

1	41.9				$35.87	-
2	25.0				$76.83	-
3	18.0				$139.95	-

Table A.1-15 Cost and Efficiency Relationship for BC Product Class 7: High Energy

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	290.0				$79.01	-
1	250.0				$94.94	-
2	200.0				$127.05	-
3	150.0				$192.32	-

Table A.1-16 Cost and Efficiency Relationship for BC Product Class 8: Low Energy, Low Voltage DC Input

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	1.5				$0.62	-
1	0.9				$1.42	-
2	0.8				$2.17	-
3	-				-	-

Table A.1-17 Cost and Efficiency Relationship for BC Product Class 9: Low Energy, High Voltage DC Input

CSL	UEC *kWh/yr*				MSP from Interviews *2009$*	MSP from Teardowns *2009$*
0	1.3				$0.62	-
1	0.8				$1.11	-
2	0.5				$2.76	-
3	-				-	-

Table A.1-18 Cost and Efficiency Relationship for BC Product Class 10: Low Energy, AC Output

CSL	**UEC** ***kWh/yr***				**MSP from Interviews** ***2009$***	**MSP from Teardowns** ***2009$***
0	19.6				$2.76	$2.76
1	6.4				$3.93	$2.11
2	4.0				$4.25	-
3	1.5				$4.64	-

2.17 Please provide any comments that you may have about the aggregate manufacturer costs that DOE published for the preliminary analysis engineering analysis?

2.18 For some product classes there were a limited number of products available and DOE did not perform teardowns for the preliminary analysis. However, it did consult manufacturers to develop costs corresponding to the CSLs examined (and listed above). Do these costs seem reasonable with your expectations for this product class?

1-3 KEY ISSUES

DOE conducts the manufacturer impact analysis (MIA) as part of the rulemaking process to determine whether to amend energy conservation standards for battery chargers (BCs). For the MIA, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

3.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

Concerns with the overall rulemaking:

3.2 For the issues identified, how significant are they for each efficiency level?

Application	Efficiency Level			
	Baseline	CSL1	CSL2	CSL3

Figure A.1-2 represents DOE’s understanding of the four possible arrangements for BC production.

1. The OEM manufactures both the end-use product and all BC components
2. The OEM manufactures the end-use product but purchases all BC components from an ODM or ODMs
3. The OEM manufactures the end-use product, including any BC components embedded in the end-use product, while purchasing remaining BC components from an ODM or ODMs
4. The OEM manufactures nothing; instead it purchases the end-use product and all BC components from an ODM or ODMs

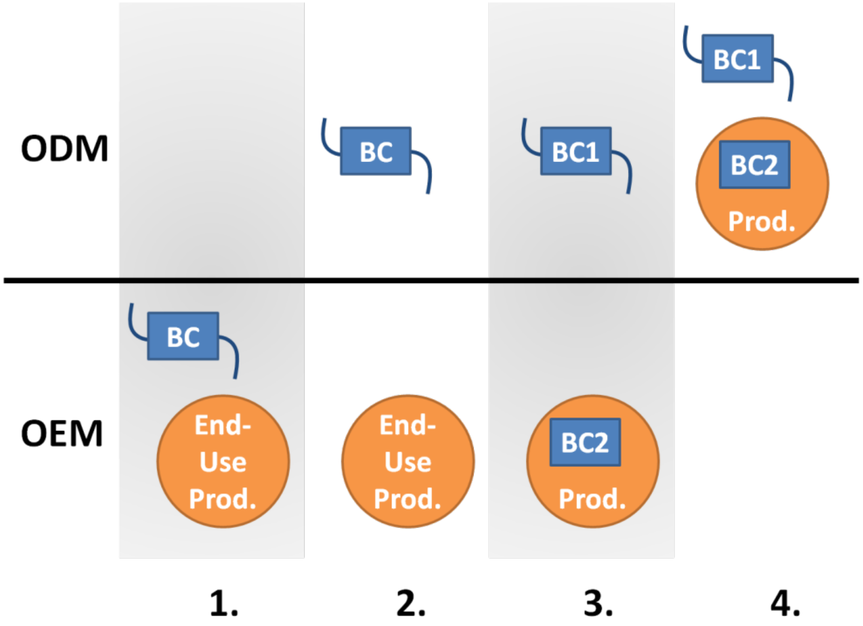


Figure A.1-2 The four ways that BC and end-use product manufacture can be divided between the BC supplier or original device manufacturer (ODM) and the original equipment manufacturer (OEM)

3.3 Using the diagram above, please qualitatively describe your relationship to the BC production process. For example, does your company design, manufacture, and/or specify components of BC, the entire BC, or the final product incorporating the BC?

1-4 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the profit center level directly related to your products that include battery chargers covered by this rulemaking. However, the context within which your production occurs and the associated costs are not readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical.

4.1 Do you have a parent company and/or any subsidiaries relevant to the battery charger industry?

4.2 What is your company's approximate share of the market(s) below?

4.3 Would you expect your market share to change if higher energy conservation standards were adopted?

4.4 Who are your main competitors in this market?

4.5 What percentage of your total revenue corresponds to the products listed below that incorporate covered battery chargers?

1-5 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company's markup structure and profitability.

In the engineering analysis, DOE estimated the manufacturer production costs (MPC) for the covered BCs included in products you produce. DOE defines manufacturer production cost as all direct costs associated with manufacturing *the battery charger*: direct labor, direct materials, and overhead (which includes depreciation). This MPC reflects cost to produce the battery charger, *not the final product.* The manufacturer markup is a multiplier applied to manufacturer production cost to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a "profit margin."* The MPC times the manufacturer markup equals the manufacturer selling price (MSP).

DOE estimated a baseline markup of XX for product class X BCs. In other words, if you purchased the BC from a supplier you would pay XX times the cost to produce the BC.

5.1 Do you believe the XX baseline markup is representative of an average industry markup for BC manufacturers?

In the product price determination, DOE also estimated the markup on the final product that incorporates the covered battery charger. DOE estimated a baseline markup of XX for application YY.

5.2 Is the XX baseline markup representative of an average industry markup? How about your company's markup?

5.3 Do you mark up the cost of the battery charger any differently than the other components included in the final product you sell? If not, how and why do they vary?

5.4 What percentage of your final product's MPC is due to the battery charger?

5.5 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Do markups vary by efficiency of your final product?

5.6 What others factors affect the profitability of these products?

5.7 If all companies producing the below products for the US market faced in increase in the cost of the battery chargers, how would you expect industry pricing to change?

5.8 Is the markup on incremental costs for more efficient designs different than the markup on the baseline models (as is assumed for retailer markups used in the analyses)?

5.9 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

1-6 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, and prices. The industry revenue and national energy savings calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base-case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards-case shipments (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE modeled a "roll-up" scenario for 2013 and subsequent years. In the roll-up scenario, DOE assumed that product efficiencies in the base case that did not meet the standard would roll up to meet the new standard in 2013 and those products at or above the standard would be unaffected.

Table A.1-19 Battery Charger Shipment Volumes by Application

Top Applications by Shipments		2008 BC Shipments (thousands)	Percent of Shipments
Product Class 1 (Low Energy, Inductive)			
1	Rechargeable Toothbrushes	4,868	90.9%
2	Rechargeable water Jets	487	9.1%
	Total	5,354	100.0%
Product Class 2 (Low Energy, Low Voltage)			
1	Mobile Phones	105,120	51.0%
2	Answering Machines	20,175	9.8%
3	Cordless Phones	19,151	9.3%
4	Portable Video Game Systems	13,777	6.7%
5	Digital Cameras	10,879	5.3%
	Other	37,119	18.0%
	Total	206,221	100.0%
Product Class 3 (Low Energy, Medium Voltage)			
1	Portable DVD Players	7,140	30.9%
2	Camcorders	4,206	18.2%
3	Toy Ride-On Vehicles	3,548	15.3%
4	RC Toys	2,100	9.1%
5	DIY Power Tools (External)	1,753	7.6%
	Other	4,369	18.9%
	Total	23,116	100.0%
Product Class 4 (Low Energy, High Voltage)			
1	Notebooks	40,300	57.8%
2	Professional Power Tools	11,688	16.8%
3	DIY Power Tools (External)	5,259	7.5%
4	Netbooks	3,700	5.3%
5	Handheld Vacuums	2,797	4.0%
	Other	6,014	8.6%
	Total	69,758	100.0%
Product Class 5 (Medium Energy, Low Voltage)			
1	Toy Ride-On Vehicles	1,774	76.0%
2	Marine/Automotive/RV Chargers	500	21.4%

Top Applications by Shipments		2008 BC Shipments (thousands)	Percent of Shipments
3	Portable O2 concentrator - Others	50	2.1%
4	Portable O2 concentrator - Higher output	9	0.4%
	Total	2,333	100.0%
Product Class 6 (Medium Energy, High Voltage)			
1	Electric Scooters	250	26.6%
2	Mobility Scooters	192	20.4%
3	Lawn Mowers	182	19.4%
4	Wheelchairs	166	17.7%
5	Motorized Bicycles	150	15.9%
	Total	940	100.0%
Product Class 7 (High Energy)			
1	Golf Carts	214	100.0%
	Total	214	100.0%
Product Class 8 (Low Energy, <9 V Input)			
1	MP3 Players	39,358	54.8%
2	Mobile Phones	26,280	36.6%
3	Digital Cameras	2,720	3.8%
4	Personal Digital Assistants	1,779	2.5%
5	Camcorders	1,402	2.0%
	Other	286	0.4%
	Total	71,825	100.0%
Product Class 9 (Low Energy, ≥9 V Input)			
1	In-Vehicle GPS	15,320	98.7%
2	Medical Nebulizer	90	0.6%
3	Portable O2 concentrator – Others	50	0.3%
4	Flashlights/Lanterns	50	0.3%
5	**Portable O2 concentrator - Higher output**	9	0.1%
	Total	15,519	100.0%
Product Class 10 (Low Energy, AC Output from Battery)			
1	**Uninterruptible Power Supplies**	6,900	100.0%
	Total	6,900	100.0%

6.1 Do you expect to see any migration to other power sources for your products in the base case or standards case?

6.2 Would amended energy conservation standards impact the sales of more efficient products in any way? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

6.3 DOE assumed that revised standards that increase the product's purchase price do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes?

6.4 Do you expect non-efficiency-related characteristics of the below products to change in response to the standards? If so, how?

1-7 FINANCIAL PARAMETERS

To assess the financial impacts of energy conservation standards on manufacturers of products that include covered battery chargers, Navigant Consulting built a "strawman" cash flow model called the Government Regulatory Impact Model (GRIM). However, available public information might not be reflective of your financial performance at the profit center level, particularly as it relates to specific applications. At this time DOE's estimates are limited to much broader corporate settings. This section attempts to understand the financial parameters for your company (or division) and how those figures may differ from an industry aggregate picture.

7.1 In order to accurately collect information about battery charger manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table A.1-20 Financial Parameters for BC Application Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	27.6%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.0%	
Working Capital	Current assets less current liabilities (percentage of revenues)	8.3%	
Net PPE	Net plant property and equipment (percentage of revenues)	14.6%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	19.4%	
R&D	Research and development expenses (percentage of revenues)	3.8%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.7%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	4.2%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	70%	

7.2 If your company manufacturers multiple applications that incorporate covered battery charges, do any of the financial parameters in Table A.1-20 change significantly based on application? Please describe any differences.

7.3 Would you expect any of the financial parameters in Table A.1-20 to change for a particular subgroup of manufacturers? Please describe any differences.

1-8 CONVERSION COSTS

DOE understands that amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical portion of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers two types of conversion costs:

- *Capital conversion costs* are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- *Product conversion costs* are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

Table A.1-21 shows the design options used to reach higher efficiencies for the given product class(es). DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs.

Table A.1-21 Design Options Used to Improve Efficiency

Product Class X			
CSL	**Estimated Product Conversion Costs ($)**	**Estimated Capital Conversion Costs ($)**	**Description**
1			
2			
3			

8.1 In the table(s) above, for each product class, please provide estimates for your product and capital conversion costs. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level.

8.2 At your manufacturing facilities, would these design options be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

8.3 Are there certain design options that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

8.4 For each of the product classes shown in this section, which CSLs could be made within existing product designs and which would result in major product redesigns?

1-9 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from the overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

9.1 Below is a list of regulations that could affect manufacturers of products that incorporate covered battery chargers. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table A.1-22 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for Other Products and Equipment			
EMC Requirements			
UL Certifications			

9.2 Are there any other recent or impending regulations that manufacturers of products that incorporate covered battery chargers face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

9.3 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with an amended energy conservation standard?

9.4 DOE research has not identified any production tax credits for manufacturers of battery chargers. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient battery chargers? If so, please describe.

1-10 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in industry employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

10.1 Where are your facilities that produce covered products for the United States and what types of products are manufactured at each location? Please provide annual shipment figures for your company's battery charger products at each location by product class. Please also provide employment levels at each of these facilities.

Table A.1-23 Battery Charger Application Manufacturing Facilities

Facility	**Location**	**Product Types Manufactured**	**Employees**	**Annual Shipments**
Example	*Jackson, MS*	*PC 1, PC 8*	*650*	*300,000for PC 1,* *200,000 for PC 8*
1				
2				
3				
4				
5				

10.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

10.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

10.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

1-11 MANUFACTURING CAPACITY AND NON-US SALES

11.1 How would amended energy conservation standards impact your company's manufacturing capacity?

11.2 For any design changes that would require new production equipment, please describe how much downtime would be required, if any.

11.3 Are there any design changes that could not be implemented before the compliance date of the final rule (2013)?

11.4 What percentage of your products that incorporate covered battery chargers is *produced* in the United States? What percentage of these is exported, if any?

11.5 What percentage of your products that incorporate covered battery chargers is *sold* within the United States?

11.6 Are there any foreign companies in this industry with production facilities based in the United States?

11.7 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions?

1-12 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

12.1 How would industry competition change as a result of amended energy conservation standards? How would amended energy conservation standards affect *your* ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

12.2 Do any firms hold intellectual property that would yield them a competitive advantage following amended energy conservation standards?

1-13 IMPACTS ON SMALL BUSINESS

13.1 The Small Business Administration (SBA) denotes a small business in the battery charger manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[4] By this definition, is your company considered a small

---

[4] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a power, distribution, and specialty

business?

13.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

13.3 To your knowledge, are there any small businesses for which the adoption of amended energy conservation standards would have a particularly severe impact?

13.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

---

transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

12A.2 EXTERNAL POWER SUPPLY – ORIGINAL EQUIPMENT MANUFACTURER (OEM) MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Spring 2011

As part of the rulemaking process for energy conservation standards for external power supplies (EPSs), the Department of Energy (DOE) conducts the engineering analysis and the manufacturer impact analysis (MIA). In these analyses, DOE uses publicly available information and information provided by manufacturers during interviews to assess possible impacts on manufacturers due to new energy conservation standards.

2-1 SCOPE OF COVERAGE AND PRODUCT CLASSES

Definitions

The term **external power supply** means an external power supply circuit that is used to convert household electric current into DC current or lower-voltage AC current to operate a consumer product. (42 U.S.C. 6291(36)(A)

DOE understands an EPS to have four key attributes:

1. An EPS is outside (external to) the product it operates,
2. An EPS attaches to and obtains power from mains (household electric power),
3. An EPS performs power conversion but does not contain additional charge control functions, and
4. An EPS powers a consumer product

EPCA provides definitions for EPS and Class A EPS. Non-Class A EPSs, then, are those devices that fit the definition of an EPS but do not fit the definition of a Class A EPS. DOE has identified four types of non-Class A EPSs:

1. Multiple-Voltage EPSs: These devices are able to convert to more than one AC or DC output voltage at a time.
2. High-Power EPSs: These devices have a nameplate output power greater than 250 watts.
3. Medical EPSs: These devices are used to power medical devices regulated by the Food and Drug Administration.
4. MADB EPSs: These devices provide power to the battery chargers of motorized applications and detachable battery (MADB) packs.

Product Class Definitions

To establish effective energy conservation standards, DOE divides covered products into classes by the type of energy used, the capacity of the product, and any other performance-related feature that justifies different standard levels, such as features affecting consumer utility. (42

U.S.C. 6295(q)) DOE then conducts its analysis and considers establishing or amending standards to provide separate standard levels for each product class.

For EPSs, DOE examined a number of different performance related features including output power, output voltage, output cord length, type of power conversion, medical use, and use with battery chargers of motorized applications and detachable batteries.

The product classes DOE established for the preliminary analysis appear in Table A.2-1, Table A.2-2, Table A.2-3, Table A.2-4 and Table A.2-5.

Table A.2-1 Class A EPS Product Classes

	Basic Voltage Output	**Low Voltage Output**[*]
AC-DC Conversion	A1	A2
AC-AC Conversion	A3	A4

[*] Low voltage output EPSs have nameplate output voltage less than 6 volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic voltage output.

Table A.2-2 Multiple Voltage EPS Product Classes

	Product Class
Nameplate Output Power < 100 watts	X1
Nameplate Output Power ≥ 100 watts	X2

Table A.2-3 High Power EPS Product Classes

	Product Class
Nameplate Output Power > 250 watts	H1

Table A.2-4 Medical EPS Product Classes

	Basic Voltage Output	**Low Voltage Output**[*]
AC-DC Conversion	M1	M2
AC-AC Conversion	M3	M4

[*] Low voltage output EPSs have nameplate output voltage less than 6 volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic voltage output.

Table A.2-5 MADB EPS Product Classes

	Basic Voltage Output	**Low Voltage Output**[*]
AC-DC Conversion	B1	B2
AC-AC Conversion	B3	B4

[*] Low voltage output EPSs have nameplate output voltage less than six volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic voltage output.

1.1 Please provide any comments that you may have regarding the appropriateness of these product class definitions. Should DOE divide them into additional product classes, combine certain products classes, or consider any other EPS characteristics for establishing product classes?

2-2 ENGINEERING ANALYSIS

Overview

In the engineering analysis, DOE develops a relationship between the manufacturer selling price (MSP) and increases in EPS efficiency. The efficiency values range from that of a typical EPS sold today (*i.e.*, the baseline or "CSL 0") to the maximum technologically feasible efficiency level. At each efficiency level examined, DOE determines the consequent MSP, a relationship referred to as a cost-efficiency curve.

DOE structured its EPS engineering analysis around two methodologies: (1) test and teardowns, which involve testing products for efficiency and determining cost from a detailed bill of materials derived from tear-downs and (2) the efficiency-level approach, whereby manufacturers provide and explain their costs of achieving increases in energy efficiency at discrete levels of efficiency.

External Power Supply Representative Units

As discussed above, DOE divided Class A EPSs into four product classes for the preliminary analysis, following an examination of EPS technologies in the market and approaches used in other energy-efficiency programs. Further examination of EPS units in the market led to the selection of one of the four product classes for further analysis as the *representative* product class. This class collectively constitutes the majority of EPS shipments and national energy consumption. For those product classes that are not analyzed directly, DOE extrapolates the analysis from representative product classes. Table A.2-6 presents representative product class A1 in the context of the EPS product classes presented in Table A.2-1.

Table A.2-6 Class A EPS Representative Product Class and Scaled Product Classes

	Basic Voltage Output	**Low Voltage Output ***
AC-DC Conversion	A1 (representative)	A2 (scaled)
AC-AC Conversion	A3 (scaled)	A4 (scaled)

* Low voltage output EPSs have nameplate output voltage less than six volts and nameplate output current greater than or equal to 550 milliamps. All other EPSs are basic voltage output.

As seen in Figure A.2-1, DOE believes that there is a relationship between voltage and average efficiency as well as output voltage type and no-load power. Specifically, for the same cost, lower voltage EPSs will achieve a lower average efficiency. Similarly, AC-output EPSs will have higher no-load power consumption than DC-output EPSs. Thus, DOE's analysis focused on product class A1 and DOE extrapolated the analysis to the other product classes using these relationships.

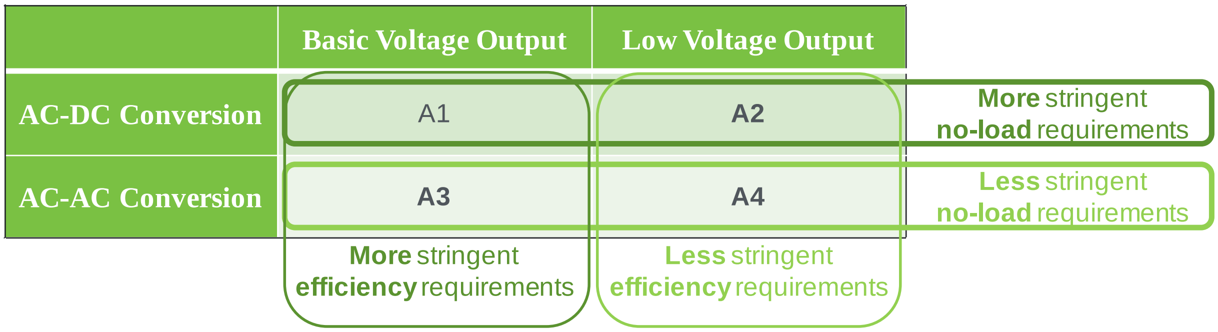


Figure A.2-1 Relationship between A1 and scaled product classes A2, A3, A4

DOE subsequently focused its analysis on four representative units within the representative product class (A1), presented in Table A.2-7. Because results from the analysis of these representative units would later be extended to additional EPSs within the product class, they were selected from high-volume and/or high-energy-consumption applications that use EPSs that are typical across EPSs in product class A1.

Table A.2-7 Class A EPS Representative Units

Representative Unit	Nameplate Output Power [watts]	Nameplate Output Voltage [volts]	Example Application
1	2.5	5	Mobile phone
2	18	12	Modem
3	60	15	Laptop Computer
4	120	19	Laptop Computer

2.1 Please comment on the appropriateness of these representative unit values for products with which you have familiarity.

2.2 Please provide a description of EPS end-use product applications that you sell or for which you sell components. Do any of those applications use EPSs with electrical characteristics similar to the representative values shown above?

2.3 What are the highest volume products (related to this rulemaking) that you sell? Please include output voltage, output power, and application.

External Power Supply Efficiency Metrics

DOE’s test procedure, based on the California Energy Commission (CEC) EPS test procedure, yields two measurements: active-mode average efficiency and no-load-mode (standby-mode) power consumption.

Active mode conversion efficiency is the ratio of output power to input power. The DOE test procedure averages the efficiency at four loading conditions—25, 50, 75, and 100 percent of maximum rated output current—to assess the performance of an EPS when powering diverse loads.

The test procedure also measures the power consumption of the EPS when disconnected from the consumer product, which is termed no-load power consumption. Because both the average efficiency and no-load power consumption affect the energy consumption of the EPS, DOE developed CSLs for the engineering analysis that are "matched pairs" of limits on both metrics simultaneously.

External Power Supply Performance

DOE is evaluating the impacts of various candidate standard levels (CSLs). Each CSL corresponds to different product efficiency, beginning with a baseline efficiency level that represents the least efficient products on the market. DOE evaluates four efficiency levels higher than the baseline level: ENERGY STAR 2.0, an intermediate level, a best-in-market level, and a maximum-technology-feasible level.

DOE determined the CSLs based on existing standard levels, products available in the market, and information obtained from manufacturers during preliminary analysis interviews, in the manner shown in Table A.2-8.

Table A.2-8 Candidate Standard Levels of Efficiency for Product Class A1

Number	Reference	Basis
CSL0	EISA 2007	EISA 2007 equations for efficiency and no-load power
CSL1	Energy Star 2.0	Energy Star 2.0 equations for efficiency and no-load power
CSL2	Intermediate	Curve fit to manufacture data points
CSL3	Best in Market	Curve fit to test unit data points
CSL4	Max Tech	Curve fit to manufacture data points

2.4 Are there any EPS design concerns unique to certain applications?

2.5 DOE estimated EPS markups as:

  - MPC to MSP is 35.5% or 1.355 (range of 1.2 to 1.85)
  - BOM to MSP is 62.5% or 1.625

Please comment on the markups that DOE used. (See Figure A.2-2 below for more detail)

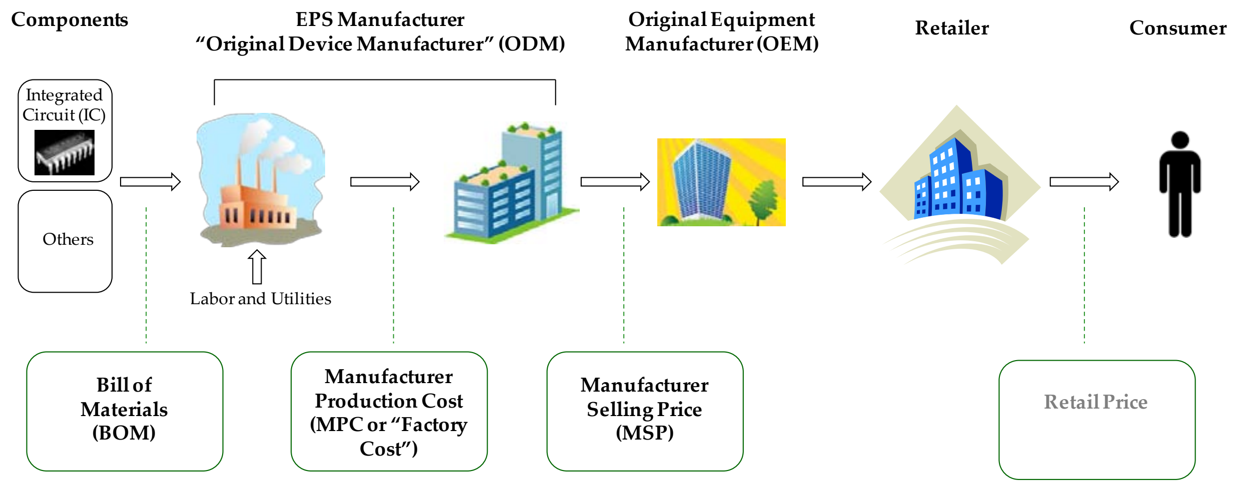


Figure A.2-2 EPS Markups

External Power Supply Relationships between Cost and Efficiency

For the preliminary analysis, Navigant Consulting Inc. (NCI), a DOE contractor, entered into non-disclosure agreements and interviewed representatives of several firms that manufacture EPSs, EPS components, and applications which use EPSs. For each representative unit, the manufacturers described the technological improvements and associated costs necessary to meet each of the CSLs. NCI aggregated the responses from these interviews and presented DOE with generalized responses free of any proprietary data for use in the analysis.

The results of the Preliminary Analysis are presented in Table A.2-9, Table A.2-10, Table A.2-11 and Table A.2-12. Figure A.2-3, Figure A.2-4, Figure A.2-5, and Figure A.2-6 display the relationship between cost vs. efficiency and cost vs. no-load power based on results from both manufacturer interviews and testing and teardowns. Following the tables and figures are related questions.

Table A.2-9 Cost and Efficiency Relationship for 2.5W EPS (Manufacturer Interviews)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Mfr Unit Efficiency [%]:	58.3%	67.9%	71.0%	73.5%	74.0%
Mfr Unit No Load Power [W]:	0.500	0.300	0.130	0.100	0.053
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
MSP Difference with CSL0 [$]:	$0.00	$0.04	$0.23	$0.31	$0.42

Table A.2-10 Cost and Efficiency Relationship for 18W EPS (Manufacturer Interviews)

	CSL 0	CSL 1	CSL2	CSL 3	CSL 4
Mfr Unit Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.5%
Mfr Unit No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
MSP Difference with CSL0 [$]:	$0.00	$0.32	$0.42	$0.79	$1.23

Table A.2-11 Cost and Efficiency Relationship for 60W EPS (Manufacturer Interviews)

	CSL 0	CSL 1	CSL2	CSL 3	CSL 4
Mfr Unit Efficiency [%]:	85.0%	87.0%	87.0%	88.0%	91.0%
Mfr Unit No Load Power [W]:	0.500	0.500	0.200	0.073	0.073
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
MSP Difference with CSL0 [$]:	$0.00	$0.24	$0.71	$1.58	$2.90

Table A.2-12 Cost and Efficiency Relationship for 120W EPS (Manufacturer Interviews)

	CSL 0	CSL 1	CSL2	CSL 3	CSL 4
Mfr Unit Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
Mfr Unit No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
MSP Difference with CSL0 [$]:	$0.00	$0.66	$1.23	$1.41	$5.03

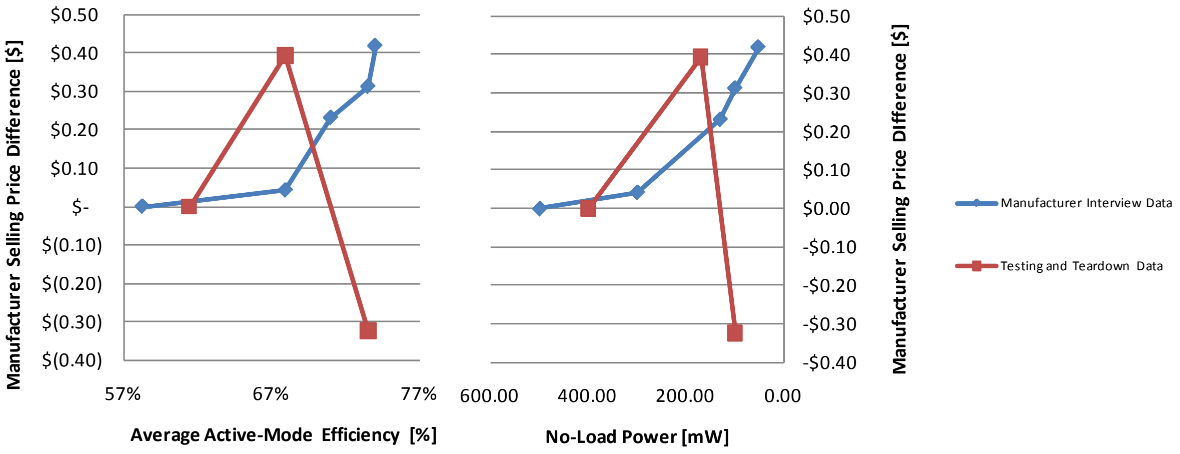


Figure A.2-3 MSP versus Efficiency and No-Load Power for 2.5W EPSs

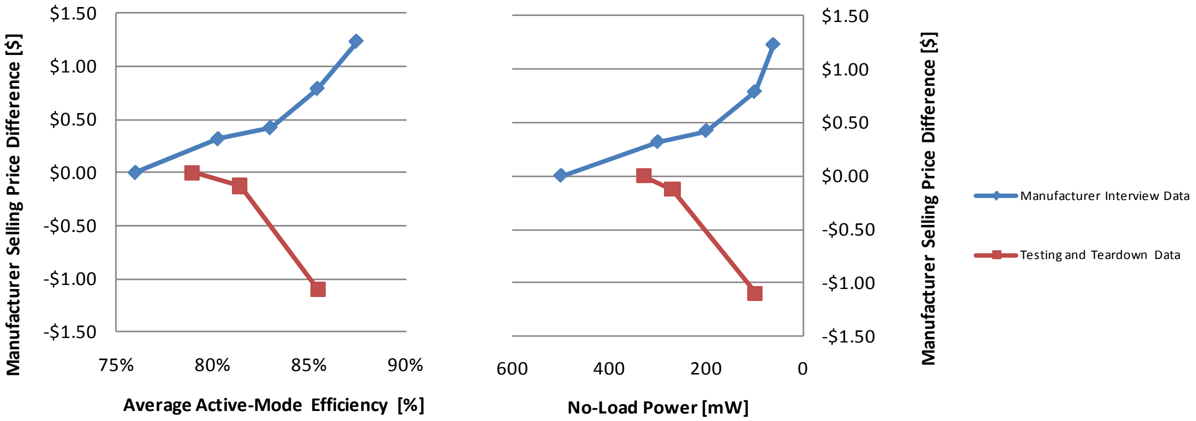


Figure A.2-4 MSP versus Efficiency and No-Load Power for 18W EPSs

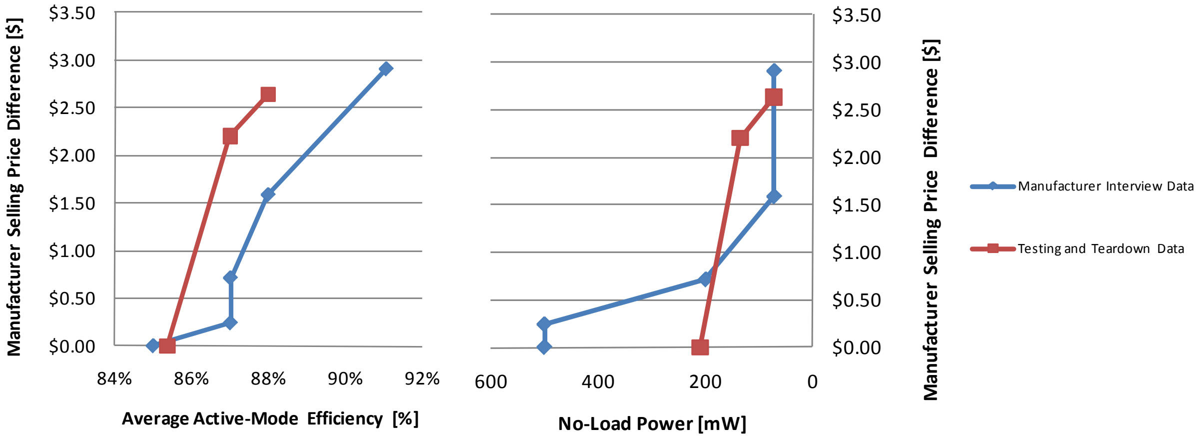


Figure A.2-5 MSP versus Efficiency and No-Load Power for 60W EPSs

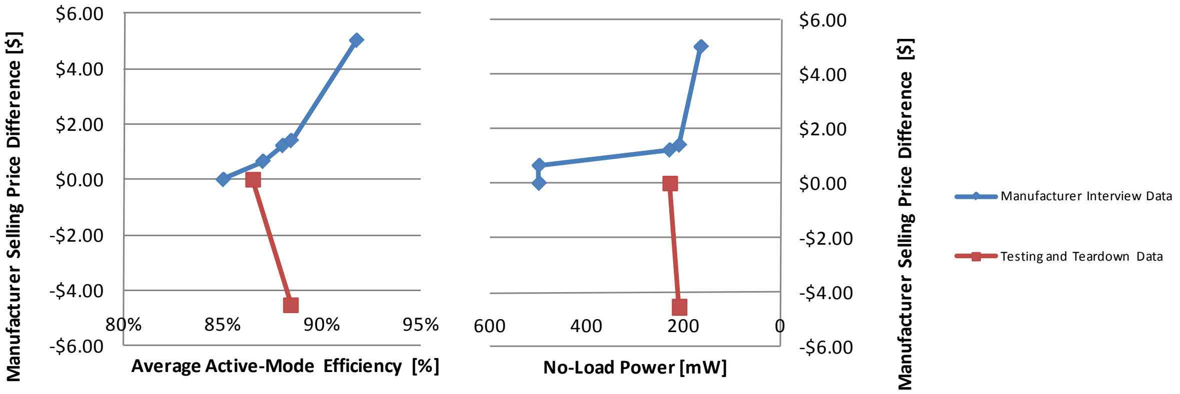


Figure A.2-6 MSP versus Efficiency and No-Load Power for 120W EPSs

2.6 DOE verified the reasonableness of the aggregated manufacturer max-tech data which it used to create curve fit equations for CSL 4 (max-tech). To that end, DOE's subject matter experts (SMEs) reviewed the data and confirmed that the data fell within the expected ranges of efficiencies based on their extensive experience with EPSs, other than the max-tech value for the 2.5W EPSs. The SMEs believe that 2.5W EPSs may be able to achieve a max tech efficiency of 80 percent rather than the 74.0 percent efficiency derived from manufacturers. Do you agree with the max-tech value for the 2.5W EPSs provided in Table A.2-9?

2.7 Has your company made progress with any products that exceed the max-tech efficiency levels listed in Table A.2-9, Table A.2-10, Table A.2-11 and Table A.2-12? If so, which ones? How might you achieve higher max-tech efficiencies?

2.8 Do the cost results from the aggregated manufacturer interview data seem reasonable with your experience?

2.9 The cost-efficiency curves for the testing and teardown data show a downward trend, indicating decreasing cost with increasing efficiency. Does this seem reasonable with your experience? Do you have possible explanations for why this may be?

2.10 Do you offer any products with performance characteristics similar to those shown in Table A.2-9, Table A.2-10, Table A.2-11 and Table A.2-12? Can you recommend any of your products that DOE should test to either corroborate or dispute these numbers when it proceeds with developing the engineering analysis in the Notice of Proposed Rulemaking (NOPR)?

2.11 DOE scaled CSLs for product class A1 to product classes A2, A3, and A4, per Figure A.2-1. DOE reduced low-voltage EPS CSLs consistent with ENERGY STAR. Similarly, the stringency of no-load power requirements for AC-AC EPSs was reduced consistent with ENERGY STAR. Please comment on DOE's use of scaling from product class A1 to scaled product classes A2, A3 and A4.

2.12 DOE identified four types of non-Class A EPSs:

- Medical EPSs
- Motorized-application and detachable battery (MADB) EPSs
- Multiple-voltage EPSs, and
- High Power EPSs

Do you have any comments or suggestions for how DOE should approach the analysis of these non-Class A EPSs?

2.13 For medical EPSs in particular, DOE believes that there may be an additional fixed cost for medical EPSs to meet relevant standards (UL 60601), but no incremental cost associated with increasing efficiency. Therefore, DOE intends to apply the Class A EPS analysis to medical EPSs. Please comment on this approach. If you believe that there may be an incremental cost associated with increasing the efficiency of medical EPSs, is there a way that DOE can account for that while applying the Class A EPS analysis?

2-3 KEY ISSUES

DOE conducts the manufacturer impact analysis (MIA) as part of the rulemaking process to determine whether to amend energy conservation standards for external power supplies (EPSs). For the MIA, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

3.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

3.2 For the issues identified, how significant are they for each efficiency level?

3.3 Figure A.2-7 represents DOE's understanding of the EPS value chain. Please describe your relationship to the EPS production process and the other parties in this chain. For example, does your company design, manufacture, and/or specify components of EPSs, the entire EPS, or the final product sold with the EPS?

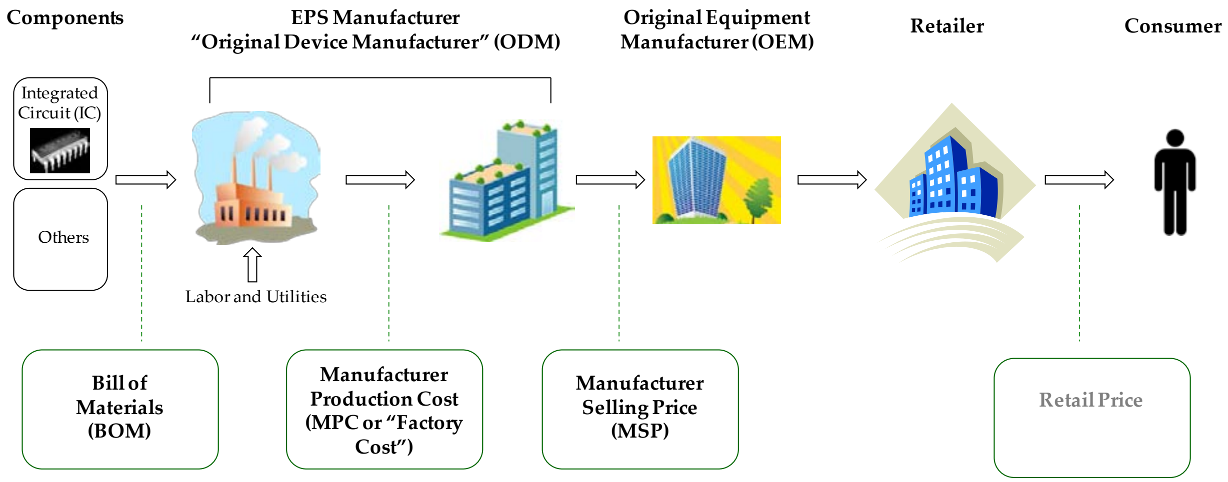


Figure A.2-7 EPS Value Chain

2-4 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the profit center level directly related to your products included with the external power supplies covered by this rulemaking. However, the context within which your production occurs and the associated costs are not readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical.

4.1 Do you have a parent company and/or any subsidiaries relevant to the EPS industry?

4.2 Would you expect your market share to change if higher energy conservation standards were adopted?

4.3 Who are your main competitors in this market?

4.4 What percentage of your total revenue corresponds to those products sold with covered EPSs?

2-5 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company's markup structure and profitability.

In the engineering analysis, DOE estimated the manufacturer production costs (MPC) for the covered EPSs included with products you produce. DOE defines MPC as all direct costs associated with manufacturing *the EPS*: direct labor, direct materials, and overhead (which includes depreciation). This MPC reflects cost to produce the EPS, *not the final product.* The manufacturer markup is a multiplier applied to MPC to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a "profit margin."* The MPC times the manufacturer markup equals the manufacturer selling price (MSP).

DOE estimated EPS markups as:

- MPC to MSP is 35.5% or 1.355 (range of 1.2 to 1.85)
- BOM to MSP is 62.5% or 1.625

5.1 Do you believe these markups are representative of an average industry markup for EPS manufacturers?

5.2 In the product price determination, DOE also estimated the markup on the final product (including the EPS) sold by the OEM to its first customer. DOE estimated this markup to be 1.48 for consumer products.

Is the 1.48 baseline markup representative of an average industry markup for consumer products? How about your company's markup?

5.3 Do you mark up the cost of the EPS any differently than the other components included in the final product you sell? If not, how and why do they vary?

5.4 What percentage of your final product's MPC is due to the EPS?

5.5 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Do markups vary by efficiency of your final product?

5.6 If all companies in your industry producing for the US market faced in increase in the cost of the EPSs, how would you expect industry pricing to change?

5.7 What factors affect the profitability of consumer products?

5.8 Is the markup on incremental costs for more efficient designs different than the markup on the baseline models (as is assumed for retailer markups used in the analyses)?

5.9 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

2-6 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, and prices. The industry revenue and national energy savings calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base-case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards-case shipments (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE modeled a "roll-up" scenario for 2013 and subsequent years. In the roll-up scenario, DOE assumed that product efficiencies in the base case that did not meet the standard would roll up to meet the new standard in 2013 and those products at or above the standard would be unaffected.

Table A.2-13 through Table A.2-15 display DOE's estimated shipments by product class and application for 2008.

Table A.2-13 Summary of EPS Shipments

EPS Product Class	2008 EPS Shipments (thousands)
Class A1 (DC Output, Basic Voltage)	206,176
Class A2 (DC Output, Low Voltage)	72,195
Class A3 (AC Output, Basic Voltage)	7,994
Class A4 (AC Output, Low Voltage)	2,250
Non-Class A	12,405
All EPSs	301,021

Table A.2-14 Class A External Power Supply Shipments by Product Class and Segment

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
Product Class A1 (DC Output, Basic Voltage): 0-10.25 W			
1	Answering Machines	20,175	26.5%
2	Cordless Phones	19,151	25.1%
3	Mobile Phones	13,140	17.2%
4	Portable Video Game Systems	10,884	14.3%
5	In-Vehicle GPS	7,660	10.0%
	Other	5,217	6.8%
	Total	76,227	100.0%
Product Class A1 (DC Output, Basic Voltage): 10.25-39 W			
1	LAN Equipment	27,581	41.3%
2	VoIP Adapters	8,845	13.3%
3	Digital Picture Frames	7,472	11.2%
4	Portable DVD Players	7,140	10.7%
5	MP3 Speaker Docks	7,012	10.5%
	Other	8,671	13.0%
	Total	66,721	100.0%
Product Class A1 (DC Output, Basic Voltage): 39-90 W			
1	Notebooks	30,225	57.0%
2	Video Game Consoles	13,512	25.5%
3	Ink Jet Imaging Equipment	5,557	10.5%
4	Netbooks	3,700	7.0%
	Total	56,776	100.0%
Product Class A1 (DC Output, Basic Voltage): 90-250 W			
1	Notebooks	10,075	98.4%
2	LED Monitors	160	1.6%
	Total	10,235	100.0%
Product Class A2 (DC Output, Low Voltage)			
1	Mobile Phones	52,560	72.8%
2	In-Vehicle GPS	7,660	10.6%
3	MP3 Players	4,373	6.1%
4	Portable Video Game Systems	2,893	4.0%
5	Personal Digital Assistants	1,582	2.2%
	Other	3,127	4.3%
	Total	72,195	100.0%
Product Class A3 (AC Output, Basic Voltage)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
1	Home Security Systems	4,219	52.8%
2	Aquarium Accessories	1,750	21.9%
3	Water Softeners/Purifiers	1,150	14.4%
4	Indoor Fountains	500	6.3%
5	Irrigation Timers	375	4.7%
	Total	7,994	100.0%
Product Class A4 (AC Output, Low Voltage)			
1	Aquarium Accessories	1,750	77.8%
2	Indoor Fountains	500	22.2%
	Total	2,250	100.0%

Table A.2-15 Non-Class A External Power Supply Shipments by Product Class

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
Product Class X1(Multiple-Voltage)			
1	Ink Jet Imaging Equipment	3,782	100.0%
	Total	3,782	100.0%
Product Class X2 (Multiple Voltage)			
1	Gaming System (multi-voltage EPS)	4,901	100.0%
	Total	4,901	100.0%
Product Class H1(High Power)			
1	Amateur Radios	3	100.0%
	Total	3	100.0%
Product Class M1(Medical Devices)			
1	Sleep Apnea Machines	1,000	65.2%
2	Medical Nebulizers	450	29.3%
3	Portable O2 Concentrators - Others	50	3.3%
4	Blood Pressure Monitors	25	1.6%
5	Portable O2 Concentrators - Higher Output	9	0.6%
	Total	1,534	
Product Class M2 (Medical Devices)			
1	Blood Pressure Monitors	25	100.0%
	Total	25	100.0%
Product Class M3 (Medical Devices)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
	[no products identified]		
	Total	0	
Product Class M4 (Medical Devices)			
	[no products identified]		
	Total	0	
Product Class B1(MADB)			
1	Toy Ride-On Vehicles	355	18.8%
2	RC Toys	350	18.6%
3	DIY Power Tools (External)	281	14.9%
4	DIY Power Tools (Integral)	234	12.4%
5	Handheld Vacuums	209	11.1%
	Other	457	24.2%
	Total	1,884	100.0%
Product Class B2 (MADB)			
1	Shavers	164	59.7%
2	Beard and Mustache Trimmers	59	21.3%
3	Hair Clippers	38	13.8%
4	Can Openers	14	5.2%
	Total	275	100.0%
Product Class B3 (MADB)			
	[no products identified]		
	Total	0	
Product Class B4 (MADB)			
	[no products identified]		
	Total	0	

6.1 Please review the shipments for those products you manufacturer. To your knowledge, do the estimates appear reasonable?

6.2 Do you expect to see any migration to other power sources or substitute products in any of the product classes or applications above?

6.3 Do you expect to see any migration to other power sources for your products in the base case or standards case?

6.4 Would amended energy conservation standards impact the sales of more efficient products in any way? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

6.5 DOE assumed that revised standards that increase the product's purchase price—across the industry (not just one manufacturer)—do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes?

6.6 Do you expect characteristics of consumer products to change in response to the standards? If so, how?

2-7 FINANCIAL PARAMETERS

To assess the financial impacts of energy conservation standards on manufacturers of products that include covered EPSs, Navigant Consulting built a "strawman" cash flow model called the Government Regulatory Impact Model (GRIM). However, available public information might not be reflective of your financial performance at the profit center level, particularly as it relates to specific applications. At this time DOE's estimates are limited to much broader corporate settings. This section attempts to understand the financial parameters for your company (or division) and how those figures may differ from an industry aggregate picture.

7.1 In order to accurately collect information about EPS manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table A.2-16 Financial Parameters for EPS Application Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	27.6%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.0%	
Working Capital	Current assets less current liabilities (percentage of revenues)	8.3%	
Net PPE	Net plant property and equipment (percentage of revenues)	14.6%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	19.4%	
R&D	Research and development expenses (percentage of revenues)	3.8%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.7%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	4.2%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	73.8%	

7.2 If your company manufacturers multiple applications sold with covered EPSs, do any of the financial parameters in Table A.2-16 change significantly based on application? Please describe any differences.

7.3 Would you expect any of the financial parameters in Table A.2-16 to change for a particular subgroup of manufacturers? Please describe any differences.

2-8 CONVERSION COSTS

DOE understands that amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical portion of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers three types of conversion costs:

- *Capital conversion costs* are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- *Product conversion costs* are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.
- *Standard assets* are assets that new standards would render obsolete before the end of their useful life.

Table A.2-17 through Table A.2-20 show the efficiency levels for the four representative units of product class A1—AC-DC Conversion, Basic Voltage Output. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs.

8.1 In the tables below, for each product class, please provide estimates for your product and capital conversion costs. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level.

Table A.2-17 Conversion Costs for Product Class A1, Rep Unit 1 (Mobile Phone)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.2-18 Conversion Costs for Product Class A1, Rep Unit 2 (Modem)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.2-19 Conversion Costs for Product Class A1, Rep Unit 3 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.2-20 Conversion Costs for Product Class A1, Rep Unit 4 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				

Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.2-21 Conversion Costs for Product Medical EPS Class M1 18-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.2-22 Conversion Costs for MADB Product Class B1 2.5-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

8.2 At your manufacturing facilities, would these design options be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

8.3 Are there certain design options that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

8.4 For each of the product classes shown in the tables above, which CSLs could be made within existing product designs and which would result in major product redesigns?

8.5 Would you expect similar conversion costs for non-representative product classes?

2-9 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from the overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

9.1 Below is a list of regulations that could affect manufacturers of products that incorporate covered EPSs. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table A.2-23 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for Battery Chargers			
FDA Approval for Medical Device Design Changes			

9.2 Are there any other recent or impending regulations that manufacturers of products that incorporate covered EPSs face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

9.3 Under what circumstances would you be able to coordinate any expenditure related to these other regulations with an amended energy conservation standard?

9.4 DOE research has not identified any production tax credits for manufacturers of products that incorporate covered EPSs. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient EPSs? If so, please describe.

2-10 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in industry employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

10.1 Where are your facilities that produce covered products for the United States and what types of products are manufactured at each location? Please provide annual shipment figures for your company's EPS products at each location by product class. Please also provide employment levels at each of these facilities.

Table A.2-24 EPS Manufacturing Facilities

Facility	Location	Product Types Manufactured	Employees	Annual Shipments
Example	*Jackson, MS*	*PC 1, PC 5*	*650*	*300,000 for PC 1,* *200,000 for PC 5*
1				
2				
3				
4				
5				

10.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

10.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

10.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

2-11 MANUFACTURING CAPACITY AND NON-US SALES

11.1 How long is a typical design cycle for your products covered by this rulemaking?

11.2 How would amended energy conservation standards impact your company's manufacturing capacity?

11.3 For any design changes that would require new production equipment, please describe how much downtime would be required, if any.

11.4 Are there any design changes that could not be implemented before the compliance date of the final rule (2013)?

11.5 What percentage of your products that incorporate covered EPSs are *produced* in the United States? What percentage of these are exported, if any?

11.6 What percentage of your products that incorporate covered EPSs are *sold* within the United States?

11.7 Are there any foreign companies in this industry with production facilities based in the United States?

11.8 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions?

2-12 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

12.1 How would industry competition change as a result of amended energy conservation standards? How would amended energy conservation standards affect *your* ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

12.2 Do any firms hold intellectual property that would yield them a competitive advantage following amended energy conservation standards?

2-13 IMPACTS ON SMALL BUSINESS

13.1 The Small Business Administration (SBA) denotes a small business in the EPS manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[5] By this definition, is your company considered a small business?

13.2 Are there any reasons that a small business manufacturer might be at a disadvantage relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

13.3 To your knowledge, are there any small businesses for which the adoption of amended energy conservation standards would have a particularly severe impact?

13.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

---

[5] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a power, distribution, and specialty transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business’s parent company and any other subsidiaries.

12A.3 EXTERNAL POWER SUPPLY – ORIGINAL DEVICE MANUFACTURER (ODM) MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

Spring 2011

3-1 KEY ISSUES

DOE conducts the manufacturer impact analysis (MIA) as part of the rulemaking process to determine whether to amend energy conservation standards for external power supplies (EPSs). For the MIA, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

1.2 For the issues identified, how significant are they for each efficiency level?

1.3 Figure A.3-1 represents DOE's understanding of the EPS value chain. Please describe your relationship to the EPS production process and the other parties in this chain. For example, does your company design, manufacture, and/or specify components of EPSs, the entire EPS, or the final product sold with the EPS?

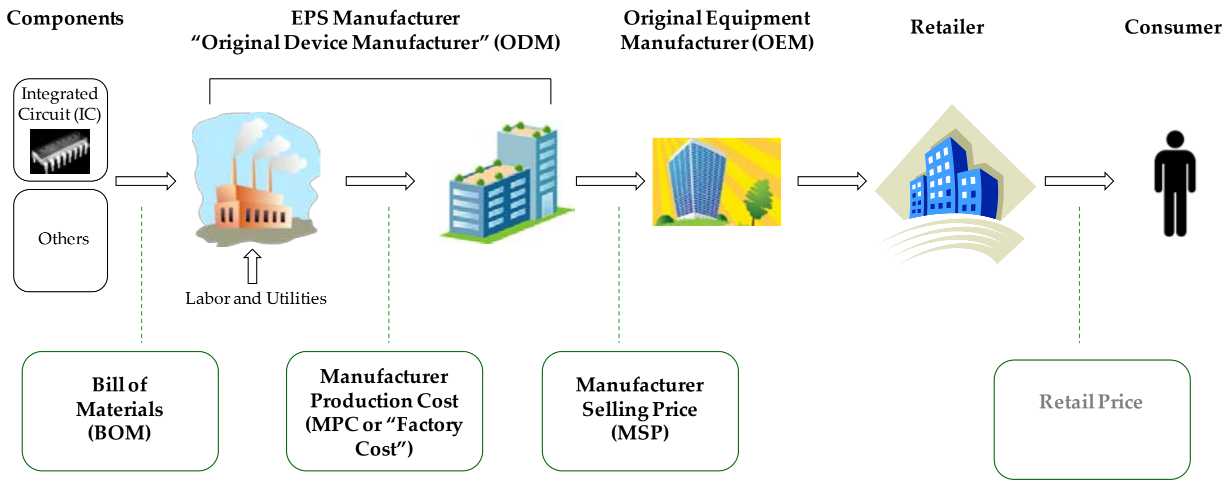


Figure A.3-1 EPS Value Chain

3-2 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the profit center level directly related to the EPS covered by this rulemaking. However, the context within which your production occurs and the associated costs are not readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical.

2.1 Do you have a parent company and/or any subsidiaries relevant to the EPS industry?

2.2 What is your company’s approximate share of the EPS market? Does it vary by product class?

2.3 Would you expect your market share to change if higher energy conservation standards were adopted?

2.4 Who are your main competitors in this market?

2.5 What percentage of your total revenue derives from covered EPSs?

3-3 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company’s markup structure and profitability.

In the engineering analysis, DOE estimated the manufacturer production costs (MPC) for the covered EPSs. DOE defines MPC as all direct costs associated with manufacturing *the EPS*: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to MPC to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a “profit margin.”* The MPC cost times the manufacturer markup equals the manufacturer selling price (MSP).

DOE estimated EPS markups as:

- MPC to MSP is 35.5% or 1.355 (range of 1.2 to 1.85)
- BOM to MSP is 62.5% or 1.625

3.1 Do you believe these markups are representative of an average industry markup for EPS manufacturers?

3.2 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Do markups vary by efficiency?

3.3 What other factors affect the profitability and markups of EPSs?

3.4 If all companies in your industry producing for the US market faced in increase in the cost to produce EPSs, how would you expect industry pricing to change?

3.5 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

3-4 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, and prices. The industry revenue and national energy savings calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base-case (i.e., total industry shipments absent amended energy conservation standards) and the standards-case (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE modeled a "roll-up" scenario for 2013 and subsequent years. In the roll-up scenario, DOE assumed that product efficiencies in the base case that did not meet the standard would roll up to meet the new standard in 2013 and those products at or above the standard would be unaffected.

Table A.3-1 through Table A.3-3 display DOE's estimated shipments by product class and application for 2008.

Table A.3-1 Summary of EPS Shipments

EPS Product Class	2008 EPS Shipments (thousands)
Class A1 (DC Output, Basic Voltage)	206,176
Class A2 (DC Output, Low Voltage)	72,195
Class A3 (AC Output, Basic Voltage)	7,994
Class A4 (AC Output, Low Voltage)	2,250
Non-Class A	12,405
All EPSs	301,021

Table A.3-2 Class A External Power Supply Shipments by Product Class and Segment

Top Applications by Shipments		**2008 EPS Shipments (thousands)**	**Percent of Shipments**
Product Class A1 (DC Output, Basic Voltage): 0-10.25 W			
1	Answering Machines	20,175	26.5%
2	Cordless Phones	19,151	25.1%
3	Mobile Phones	13,140	17.2%
4	Portable Video Game Systems	10,884	14.3%
5	In-Vehicle GPS	7,660	10.0%
	Other	5,217	6.8%
	Total	76,227	100.0%
Product Class A1 (DC Output, Basic Voltage): 10.25-39 W			
1	LAN Equipment	27,581	41.3%
2	VoIP Adapters	8,845	13.3%
3	Digital Picture Frames	7,472	11.2%
4	Portable DVD Players	7,140	10.7%
5	MP3 Speaker Docks	7,012	10.5%
	Other	8,671	13.0%
	Total	66,721	100.0%
Product Class A1 (DC Output, Basic Voltage): 39-90 W			
1	Notebooks	30,225	57.0%
2	Video Game Consoles	13,512	25.5%
3	Ink Jet Imaging Equipment	5,557	10.5%
4	Netbooks	3,700	7.0%
	Total	56,776	100.0%
Product Class A1 (DC Output, Basic Voltage): 90-250 W			
1	Notebooks	10,075	98.4%
2	LED Monitors	160	1.6%
	Total	10,235	100.0%
Product Class A2 (DC Output, Low Voltage)			
1	Mobile Phones	52,560	72.8%
2	In-Vehicle GPS	7,660	10.6%
3	MP3 Players	4,373	6.1%
4	Portable Video Game Systems	2,893	4.0%
5	Personal Digital Assistants	1,582	2.2%
	Other	3,127	4.3%
	Total	72,195	100.0%
Product Class A3 (AC Output, Basic Voltage)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
1	Home Security Systems	4,219	52.8%
2	Aquarium Accessories	1,750	21.9%
3	Water Softeners/Purifiers	1,150	14.4%
4	Indoor Fountains	500	6.3%
5	Irrigation Timers	375	4.7%
	Total	7,994	100.0%
Product Class A4 (AC Output, Low Voltage)			
1	Aquarium Accessories	1,750	77.8%
2	Indoor Fountains	500	22.2%
	Total	2,250	100.0%

Table A.3-3 Non-Class A External Power Supply Shipments by Product Class

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
Product Class X1(Multiple-Voltage)			
1	Ink Jet Imaging Equipment	3,782	100.0%
	Total	3,782	100.0%
Product Class X2 (Multiple Voltage)			
1	Gaming System (multi-voltage EPS)	4,901	100.0%
	Total	4,901	100.0%
Product Class H1(High Power)			
1	Amateur Radios	3	100.0%
	Total	3	100.0%
Product Class M1(Medical Devices)			
1	Sleep Apnea Machines	1,000	65.2%
2	Medical Nebulizers	450	29.3%
3	Portable O2 Concentrators - Others	50	3.3%
4	Blood Pressure Monitors	25	1.6%
5	Portable O2 Concentrators - Higher Output	9	0.6%
	Total	1,534	
Product Class M2 (Medical Devices)			
1	Blood Pressure Monitors	25	100.0%
	Total	25	100.0%
Product Class M3 (Medical Devices)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
	[no products identified]		
	Total	0	
Product Class M4 (Medical Devices)			
	[no products identified]		
	Total	0	
Product Class B1(MADB)			
1	Toy Ride-On Vehicles	355	18.8%
2	RC Toys	350	18.6%
3	DIY Power Tools (External)	281	14.9%
4	DIY Power Tools (Integral)	234	12.4%
5	Handheld Vacuums	209	11.1%
	Other	457	24.2%
	Total	1,884	100.0%
Product Class B2 (MADB)			
1	Shavers	164	59.7%
2	Beard and Mustache Trimmers	59	21.3%
3	Hair Clippers	38	13.8%
4	Can Openers	14	5.2%
	Total	275	100.0%
Product Class B3 (MADB)			
	[no products identified]		
	Total	0	
Product Class B4 (MADB)			
	[no products identified]		
	Total	0	

4.1 Please review the shipments for those products you manufacturer. To your knowledge, do the estimates appear reasonable?

4.2 Do you expect to see any migration to other power sources or substitute products in any of the product classes or applications above?

4.3 Would amended energy conservation standards impact the sales of more efficient products in any way? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

4.4 DOE assumed that revised standards that increase the product's purchase price—across the industry (not just one manufacturer)—do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes?

4.5 Do you expect any other characteristics of EPSs to change in response to the standards? If so, how?

3-5 FINANCIAL PARAMETERS

To assess the financial impacts of energy conservation standards on manufacturers of covered EPSs, Navigant Consulting built a "strawman" cash flow model called the Government Regulatory Impact Model (GRIM). However, available public information might not be reflective of your financial performance at the profit center level. At this time DOE's estimates are limited to much broader corporate settings. This section attempts to understand the financial parameters for your company (or division) and how those figures may differ from an industry aggregate picture.

5.1 In order for DOE to accurately collect information about EPS manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table A.3-4 Financial Parameters for EPS Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	27.6%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.0%	
Working Capital	Current assets less current liabilities (percentage of revenues)	8.3%	
Net PPE	Net plant property and equipment (percentage of revenues)	14.6%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	19.4%	
R&D	Research and development expenses (percentage of revenues)	3.8%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.7%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	4.2%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	73.8%	

5.2 Do any of the financial parameters in Table A.3-4 change significantly based on EPS product class or the application for which it is produced? Please describe any differences.

5.3 Would you expect any of the financial parameters in Table A.3-4 to change for a particular subgroup of manufacturers? Please describe any differences.

3-6 CONVERSION COSTS

DOE understands that amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical portion of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers three types of conversion costs:

- *Capital conversion costs* are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- *Product conversion costs* are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

- *Standard assets* are assets that new standards would render obsolete before the end of their useful life.

Table A.3-5 through Table A.3-8 show the efficiency levels for the four representative units of product class A1—AC-DC Conversion, Basic Voltage Output. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs.

6.1 In the tables below, for each product class, please provide estimates for your product and capital conversion costs. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level.

Table A.3-5 Conversion Costs for Product Class A1, Rep Unit 1 (Mobile Phone)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.3-6 Conversion Costs for Product Class A1, Rep Unit 2 (Modem)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.3-7 Conversion Costs for Product Class A1, Rep Unit 3 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.3-8 Conversion Costs for Product Class A1, Rep Unit 4 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.3-9 Conversion Costs for Product Medical EPS Class M1 18-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.3-10 Conversion Costs for MADB Product Class B1 2.5-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

6.2 At your manufacturing facilities, would these design options be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

6.3 Are there certain design options that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

6.4 For each of the product classes shown in the tables above, which CSLs could be made within existing product designs and which would result in major product redesigns?

6.5 Would you expect similar conversion costs for non-representative product classes?

3-7 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from the overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

7.1 Below is a list of regulations that could affect manufacturers of covered EPSs. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table A.3-11 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE's Energy Conservation Standards for Battery Chargers			
FDA Approval for Medical Device Design Changes			

7.2 Are there any other recent or impending regulations that manufacturers of EPSs face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

7.3 Under what circumstances would you be able to coordinate any expenditures related to these other regulations with an amended energy conservation standard?

7.4 DOE research has not identified any production tax credits for manufacturers of EPSs. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient EPSs? If so, please describe.

3-8 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in industry employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

8.1 Where are your facilities that produce covered products for the United States and what types of products are manufactured at each location? Please provide annual shipment figures for your company's EPS products at each location by product class. Please also provide employment levels at each of these facilities.

Table A.3-12 EPS Manufacturing Facilities

Facility	Location	Product Types Manufactured	Employees	Annual Shipments
Example	*Jackson, MS*	*PC 1, PC 8*	*650*	*300,000 for PC 1, 200,000 for PC 8*
1				
2				
3				
4				
5				

8.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

8.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

8.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

3-9 MANUFACTURING CAPACITY AND NON-US SALES

9.1 How long is a typical design cycle for your products covered by this rulemaking?

9.2 How would amended energy conservation standards impact your company’s manufacturing capacity?

9.3 For any design changes that would require new production equipment, please describe how much downtime would be required, if any.

9.4 Are there any design changes that could not be implemented before the compliance date of the final rule (2013)?

9.5 What percentage of your EPSs are *produced* in the United States? What percentage of these are exported, if any?

9.6 What percentage of your covered EPSs are *sold* within the United States?

9.7 Are there any foreign companies in this industry with production facilities based in the United States?

9.8 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions?

3-10 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

10.1 How would industry competition change as a result of amended energy conservation standards? How would amended energy conservation standards affect *your* ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

10.2 Do any firms hold intellectual property that would yield them a competitive advantage following amended energy conservation standards?

3-11 IMPACTS ON SMALL BUSINESS

11.1 The Small Business Administration (SBA) denotes a small business in the EPS manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[6] By this definition, is your company considered a small business?

11.2 Are there any reasons that a small business manufacturer might be at a disadvantage

---

[6] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a power, distribution, and specialty transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

11.3 To your knowledge, are there any small businesses for which the adoption of amended energy conservation standards would have a particularly severe impact?

11.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

12A.4 EXTERNAL POWER SUPPLY – INTERNAL CIRCUITRY MANUFACTURER MANUFACTURER IMPACT ANALYSIS INTERVIEW

Spring 2011

4-1 KEY ISSUES

The Department of Energy (DOE) conducts the manufacturer impact analysis (MIA) as part of the rulemaking process to determine whether to amend energy conservation standards for external power supplies (EPSs). For the MIA, DOE uses publicly available information and information provided during interviews to assess possible impacts on manufacturers due to amended energy conservation standards.

1.1 In general, what are the key issues for your company regarding amended energy conservation standards and this rulemaking?

1.2 For the issues identified, how significant are they for each efficiency level?

1.3 Figure A.4-1 represents DOE's understanding of the EPS value chain. Please describe your relationship to the EPS production process and the other parties in this chain. For example, does your company design, manufacture, and/or specify components of EPSs, the entire EPS, or the final product sold with the EPS?

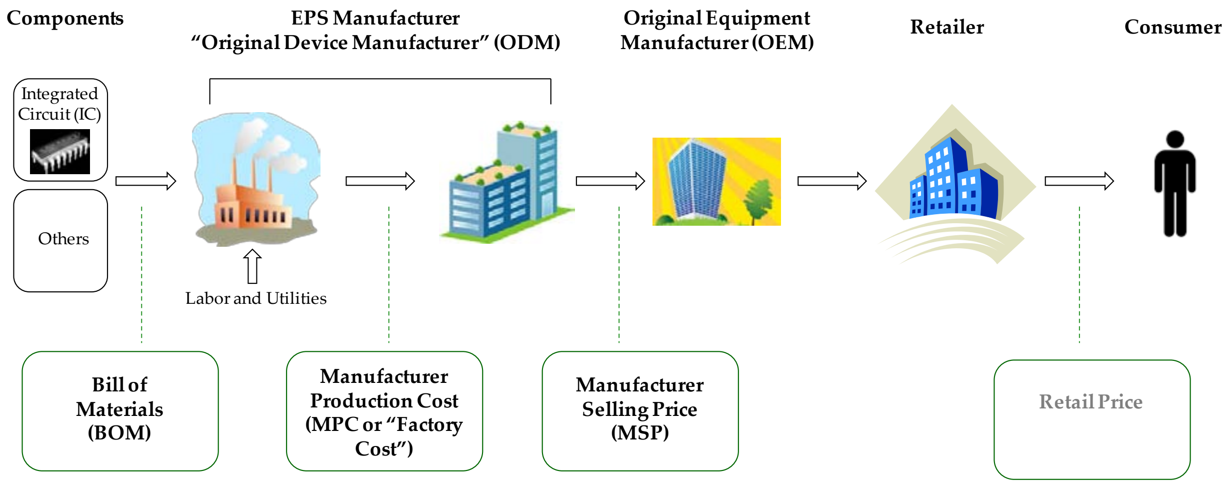


Figure A.4-1 EPS Value Chain

4-2 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

DOE is interested in understanding manufacturer impacts at the profit center level directly related to the EPS covered by this rulemaking. However, the context within which your production occurs and the associated costs are not readily available from public sources. Therefore, DOE invites you to provide these details confidentially in your own words to the extent possible and practical.

2.1 Do you have a parent company and/or any subsidiaries relevant to the EPS industry?

2.2 What is your company's approximate share of the EPS market? Does it vary by product class?

2.3 Would you expect your market share to change if higher energy conservation standards were adopted?

2.4 Who are your main competitors in this market?

2.5 What percentage of your total revenue derives from covered EPSs?

4-3 MARKUPS AND PROFITABILITY

One of the primary objectives of the MIA is to assess the impact of amended energy conservation standards on industry profitability. In this section, DOE would like to understand the current markup structure of the industry and how amended energy conservation standards would impact your company's markup structure and profitability.

In the engineering analysis, DOE estimated the manufacturer production costs (MPC) for the covered EPSs. DOE defines MPC as all direct costs associated with manufacturing *the EPS*: direct labor, direct materials, and overhead (which includes depreciation). The manufacturer markup is a multiplier applied to MPC to cover non-production costs, such as SG&A and R&D, as well as profit. *It does not reflect a "profit margin."* The MPC cost times the manufacturer markup equals the manufacturer selling price (MSP).

DOE estimated EPS markups as:

- MPC to MSP is 35.5% or 1.355 (range of 1.2 to 1.85)
- BOM to MSP is 62.5% or 1.625

3.1 Do you believe these markups are representative of an average industry markup for EPS manufacturers?

3.2 Because the market disruption caused by standards can alter the pricing of premium products, DOE is interested in understanding how margins currently change with efficiency. Do markups vary by efficiency?

3.3 What other factors affect the profitability and markups of EPSs?

3.4 If all companies in your industry producing for the US market faced in increase in the cost to produce EPSs, how would you expect industry pricing to change?

3.5 Would you expect changes in your estimated profitability following an amended energy conservation standard? If so, please explain why.

4-4 SHIPMENT PROJECTIONS

An amended energy conservation standard can change overall shipments by altering product attributes, marketing approaches, and prices. The industry revenue and national energy savings calculations are based on the shipment projections developed in DOE's shipments model. The shipments model includes forecasts for the base-case (i.e., total industry shipments absent amended energy conservation standards) and the standards-case (i.e., total industry shipments with amended energy conservation standards).

To determine efficiency distributions after the effective date of the standard, DOE modeled a "roll-up" scenario for 2013 and subsequent years. In the roll-up scenario, DOE assumed that product efficiencies in the base case that did not meet the standard would roll up to meet the new standard in 2013 and those products at or above the standard would be unaffected.

Table A.4-1 through Table A.4-3 display DOE's estimated shipments by product class and application for 2008.

Table A.4-1 Summary of EPS Shipments

EPS Product Class	2008 EPS Shipments (thousands)
Class A1 (DC Output, Basic Voltage)	206,176
Class A2 (DC Output, Low Voltage)	72,195
Class A3 (AC Output, Basic Voltage)	7,994
Class A4 (AC Output, Low Voltage)	2,250
Non-Class A	12,405
All EPSs	301,021

Table A.4-2 Class A External Power Supply Shipments by Product Class and Segment

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
Product Class A1 (DC Output, Basic Voltage): 0-10.25 W			
1	Answering Machines	20,175	26.5%
2	Cordless Phones	19,151	25.1%
3	Mobile Phones	13,140	17.2%
4	Portable Video Game Systems	10,884	14.3%
5	In-Vehicle GPS	7,660	10.0%
	Other	5,217	6.8%
	Total	76,227	100.0%
Product Class A1 (DC Output, Basic Voltage): 10.25-39 W			
1	LAN Equipment	27,581	41.3%
2	VoIP Adapters	8,845	13.3%
3	Digital Picture Frames	7,472	11.2%
4	Portable DVD Players	7,140	10.7%
5	MP3 Speaker Docks	7,012	10.5%
	Other	8,671	13.0%
	Total	66,721	100.0%
Product Class A1 (DC Output, Basic Voltage): 39-90 W			
1	Notebooks	30,225	57.0%
2	Video Game Consoles	13,512	25.5%
3	Ink Jet Imaging Equipment	5,557	10.5%
4	Netbooks	3,700	7.0%
	Total	56,776	100.0%
Product Class A1 (DC Output, Basic Voltage): 90-250 W			
1	Notebooks	10,075	98.4%
2	LED Monitors	160	1.6%
	Total	10,235	100.0%
Product Class A2 (DC Output, Low Voltage)			
1	Mobile Phones	52,560	72.8%
2	In-Vehicle GPS	7,660	10.6%
3	MP3 Players	4,373	6.1%
4	Portable Video Game Systems	2,893	4.0%
5	Personal Digital Assistants	1,582	2.2%
	Other	3,127	4.3%
	Total	72,195	100.0%
Product Class A3 (AC Output, Basic Voltage)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
1	Home Security Systems	4,219	52.8%
2	Aquarium Accessories	1,750	21.9%
3	Water Softeners/Purifiers	1,150	14.4%
4	Indoor Fountains	500	6.3%
5	Irrigation Timers	375	4.7%
	Total	7,994	100.0%
Product Class A4 (AC Output, Low Voltage)			
1	Aquarium Accessories	1,750	77.8%
2	Indoor Fountains	500	22.2%
	Total	2,250	100.0%

Table A.4-3 Non-Class A External Power Supply Shipments by Product Class

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
Product Class X1(Multiple-Voltage)			
1	Ink Jet Imaging Equipment	3,782	100.0%
	Total	3,782	100.0%
Product Class X2 (Multiple Voltage)			
1	Gaming System (multi-voltage EPS)	4,901	100.0%
	Total	4,901	100.0%
Product Class H1(High Power)			
1	Amateur Radios	3	100.0%
	Total	3	100.0%
Product Class M1(Medical Devices)			
1	Sleep Apnea Machines	1,000	65.2%
2	Medical Nebulizers	450	29.3%
3	Portable O2 Concentrators - Others	50	3.3%
4	Blood Pressure Monitors	25	1.6%
5	Portable O2 Concentrators - Higher Output	9	0.6%
	Total	1,534	
Product Class M2 (Medical Devices)			
1	Blood Pressure Monitors	25	100.0%
	Total	25	100.0%
Product Class M3 (Medical Devices)			

Top Applications by Shipments		2008 EPS Shipments (thousands)	Percent of Shipments
	[no products identified]		
	Total	0	
Product Class M4 (Medical Devices)			
	[no products identified]		
	Total	0	
Product Class B1(MADB)			
1	Toy Ride-On Vehicles	355	18.8%
2	RC Toys	350	18.6%
3	DIY Power Tools (External)	281	14.9%
4	DIY Power Tools (Integral)	234	12.4%
5	Handheld Vacuums	209	11.1%
	Other	457	24.2%
	Total	1,884	100.0%
Product Class B2 (MADB)			
1	Shavers	164	59.7%
2	Beard and Mustache Trimmers	59	21.3%
3	Hair Clippers	38	13.8%
4	Can Openers	14	5.2%
	Total	275	100.0%
Product Class B3 (MADB)			
	[no products identified]		
	Total	0	
Product Class B4 (MADB)			
	[no products identified]		
	Total	0	

4.1 Please review the shipments for those products you manufacturer. To your knowledge, do the estimates appear reasonable?

4.2 Do you expect to see any migration to other power sources or substitute products in any of the product classes or applications above?

4.3 Would amended energy conservation standards impact the sales of more efficient products in any way? For example, would customers continue to buy products that exceed the energy conservation standard level? Would your response change for higher mandated efficiency levels?

4.4 DOE assumed that revised standards that increase the product's purchase price—across the industry (not just one manufacturer)—do not result in reduced demand or shipments (price inelasticity). Do you agree with this assumption? If not, how sensitive do you think shipments will be to price changes?

4.5 Do you expect any other characteristics of EPSs to change in response to the standards? If so, how?

4-5 FINANCIAL PARAMETERS

To assess the financial impacts of energy conservation standards on manufacturers of covered EPSs, Navigant Consulting built a "strawman" cash flow model called the Government Regulatory Impact Model (GRIM). However, available public information might not be reflective of your financial performance at the profit center level. At this time DOE's estimates are limited to much broader corporate settings. This section attempts to understand the financial parameters for your company (or division) and how those figures may differ from an industry aggregate picture.

5.1 In order for DOE to accurately collect information about EPS manufacturing, please compare your financial parameters to the GRIM parameters tabulated below.

Table A.4-4 Financial Parameters for EPS Manufacturers

GRIM Input	Definition	Industry Estimated Value	Your Actual (If Significantly Different from DOE's Estimate)
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	27.6%	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	7.0%	
Working Capital	Current assets less current liabilities (percentage of revenues)	8.3%	
Net PPE	Net plant property and equipment (percentage of revenues)	14.6%	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	19.4%	
R&D	Research and development expenses (percentage of revenues)	3.8%	
Depreciation	Amortization of fixed assets (percentage of revenues)	3.7%	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	4.2%	
Cost of Goods Sold	Includes material, labor, overhead, and depreciation (percentage of revenues)	73.8%	

5.2 Do any of the financial parameters in Table A.4-4 change significantly based on EPS product class or the application for which it is produced? Please describe any differences.

5.3 Would you expect any of the financial parameters in Table A.4-4 to change for a particular subgroup of manufacturers? Please describe any differences.

4-6 CONVERSION COSTS

DOE understands that amended energy conservation standards may cause your company to incur capital and product conversion costs to redesign existing products and make changes to existing production lines. Understanding the nature and magnitude of the conversion costs is a critical portion of the MIA. Depending on their magnitude, the conversion costs can have a substantial impact on the outputs used by DOE to evaluate the industry impacts. The MIA considers three types of conversion costs:

- *Capital conversion costs* are one-time investments in plant, property, and equipment (PPE) necessitated by an amended energy conservation standard. These may be incremental additions to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- *Product conversion costs* are costs related to research, product development, testing, marketing and other costs for redesigning products necessitated by an amended energy conservation standard.

- *Standard assets* are assets that new standards would render obsolete before the end of their useful life.

Table A.4-5 through Table A.4-8 show the efficiency levels for the four representative units of product class A1—AC-DC Conversion, Basic Voltage Output. DOE asks a number of questions to understand the nature and magnitude of your expected capital and product conversion costs.

6.1 In the tables below, for each product class, please provide estimates for your product and capital conversion costs. In the description column, DOE is interested in understanding the kinds of changes that would need to be implemented to production lines and production facilities at each efficiency level.

Table A.4-5 Conversion Costs for Product Class A1, Rep Unit 1 (Mobile Phone)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.4-6 Conversion Costs for Product Class A1, Rep Unit 2 (Modem)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.4-7 Conversion Costs for Product Class A1, Rep Unit 3 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.4-8 Conversion Costs for Product Class A1, Rep Unit 4 (Laptop Computer)

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	85.0%	87.0%	88.0%	88.4%	91.7%
No Load Power [W]:	0.500	0.500	0.230	0.210	0.165
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.4-9 Conversion Costs for Product Medical EPS Class M1 18-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	76.0%	80.3%	83.0%	85.4%	87.3%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

Table A.4-10 Conversion Costs for MADB Product Class B1 2.5-Watt Rep. Unit

	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4
Efficiency [%]:	58.3%	67.9%	70.9%	73.2%	73.9%
No Load Power [W]:	0.500	0.300	0.200	0.100	0.062
CSL Description:	EISA	Energy Star 2.0	Intermediate	Best in Market	Max Tech
Product Conversion Costs ($)	NA				
Capital Conversion Costs ($)	NA				
Stranded Assets ($)	NA				
Description	NA				

6.2 At your manufacturing facilities, would these design options be difficult to implement? If so, would your company modify the existing facility or develop a new facility?

6.3 Are there certain design options that would require relatively minor changes to existing products? Are there certain efficiency levels where the capital or product conversion costs significantly increase over the previous efficiency levels? Would your answer change for different product classes? Please describe these changes qualitatively.

6.4 For each of the product classes shown in the tables above, which CSLs could be made within existing product designs and which would result in major product redesigns?

6.5 Would you expect similar conversion costs for non-representative product classes?

4-7 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from the overlapping effects of new or revised DOE standards and/or other regulatory actions affecting the same product or industry.

7.1 Below is a list of regulations that could affect manufacturers of covered EPSs. Please provide any comments on the listed regulations and provide an estimate for your expected compliance cost.

Table A.4-11 Other Regulations Identified by DOE

Regulation	Estimated or Actual Effective Date(s)	Expected Expense for Compliance	Comments
DOE’s Energy Conservation Standards for Battery Chargers			
FDA Approval for Medical Device Design Changes			

7.2 Are there any other recent or impending regulations that manufacturers of EPSs face (from DOE or otherwise)? If so, please identify the regulation, the corresponding effective dates, and your expected compliance cost.

7.3 Under what circumstances would you be able to coordinate any expenditures related to these other regulations with an amended energy conservation standard?

7.4 DOE research has not identified any production tax credits for manufacturers of EPSs. Do you know of any current or future tax credits or other benefits available to your company for manufacturing more efficient EPSs? If so, please describe.

4-8 DIRECT EMPLOYMENT IMPACT ASSESSMENT

The impact of amended energy conservation standards on employment is an important consideration in the rulemaking process. This section of the interview guide seeks to explore current trends in industry employment and solicit manufacturer views on how domestic employment patterns might be affected by amended energy conservation standards.

8.1 Where are your facilities that produce covered products for the United States and what types of products are manufactured at each location? Please provide annual shipment figures for your company’s EPS products at each location by product class. Please also provide employment levels at each of these facilities.

Table A.4-12 EPS Manufacturing Facilities

Facility	**Location**	**Product Types Manufactured**	**Employees**	**Annual Shipments**
Example	*Jackson, MS*	*PC 1, PC 8*	*650*	*300,000 for PC 1,* *200,000 for PC 8*
1				
2				
3				
4				
5				

8.2 Would your domestic employment levels be expected to change significantly under amended energy conservation standards? If so, please explain how and why they would change if higher efficiency levels are required.

8.3 Would the workforce skills necessary under amended energy conservation standards require extensive retraining or replacement of employees at your manufacturing facilities?

8.4 Would amended energy conservation standards require extensive retraining of your service/field technicians? If so, could you expand on how your service infrastructure would be impacted in general as a result of amended energy conservation standards?

4-9 MANUFACTURING CAPACITY AND NON-US SALES

9.1 How long is a typical design cycle for your products covered by this rulemaking?

9.2 How would amended energy conservation standards impact your company's manufacturing capacity?

9.3 For any design changes that would require new production equipment, please describe how much downtime would be required, if any.

9.4 Are there any design changes that could not be implemented before the compliance date of the final rule (2013)?

9.5 What percentage of your EPSs are *produced* in the United States? What percentage of these are exported, if any?

9.6 What percentage of your covered EPSs are *sold* within the United States?

9.7 Are there any foreign companies in this industry with production facilities based in the United States?

9.8 Would amended energy conservation standards impact your domestic vs. foreign manufacturing or sourcing decisions?

4-10 IMPACT ON COMPETITION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that would result from an amended energy conservation standard.

10.1 How would industry competition change as a result of amended energy conservation standards? How would amended energy conservation standards affect *your* ability to compete in the marketplace? Would the effects on your company be different than others in the industry?

10.2 Do any firms hold intellectual property that would yield them a competitive advantage following amended energy conservation standards?

4-11 IMPACTS ON SMALL BUSINESS

11.1 The Small Business Administration (SBA) denotes a small business in the EPS manufacturing industry as having less than 750 total employees, including the parent company and all subsidiaries.[7] By this definition, is your company considered a small business?

11.2 Are there any reasons that a small business manufacturer might be at a disadvantage

---

[7] DOE uses the small business size standards published on August 22, 2008, as amended, by the SBA to determine whether a company is a small business. To be categorized as a small business, a power, distribution, and specialty transformer manufacturer and its affiliates may employ a maximum of 750 employees. The 750 employee threshold includes all employees in a business's parent company and any other subsidiaries.

relative to a larger business under amended energy conservation standards? Please consider such factors as technical expertise, access to capital, bulk purchasing power for materials/components, engineering resources, and any other relevant issues.

11.3 To your knowledge, are there any small businesses for which the adoption of amended energy conservation standards would have a particularly severe impact?

11.4 To your knowledge, are there any niche manufacturers or component manufacturers for which the adoption of amended energy conservation standards would have a particularly severe impact? If so, why?

APPENDIX 12B INDUSTRY NET PRESENT VALUE RESULTS FOR PRICE ELASTICITY SHIPMENT SENSITIVITY SCENARIO

TABLE OF CONTENTS

LIST OF TABLES

12B.1 INTRODUCTION

The purpose of this appendix is to display the impacts on industry net present value (INPV) of battery charger (BC) application manufacturers when a price elasticity shipment sensitivity scenario is included. The price elasticity shipment sensitivity scenario is implemented in the national impact analysis (NIA) using incremental higher prices for BCs due to new energy conservation standards that affect the total shipments of BC applications in the standards case. In the price elasticity shipment sensitivity scenario as the price of the application increases at higher efficiency levels, the number of shipments decline with a price elasticity of negative one. For example, if the price of the BC application rises 10% from the base case, due to the increased price of the BC within that application the number of BC application shipments would decline by 10% in the standards case. In this sensitivity scenario less expensive BC applications see a more dramatic decrease in shipments than more expensive BC applications, since the price elasticity is based on the BC application price, not the BC price. This is because a higher cost BC application will experience a smaller percentage increase in the application price compared to a cheaper BC application, assuming the BC price increase is nominally the same for each BC application. For example, a $1000 laptop is less affected by a $1 increase in the price of the BC than a $10 power tool is with the same $1 increase in the price of the BC. DOE describes how the price elasticity shipment sensitivity scenario is applied to the shipment analysis in appendix 9A of the technical support document (TSD).

12B.2 IMPACTS ON INDUSTRY NET PRESENT VALUE UNDER THE PRICE ELASTICITY SHIPMENT SENSITIVITY SCENARIO

DOE used the same methodology described in chapter 12 of the TSD to develop INPV results when the price elasticity shipment sensitivity scenario is included. As in chapter 12 of the TSD, DOE presents results for all markup scenarios by product class groups. The INPV results with the price elasticity shipment sensitivity scenario included are presented below in Table B-1 through Table B-21.

Product Class 1

Table B-1 Product Class 1 Net Present Value for BC (Flat Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*2010$ Millions*	491	491	489	495
Change in INPV	*2010$ Millions*	-	(0)	(2)	4
	(%)	-	-0.1%	-0.4%	0.9%

Table B-2 Product Class 1 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	491	478	458	308
Change in INPV	*2010$ Millions*	-	(13)	(33)	(183)
	(%)	-	-2.7%	-6.8%	-37.2%

Table B-3 Product Class 1 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	491	449	388	60
Change in INPV	*2010$ Millions*	-	(42)	(103)	(431)
	(%)	-	-8.5%	-21.0%	-87.7%

Product Classes 2, 3, and 4

Table B-4 Product Classes 2, 3, and 4 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	44,483	44,480	44,478	44,277	44,035
Change in INPV	*2010$ Millions*	-	(3)	(5)	(206)	(448)
	(%)	-	0.0%	0.0%	-0.5%	-1.0%

Table B-5 Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	44,259	42,657	42,234	40,263	38,145
Change in INPV	*2010$ Millions*	-	(1,602)	(2,025)	(3,996)	(6,113)
	(%)	-	-3.6%	-4.6%	-9.0%	-13.8%

Table B-6 Product Classes 2, 3, and 4 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	43,799	38,896	37,664	32,688	29,081
Change in INPV	*2010$ Millions*	-	(4,903)	(6,135)	(11,111)	(14,718)
	(%)	-	-11.2%	-14.0%	-25.4%	-33.6%

Product Classes 2, 3, and 4 Results by Industry Group

Consumer Electronics

Table B-7 Consumer Electronics in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	41,885	40,664	40,257	38,665	36,922
Change in INPV	*2010$ Millions*	-	(1,221)	(1,629)	(3,221)	(4,964)
	(%)	-	-2.9%	-3.9%	-7.7%	-11.9%

Power Tools

Table B-8 Power Tools in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	1,814	1,558	1,551	1,293	1,025
Change in INPV	*2010$ Millions*	-	(255)	(262)	(521)	(788)
	(%)	-	-14.1%	-14.5%	-28.7%	-43.5%

Small Appliances

Table B-9 Small Appliances in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	560	434	426	306	198
Change in INPV	*2010$ Millions*	-	(125)	(134)	(254)	(362)
	(%)	-	-22.4%	-24.0%	-45.4%	-64.6%

Product Classes 5 and 6

Table B-10 Product Classes 5 and 6 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	1,583	1,583	1,543	1,139
Change in INPV	*2010$ Millions*	-	(0)	(40)	(444)
	(%)	-	0.0%	-2.5%	-28.0%

Table B-11 Product Classes 5 and 6 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	1,549	1,277	1,324	832
Change in INPV	*2010$ Millions*	-	(272)	(225)	(717)
	(%)	-	-17.5%	-14.5%	-46.3%

Table B-12 Product Classes 5 and 6 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	1,552	1,222	1,429	561
Change in INPV	*2010$ Millions*	-	(330)	(123)	(990)
	(%)	-	-21.3%	-7.9%	-63.8%

Product Class 7

Table B-13 Product Class 7 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	2
INPV	*2010$ Millions*	1,034	1,030	1,028
Change in INPV	*2010$ Millions*	-	(4)	(6)
	(%)	-	-0.4%	-0.6%

Table B-14 Product Class 7 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	2
INPV	*2010$ Millions*	1,036	1,050	975
Change in INPV	*2010$ Millions*	-	14	(61)
	(%)	-	1.4%	-5.8%

Table B-15 Product Class 7 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	2
INPV	*2010$ Millions*	1,039	1,086	879
Change in INPV	*2010$ Millions*	-	47	(159)
	(%)	-	4.5%	-15.3%

Product Class 8

Table B-16 Product Class 8 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	5,702	5,627	5,705	5,491
Change in INPV	*2010$ Millions*	-	(75)	4	(211)
	(%)	-	-1.3%	0.1%	-3.7%

Table B-17 Product Class 8 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	5,702	6,062	5,729	5,482
Change in INPV	*2010$ Millions*	-	361	27	(220)
	(%)	-	6.3%	0.5%	-3.9%

Table B-18 Product Class 8 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	5,702	7,001	5,780	5,462
Change in INPV	*2010$ Millions*	-	1,299	78	(240)
	(%)	-	22.8%	1.4%	-4.2%

Product Class 10

Table B-19 Product Class 10 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	614	614	612	609
Change in INPV	*2010$ Millions*	-	(1)	(2)	(6)
	(%)	-	-0.1%	-0.4%	-0.9%

Table B-20 Product Class 10 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	614	592	586	577
Change in INPV	*2010$ Millions*	-	(21)	(28)	(37)
	(%)	-	-3.5%	-4.5%	-6.0%

Table B-21 Product Class 10 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	612	532	512	487
Change in INPV	*2010$ Millions*	-	(80)	(100)	(125)
	(%)	-	-13.1%	-16.3%	-20.4%

APPENDIX 12C GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

TABLE OF CONTENTS

12C.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards and other regulations on manufacturers. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the base case) and under different trial standard levels (TSLs) (*i.e.*, the standards case).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12C.2 EXTERNAL POWER SUPPLY MODEL DESCRIPTION

DOE analyzed the impacts of standards on the external power supply (EPS) original device manufacturers (ODMs). The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. The line items below relate to the EPS ODMs and are definitions of listed items on the printout of the output sheet (see section 12C.3).

Unit Sales: Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

Revenues: Annual revenues - computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup;

Labor: The portion of cost of goods sold (COGS) that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time;

Material: The portion of COGS that includes materials;

Overhead: The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, depreciation, property taxes, and insurance related to assets. While included in overhead, the depreciation is shown as a separate line item;

Depreciation: The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Annual depreciation computed as a percentage of COGS. While included in overhead, the depreciation is shown as a separate line item;

Stranded Assets: In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for;

Standard SG&A: Selling, general, and administrative costs are computed as a percentage of ***Revenues (2)***;

R&D: GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (2)***;

Product Conversion Costs: Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making products designs comply with the amended energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Earnings Before Interest and Taxes (EBIT): Includes profits before deductions for interest paid and taxes;

EBIT as a Percentage of Sales (EBIT/Revenues): GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

Taxes: Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in Major Assumptions by ***EBIT (11)***.

Net Operating Profits After Taxes (NOPAT): Computed by subtracting Cost of Goods Sold ((3) to (6)), SG&A (8), R&D (9), Product Conversion Costs (10), and Taxes (13) from Revenues (2).

NOPAT repeated: NOPAT is repeated in the Statement of Cash Flows;

Depreciation repeated: Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they are non-cash expenses;

Change in Working Capital: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

Cash Flow From Operations: Calculated by taking ***NOPAT (15)***, adding back non-cash items such as Depreciation ***(16)***, and subtracting the ***Change in Working Capital (17)***;

Ordinary Capital Expenditures: Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (2)***;

Capital Conversion Costs: Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation; the GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Capital Investment: Total investments in property, plant, and equipment are computed by adding ***Ordinary Capital Expenditures (19)*** and ***Capital Conversion Costs (20)***;

Free Cash Flow: Annual cash flow from operations and investments; computed by subtracting ***Capital Investment (21)*** from ***Cash Flow from Operations (18)***;

Terminal Value: Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at the beginning of 2042 at a constant rate in perpetuity;

Present Value Factor: Factor used to calculate an estimate of the present value of an amount to be received in the future;

Discounted Cash Flow: Free Cash Flows (22) multiplied by the ***Present Value Factor (24)***. For the end of 2042, the discounted cash flow includes the discounted ***Terminal Value (23)***; and

Industry Value thru the end of 2042: The sum of Discounted Cash Flows (25).

12C.3 BATTERY CHARGER MODEL DESCRIPTION

DOE analyzed the impacts of standards on the battery charger (BC) application manufacturers. The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. The line items below relate to the BC application manufacturers unless otherwise stated and are definitions of listed items on the printout of the output sheet (see section 12C.3).

Unit Sales: Total annual shipments for the industry were obtained from the National Impact Analysis Spreadsheet;

Revenues: Annual revenues - computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup;

Cost of Goods Sold (COGS): COGS includes direct labor, materials, overhead, and depreciation.

Stranded Assets: In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for;

Standard SG&A: Selling, general, and administrative costs are computed as a percentage of ***Revenues (2)***;

R&D: GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (2)***;

Product Conversion Costs: Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making products designs comply with the amended energy conservation standard. The GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Earnings Before Interest and Taxes (EBIT): Includes profits before deductions for interest paid and taxes;

EBIT as a Percentage of Sales (EBIT/Revenues): GRIM calculates EBIT as a percentage of sales to compare with the industry's average reported in financial statements;

Taxes: Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in Major Assumptions by ***EBIT (11)***.

Net Operating Profits After Taxes (NOPAT): Computed by subtracting Cost of Goods Sold ((3) to (6)), SG&A (8), R&D (9), Product Conversion Costs (10), and Taxes (13) from Revenues (2).

NOPAT repeated: NOPAT is repeated in the Statement of Cash Flows;

Depreciation: Depreciation only relates to BC application portion of BCs. The portion of overhead that includes an allowance for the total amount of fixed assets used to produce that one unit. Depreciation and Stranded Assets are added back in the Statement of Cash Flows because they are non-cash expenses;

Change in Working Capital: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues.

Cash Flow From Operations: Calculated by taking ***NOPAT (15)***, adding back non-cash items such as Depreciation ***(16)***, and subtracting the ***Change in Working Capital (17)***;

Ordinary Capital Expenditures: Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (2)***;

Capital Conversion Costs: Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under the new regulation; the GRIM allocates these costs over the period between the standard's announcement and compliance dates;

Total Capital Investment: Total investments in property, plant, and equipment are computed by adding ***Ordinary Capital Expenditures (19)*** and ***Capital Conversion Costs (20)***;

Free Cash Flow: Annual cash flow from operations and investments; computed by subtracting ***Capital Investment (21)*** from ***Cash Flow from Operations (18)***;

Terminal Value: Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at the beginning of 2042 at a constant rate in perpetuity;

Present Value Factor: Factor used to calculate an estimate of the present value of an amount to be received in the future;

Discounted Cash Flow: Free Cash Flows (22) multiplied by the ***Present Value Factor (24)***. For the end of 2042, the discounted cash flow includes the discounted ***Terminal Value (23)***; and

Industry Value thru the end of 2042: The sum of Discounted Cash Flows (25).

12C.4 EXTERNAL POWER SUPPLY DETAILED CASH FLOW EXAMPLE

Standard Case Income and Cash Flow Statements

This tab computes key parameters from an income statement based on unit sales, revenues and COGS, and initial financial inputs (parameters as a % of revenue). It also computes an INPV based on a discounted cash flow model.

STANDARD CASE SCENARIO					Base Year		Standard Year							
			2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Industry Income Statement													
Unit Sales			270.1	272.1	274.1	276.2	278.3	280.4	282.5	284.6	286.7	288.9	291.0	293.2
Revenues			917.0	926.1	935.3	944.5	1,104.3	1,112.6	1,120.9	1,129.3	1,137.8	1,146.3	1,154.9	1,163.6
Cost of Sales														
	Labor	6.1%	56.3	56.9	57.4	58.0	67.8	68.3	68.8	69.3	69.9	70.4	70.9	71.4
	Material	60.7%	556.9	562.4	568.0	573.6	670.6	675.6	680.7	685.8	690.9	696.1	701.4	706.6
	Overhead	3.2%	29.7	30.0	30.2	30.5	35.7	36.0	36.3	36.5	36.8	37.1	37.4	37.6
	Depreciation	3.7%	33.9	34.3	34.6	34.9	40.9	41.2	41.5	41.8	42.1	42.4	42.7	43.1
	Stranded Assets		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Selling, General and Administrative														
	Standard SG&A		$ 177.9	$ 179.7	$ 181.4	$ 183.2	$ 214.2	$ 215.8	$ 217.5	$ 219.1	$ 220.7	$ 222.4	$ 224.1	$ 225.7
	R&D	3.8%	$ 34.8	$ 35.2	$ 35.5	$ 35.9	$ 42.0	$ 42.3	$ 42.6	$ 42.9	$ 43.2	$ 43.6	$ 43.9	$ 44.2
	Product Conversion Costs		$ -	$ -	$ 22.3	$ 18.2	$ 0.8	$ -	$ -	$ -	$ -	$ -	$ -	$ -
							$ 4.562							
Earnings Before Interest and Taxes (EBIT)		2.9%	$ 27.5	$ 27.8	$ 5.8	$ 10.1	$ 32.293	$ 33.4	$ 33.6	$ 33.9	$ 34.1	$ 34.4	$ 34.6	$ 34.9
EBIT/Revenues			3.0%	3.0%	0.6%	1.1%	2.9%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Taxes			$ 6.4	$ 6.5	$ 1.3	$ 2.4	$ 7.6	$ 7.8	$ 7.9	$ 7.9	$ 8.0	$ 8.0	$ 8.1	$ 8.2
Net Operating Profit after Taxes (NOPAT)			$ 21.1	$ 21.3	$ 4.4	$ 7.7	$ 24.7	$ 25.6	$ 25.8	$ 25.9	$ 26.1	$ 26.3	$ 26.5	$ 26.7
	Cash Flow Statement													
	NOPAT		$ 21.1	$ 21.3	$ 4.4	$ 7.7	$ 24.7	$ 25.6	$ 25.8	$ 25.9	$ 26.1	$ 26.3	$ 26.5	$ 26.7
	Depreciation		$ 33.9	$ 34.3	$ 34.6	$ 34.9	$ 40.9	$ 41.2	$ 41.5	$ 41.8	$ 42.1	$ 42.4	$ 42.7	$ 43.1
	Change in Working Capital		$ -	$ (0.8)	$ (0.8)	$ (0.8)	$ (13.3)	$ (0.7)	$ (0.7)	$ (0.7)	$ (0.7)	$ (0.7)	$ (0.7)	$ (0.7)
Cash Flows from Operations			$ 55.0	$ 54.8	$ 38.2	$ 41.9	$ 52.3	$ 66.0	$ 66.5	$ 67.0	$ 67.5	$ 68.0	$ 68.6	$ 69.1
	Ordinary Capital Expenditures	4.2%	$ (38.5)	$ (38.9)	$ (39.3)	$ (39.7)	$ (46.4)	$ (46.7)	$ (47.1)	$ (47.4)	$ (47.8)	$ (48.1)	$ (48.5)	$ (48.9)
	Capital Conversion Costs		$ -	$ -	$ (25.1)	$ (20.6)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Investments			$ (38.5)	$ (38.9)	$ (64.4)	$ (60.2)	$ (46.4)	$ (46.7)	$ (47.1)	$ (47.4)	$ (47.8)	$ (48.1)	$ (48.5)	$ (48.9)
Free Cash Flow			$ 16.5	$ 15.9	$ (26.2)	$ (18.3)	$ 6.0	$ 19.3	$ 19.5	$ 19.6	$ 19.7	$ 19.9	$ 20.0	$ 20.2
Terminal Value			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor			0.00	0.00	1.00	0.93	0.87	0.81	0.76	0.71	0.66	0.62	0.58	0.54
Discounted Cash Flow			$ -	$ -	$ (26.2)	$ (17.1)	$ 5.2	$ 15.7	$ 14.8	$ 13.9	$ 13.1	$ 12.3	$ 11.6	$ 10.9
Industry Value thru	2042	$ 229.0												

12C.5 BATTERY CHARGER DETAILED CASH FLOW EXAMPLE

Standard Case Income and Cash Flow Statements

This tab computes key parameters from an income statement based on unit sales, revenues and COGS, and initial financial inputs (parameters as a % of revenue). It also computes an INPV based on a discounted cash flow model.

STANDARD CASE SCENARIO		2009	2010	Base Year 2011	2012	Standard Year 2013	2014	2015	2016	2017	2018	2019	2020
Industry Income Statement													
Unit Sales		$ 427	$ 430	$ 433	$ 437	$ 440	$ 443	$ 447	$ 450	$ 453	$ 457	$ 460	$ 464
Revenues		$ 65,366	$ 65,857	$ 66,351	$ 66,848	$ 67,946	$ 68,456	$ 68,969	$ 69,486	$ 70,007	$ 70,532	$ 71,061	$ 71,594
							68.18%						
Cost of Sales													
COGS		$ 44,574	$ 44,908	$ 45,245	$ 45,584	$ 46,324	$ 46,672	$ 47,022	$ 47,374	$ 47,730	$ 48,088	$ 48,448	$ 48,812
% of Revenue		68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%	68.2%
Stranded Assets		$ -	$ -	$ -	$ -	$ 11	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Selling, General and Administrative													
Standard SG&A	17.9%	$ 11,724	$ 11,812	$ 11,901	$ 11,990	$ 12,189	$ 12,281	$ 12,373	$ 12,466	$ 12,559	$ 12,653	$ 12,748	$ 12,844
R&D	5.5%	$ 3,597	$ 3,624	$ 3,651	$ 3,678	$ 3,736	$ 3,764	$ 3,792	$ 3,820	$ 3,849	$ 3,878	$ 3,907	$ 3,936
Product Conversion Costs		$ -	$ -	$ 49	$ 40	$ 2	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)		$ 5,472	$ 5,513	$ 5,505	$ 5,556	$ 5,684	$ 5,739	$ 5,782	$ 5,826	$ 5,870	$ 5,914	$ 5,958	$ 6,003
% of Revenue		8.4%	8.4%	8.3%	8.3%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%	8.4%
Taxes		$ 1,549	$ 1,560	$ 1,572	$ 1,584	$ 1,612	$ 1,624	$ 1,636	$ 1,648	$ 1,661	$ 1,673	$ 1,686	$ 1,698
Net Operating Profit after Taxes (NOPAT)		$ 3,923	$ 3,952	$ 3,933	$ 3,972	$ 4,072	$ 4,115	$ 4,146	$ 4,177	$ 4,209	$ 4,240	$ 4,272	$ 4,304
% of Revenue		6.0%	6.0%	5.9%	5.9%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
Cash Flow Statement													
NOPAT		$ 3,923	$ 3,952	$ 3,933	$ 3,972	$ 4,072	$ 4,115	$ 4,146	$ 4,177	$ 4,209	$ 4,240	$ 4,272	$ 4,304
Depreciation		$ 2,176	$ 2,192	$ 2,209	$ 2,225	$ 2,261	$ 2,278	$ 2,295	$ 2,313	$ 2,330	$ 2,347	$ 2,365	$ 2,383
Change in Worki		$ -	$ 116	$ 117	$ 117	$ 251	$ 120	$ 121	$ 122	$ 123	$ 124	$ 125	$ 126
Cash Flows from Operations		$ 6,099	$ 6,029	$ 6,025	$ 6,080	$ 6,083	$ 6,274	$ 6,321	$ 6,368	$ 6,416	$ 6,464	$ 6,512	$ 6,561
Ordinary Capital Expenditures		$ 1,940	$ 1,954	$ 1,969	$ 1,984	$ 2,017	$ 2,032	$ 2,047	$ 2,062	$ 2,078	$ 2,093	$ 2,109	$ 2,125
Capital Conversion Costs		$ -	$ -	$ 12	$ 10	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Capital Investments		$ 1,940	$ 1,954	$ 1,981	$ 1,993	$ 2,017	$ 2,032	$ 2,047	$ 2,062	$ 2,078	$ 2,093	$ 2,109	$ 2,125
Free Cash Flow		$ 4,159	$ 4,075	$ 4,045	$ 4,086	$ 4,077	$ 4,242	$ 4,274	$ 4,306	$ 4,338	$ 4,371	$ 4,403	$ 4,436
Terminal Value		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor		1.19	1.09	1.00	0.92	0.84	0.77	0.71	0.65	0.59	0.54	0.50	0.46
Discounted Cash Flow		$ 4,951	$ 4,446	$ 4,045	$ 3,746	$ 3,425	$ 3,267	$ 3,017	$ 2,786	$ 2,572	$ 2,376	$ 2,194	$ 2,026
INPV	$ 54,037												

APPENDIX 12D INDUSTRY NET PRESENT VALUE RESULTS FOR THE ALTERNATIVE CALIFORNIA BASE CASE SENSITIVITY SCENARIO

TABLE OF CONTENTS

LIST OF TABLES

12D.1 INTRODUCTION

The purpose of this appendix is to display the impacts on industry net present value (INPV) of battery charger (BC) application manufacturers when all shipments of BCs in the nation are affected by the California Energy Commission (CEC) standards and that all products shipped meet the CEC regulations in the base case. The alternative California base case sensitivity scenario is implemented in the national impact analysis (NIA) using a different efficiency distribution than the reference base case scenario, used in DOE's main analysis presented in the NOPR. In the alternative California base case sensitivity scenario all products sold in the nation are assumed to meet the California standards in the base case. This means that in order for a DOE standard to make any kind of impact on BC manufactures DOE's standards must be higher than the California standards. For example, if the CEC standard for product class 2 is set at CSL 2, if DOE set the national efficiency standard at either CSL 1 or CSL 2, it would not have any additional effect on manufacturers in DOE's standards case, since it is assumed that in the base case all product class 2 BCs already meet CSL 2.

12D.2 IMPACTS ON INDUSTRY NET PRESENT VALUE UNDER THE ALTERNATIVE CALIFORNIA BASE CASE SENSTIVITY SCENARIO

DOE used the same methodology described in chapter 12 of the TSD to develop INPV results when the alternative California base case sensitivity scenario is included. As in chapter 12 of the TSD, DOE presents results for all markup scenarios by product class groups. The INPV results with the alternative California base case sensitivity scenario included are presented below in Table D-1 through Table D-21.

Product Class 1

Table D-1 Product Class 1 Net Present Value for BC (Flat Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*2010$ Millions*	491	492	493	520
Change in INPV	*2010$ Millions*	-	1	1	29
	(%)	-	0.1%	0.3%	5.9%

Table D-2 Product Class 1 Net Present Value for BC (Pass Through Markup Scenario)

	Units	**Base Case**	**Trial Standard Level**		
			1	**2**	**3**
INPV	*2010$ Millions*	491	479	461	318
Change in INPV	*2010$ Millions*	-	(12)	(31)	(173)
	(%)	-	-2.5%	-6.2%	-35.3%

Table D-3 Product Class 1 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	491	450	390	51
Change in INPV	*2010$ Millions*	-	(41)	(101)	(441)
	(%)	-	-8.4%	-20.6%	-89.7%

Product Classes 2, 3, and 4

Table D-4 Product Classes 2, 3, and 4 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	44,729	44,729	44,729	45,020	45,467
Change in INPV	*2010$ Millions*	-	0	0	291	738
	(%)	-	0.0%	0.0%	0.7%	1.6%

Table D-5 Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	41,562	41,562	41,562	40,581	38,721
Change in INPV	*2010$ Millions*	-	0	0	(981)	(2,841)
	(%)	-	0.0%	0.0%	-2.4%	-6.8%

Table D-6 Product Classes 2, 3, and 4 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2010$ Millions*	35,416	35,416	35,416	32,237	28,538
Change in INPV	*2010$ Millions*	-	0	0	(3,179)	(6,878)
	(%)	-	0.0%	0.0%	-9.0%	-19.4%

Product Classes 2, 3, and 4 Results by Industry Group

Consumer Electronics

Table D-7 Consumer Electronics in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	39,885	39,885	39,885	38,962	37,485
Change in INPV	*2010$ Millions*	-	0	0	(923)	(2,400)
	(%)	-	0.0%	0.0%	-2.3%	-6.0%

Power Tools

Table D-8 Power Tools in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	1,337	1,337	1,337	1,328	1,082
Change in INPV	*2010$ Millions*	-	0	0	(10)	(256)
	(%)	-	0.0%	0.0%	-0.7%	-19.1%

Small Appliances

Table D-9 Small Appliances in Product Classes 2, 3, and 4 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level			
			1	2	3	4
INPV	*2010$ Millions*	339	339	339	291	153
Change in INPV	*2010$ Millions*	-	0	0	(49)	(186)
	(%)	-	0.0%	0.0%	-14.3%	-54.8%

Product Classes 5 and 6

Table D-10 Product Classes 5 and 6 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	2	3
INPV	*2010$ Millions*	2,275	2,275	2,275	2,275
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

Table D-11 Product Classes 5 and 6 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	235	235	235	235
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

Table D-12 Product Classes 5 and 6 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	409	409	409	409
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

Product Class 7

Table D-13 Product Class 7 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*2010$ Millions*	1,030	1,030	1,057
Change in INPV	*2010$ Millions*	-	0	27
	(%)	-	0.0%	2.7%

Table D-14 Product Class 7 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*2010$ Millions*	1,052	1,052	1,004
Change in INPV	*2010$ Millions*	-	0	(47)
	(%)	-	0.0%	-4.5%

Table D-15 Product Class 7 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level	
			1	**2**
INPV	*2010$ Millions*	1,091	1,091	908
Change in INPV	*2010$ Millions*	-	0	(183)
	(%)	-	0.0%	-16.8%

Product Class 8

Table D-16 Product Class 8 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	5,703	5,628	5,707	5,672
Change in INPV	*2010$ Millions*	-	(75)	4	(30)
	(%)	-	-1.3%	0.1%	-0.5%

Table D-17 Product Class 8 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	5,703	6,064	5,730	5,663
Change in INPV	*2010$ Millions*	-	361	27	(40)
	(%)	-	6.3%	0.5%	-0.7%

Table D-18 Product Class 8 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	5,703	7,002	5,781	5,642
Change in INPV	*2010$ Millions*	-	1,300	78	(61)
	(%)	-	22.8%	1.4%	-1.1%

Product Class 10

Table D-19 Product Class 10 Net Present Value for BC (Flat Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	609	609	609	609
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

Table D-20 Product Class 10 Net Present Value for BC (Pass Through Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	577	577	577	577
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

Table D-21 Product Class 10 Net Present Value for BC (Constant Price Markup Scenario)

	Units	Base Case	Trial Standard Level		
			1	**2**	**3**
INPV	*2010$ Millions*	487	487	487	487
Change in INPV	*2010$ Millions*	-	0	0	0
	(%)	-	0.0%	0.0%	0.0%

APPENDIX 16-A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 16-A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866[a]

16-A.1 EXECUTIVE SUMMARY

Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

---

[a] Prepared by Interagency Working Group on Social Cost of Carbon, United States Government.
With participation by:
Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 16-A.1.1 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

	Discount Rate			
	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

16-A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. We report estimates of the SCC in dollars per metric ton of carbon dioxide throughout this document.[b]

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms

---

[b] In this document, we present all values of the SCC as the cost per metric ton of CO_2 emissions. Alternatively, one could report the SCC as the cost per metric ton of carbon emissions. The multiplier for translating between mass of CO_2 and the mass of carbon is 3.67 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing carbon dioxide emissions. Under Executive Order 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. Most federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are $5, $21, $35, and $65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020. See section 16-A.5 for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

16-A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing carbon dioxide emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of \$2 per ton of CO_2 and a "global" SCC value of \$33 per ton of CO_2 for 2007 emission reductions (in 2007 dollars), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at \$80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in carbon dioxide emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of \$7 per ton CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of \$0-\$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of \$0 to \$20 per ton CO_2 for 2007 emission reductions (in 2007 dollars). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were \$68 and \$40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (in 2006 dollars for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of \$55, \$33, \$19, \$10, and \$5 per ton of $CO_{2.}$ The \$33 and \$5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The $55 and $10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The $19 value was chosen as a central value between the $5 and $33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

16-A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, the interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable, since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

16-A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[c] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socioeconomic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail

---

[c] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (e.g., Tol 2002a, Tol 2002b, Anthoff et al. 2009, Tol 2009).

here. In a later section, we discuss key gaps in how the models account for various scientific and economic processes (e.g. the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socioeconomic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (e.g. the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

The DICE Model

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric carbon dioxide concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, carbon dioxide emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren et al., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[d]

The PAGE Model

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (i.e., a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2°C for developed countries and 0°C for developing countries for economic impacts, and 0°C for all regions for non-economic impacts), but

---

[d] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20%, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2°C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

The FUND Model

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on the absolute temperature change but also on the rate of temperature change and level of regional income.[e] In the forestry and agricultural sectors, economic damages also depend on CO_2 concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as “big unknowns”: for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, “Exactly what would cause these sorts of changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues.”

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from CO_2 fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of CO_2 fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

---

[e] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren et al., 2006).

Damage Functions

To generate revised SCC values, we rely on the IAM modelers' current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. But given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figures 16A.4.1 and 16A.4.2, using the modeler's default scenarios and mean input assumptions. There are significant differences between the three models both at lower (figure 16A.4.2) and higher (figure 16A.4.1) increases in global-average temperature.

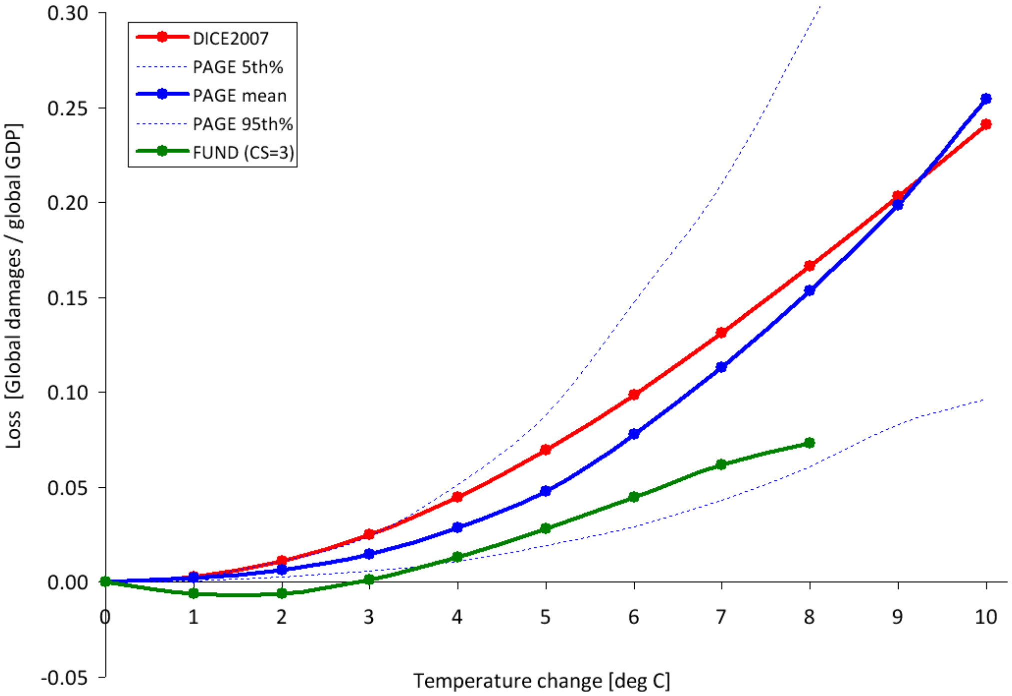


Figure 16-A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE models[f]

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

---

[f] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socioeconomic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figures 1A and 1B are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

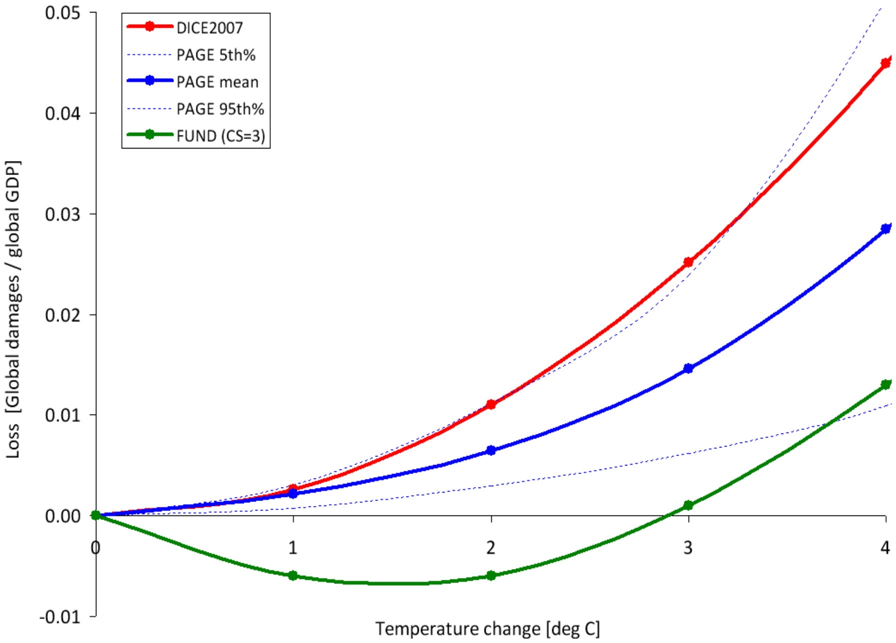


Figure 16-A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

16-A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[g]

Global SCC

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to

---

[g] It is true that federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (e.g., Anthoff, et al. 2009a) employ “equity weighting” to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[h] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

Domestic SCC

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7-10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[i]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no a priori reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not

---

[h] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.

[i] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

account for how damages in other regions could affect the United States (e.g., global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

16-A.4.3 Valuing Non-CO_2 Emissions

While CO_2 is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (i.e., radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, CO_2 emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of CO_2 fertilization. Thus, transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases.

In light of these limitations, and the significant contributions of non-CO_2 emissions to climate change, further research is required to link non-CO_2 emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-CO_2 greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for carbon dioxide emissions.

16-A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[j] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

---

[j] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100-200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (e.g. Hansen et al. 2007).

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

> *Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity', is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.* [k]
>
> *For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally worse for those high values than for values in the 2 °C to 4.5 °C range.* (Meehl et al., 2007, p 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 16A.4.1 included below gives summary statistics for the four calibrated distributions.

Table 16-A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions

	Roe & Baker	Log-normal	Gamma	Weibull
Pr(ECS < 1.5°C)	0.013	0.050	0.070	0.102
Pr(2°C < ECS < 4.5°C)	0.667	0.667	0.667	0.667
5th percentile	1.72	1.49	1.37	1.13
10th percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th percentile	5.86	5.14	4.93	4.69
95th percentile	7.14	5.97	5.59	5.17

Each distribution was calibrated by applying three constraints from the IPCC:

---

[k] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut et al.2007). "Very likely" indicates a greater than 90 percent probability.

(1) a median equal to 3°C, to reflect the judgment of "a most likely value of about 3 °C";[1]
(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0°C or greater than 10°C (see Hegerl et al. 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007, Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5°C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

---

[1] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3°C, rather than the mode or mean, gave a 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3°C produced 95th percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3°C than is the mode for the truncated distributions selected by the IPCC (Hegerl, et al., 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

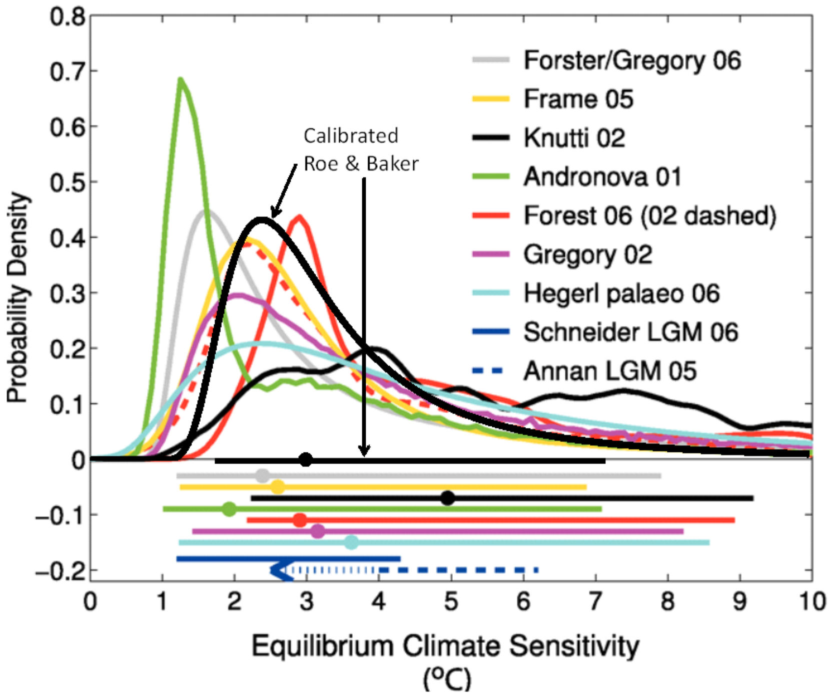


Figure 16-A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 16A.4.3 (above) overlays it on Figure 9.20 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[m]

16-A.4.5 Socioeconomic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socioeconomic and emissions parameters for use in PAGE, DICE, and FUND. Socioeconomic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, CO_2 emissions, and non-CO_2 radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (e.g., SRES 2000,

---

[m] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest et al. (2006; solid line, anthropogenic and natural forcings), Gregory et al. (2002a), Knutti et al. (2002), Frame et al. (2005), and Forster and Gregory (2006). Hegerl et al. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5-95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan et al. 2005; solid, Schneider von Deimling et al. 2006), which are based on models with different structural properties.

CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22. EMF-22 uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socioeconomic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (see Table 16A.4.2 below). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (i.e., CO_2-only concentrations of 425 – 484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[n] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

---

[n] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

Table 16-A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios

Reference Fossil and Industrial CO_2 Emissions ($GtCO_2$/yr)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8

Reference GDP (using market exchange rates in trillion 2005$)[o]

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9

Global Population (billions)

EMF – 22 Based Scenarios	2000	2010	2020	2030	2050	2100
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socioeconomic pathways.

---

[o] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP). PPP takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (e.g., Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (i.e., using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the most likely outcome span a wide range, from the more optimistic (e.g. abundant low-cost, low-carbon energy) to more pessimistic (e.g. constraints on the availability of nuclear and renewables).[p] Second, the socioeconomic trajectories associated with a 550 ppm CO_2e concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (e.g. MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[q] We chose not to include socioeconomic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 Annual Energy Outlook projected that global carbon dioxide emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be $51.8, $71.0 and $93.9 trillion (in 2005 dollars using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use CO_2 emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (e.g. aerosols and other gases). See the Annex for greater detail.

16-A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because carbon dioxide emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and

---

[p] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.

[q] For example, MiniCAM projects if all non-US OECD countries reduce CO_2 emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path CO_2 concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

non-market sectors from an additional unit of carbon dioxide emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, “If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.” For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow et al. (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled “descriptive” and “prescriptive.” The descriptive approach reflects a positive (non-normative) perspective based on observations of people’s actual choices—e.g., savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return “because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use” (Arrow et al. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (e.g., Just et al. 2004). As some have noted, the word “potentially” is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—e.g., how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is “ethically indefensible” to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above) (Arrow et al. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high-cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—

a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (see Lind 1990, Arrow et al 1996, and Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," that is the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[r] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's

---

[r] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.

recommendation to use 3 percent to represent the consumption rate of interest.[s] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes, which yields a real rate of roughly 5 percent.[t]

The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[u] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[v] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta g$, will be equal to the rate of return to capital, i.e., the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors

---

[s] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.

[t] Cambell et al (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950 – 2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20 – 40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

[u] The parameter ρ measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[v] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

articulate whether their choice is based on prescriptive or descriptive reasoning.[w] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, since η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than $\rho = 0$ would unjustly discriminate against future generations (e.g., Arrow et al. 1996, Stern et al. 2006). However, even in an inter-generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern et al. 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socioeconomic scenarios used for this exercise, the EMF models assume that g is about 1.5-2 percent to 2100.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern et al. (2006) applies this perspective through his choice of $\rho = 0.1$ percent per year, $\eta = 1$ and $g = 1.3$ percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[x]

Recently, Stern (2008) revisited the values used in Stern et al. (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with $\eta = 1$). Using Stern's

---

[w] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff, et al. (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

[x] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

assumption that $\rho = 0.1$ percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate of greater than 2 percent.

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

Accounting for Uncertainty in the Discount Rate

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2006) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (e.g., the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (see Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Groom et al. 2006; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Groom et al. (2006), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and the variation in the level of persistence over time.

While Newell and Pizer (2003) and Groom et al (2006) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (e.g., Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[y] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[z]

---

[y] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31 - 75; 2.5 percent for years 76 - 125; 2 percent for years 126 - 200; 1.5 percent for years 201 - 300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.

[z] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value

The Discount Rates Selected for Estimating SCC

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[aa] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

16-A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

---

calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity, utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.

[aa] Calculations done by Pizer et al. using the original simulation program from Newell and Pizer (2003).

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population, and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMs, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

    a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.
    b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.
    c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t.* (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10-year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Annex.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no IAM or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socioeconomic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Annex.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high-temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 16A.5.1, we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

Table 16-A.5.1 Disaggregated Social Cost of CO_2 Values by Model, Socioeconomic Trajectory, and Discount Rate for 2010 (in 2007 dollars)

	Discount rate:	**5%**	**3%**	**2.5%**	**3%**
Model	*Scenario*	Avg	Avg	Avg	95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[bb]

[bb] Nordhaus (2008) runs DICE2007 with $\rho = 1.5$ and $\eta = 2$. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Furthermore, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 16A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

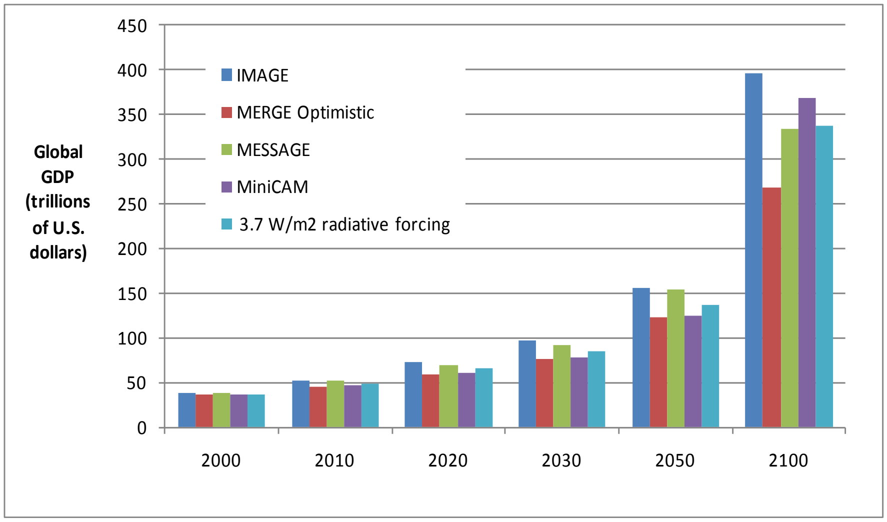


Figure 16-A.5.1 Level of Global GDP across EMF Scenarios

Table 16A.5.2 shows the four selected SCC values in five-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

---

estimates for values of ρ = 0, 1, and 3 in many recent papers (e.g. Anthoff et al. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

Table 16-A.5.2 Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

Discount	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 16A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 16-A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate (%)	**5%** Avg	**3%** Avg	**2.5%** Avg	**3.0%** 95th
2010-2020	3.6%	2.1%	1.7%	2.2%
2020-2030	3.7%	2.2%	1.8%	2.2%
2030-2040	2.7%	1.8%	1.6%	1.8%
2040-2050	2.1%	1.4%	1.1%	1.3%

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—i.e., future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in the year 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[cc]

16-A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are several areas in particular need of additional exploration and research. These caveats, and additional observations in the following section, are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. But it is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold “are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function

---

[cc] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-impact, low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures: The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (e.g., DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change: Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning; so much so, that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[dd] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea, 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs understate or overstate the likely damages.

Risk aversion: A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, but lower-impact, damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not

---

[dd] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

Assuming a risk-neutral representative agent is consistent with OMB’s Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that “emphasis on these expected values is appropriate as long as society is ‘risk neutral’ with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume ‘risk neutrality’ in [their] analysis.”

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff et al (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that “the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon.” Since Circular A-4 allows for a different assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

16-A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models’ functional forms may not adequately capture: (1) potentially discontinuous “tipping point” behavior in Earth systems, (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming, and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

Extrapolation of climate damages to high levels of warming

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic “tipping points” at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (e.g., Lenton et al, 2008, Kriegler et al., 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton et al., 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler et al. (2009); results from this study are highlighted in Table 16A.7.1. Ranges of probability are averaged across core experts on each topic.

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (i.e., ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (see Figure 16A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95th percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socioeconomic and emission trajectories of $113 per ton of CO_2 is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

Table 16-A.7.1 Probabilities of Various Tipping Points from Expert Elicitation

Possible Tipping Points	**Duration before effect is fully realized (in years)**	**Additional Warming by 2100**		
		0.5-1.5 C	**1.5-3.0 C**	**3-5 C**
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0-18%	6-39%	18-67%
Greenland Ice Sheet collapse	at least 300	8-39%	33-73%	67-96%
West Antarctic Ice Sheet collapse	at least 300	5-41%	10-63%	33-88%
Dieback of Amazon rainforest	about 50	2-46%	14-84%	41-94%
Strengthening of El Niño-Southern Oscillation	about 100	1-13%	6-32%	19-49%
Dieback of boreal forests	about 50	13-43%	20-81%	34-91%
Shift in Indian Summer Monsoon	about 1	Not formally assessed		
Release of methane from melting permafrost	Less than 100	Not formally assessed.		

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (that is, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler et al. (2009) estimate a probability of at least 16-36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2-4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

Failure to incorporate inter-sectoral and inter-regional interactions

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (e.g., Campbell et al., 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3-6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling et al., 2007; Campbell et al., 2007).

Imperfect substitutability of environmental amenities

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400-900 miles in the range of plants (Wing et al., 2005), and dwarfing of both land mammals (Gingerich, 2006) and soil fauna (Smith et al., 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy et al., 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace. Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs

(Sterner and Persson, 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

16-A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are \$5, \$21, \$35, and \$65 (in 2007 dollars). The first three estimates are based on the average SCC across models and socioeconomic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to \$24 per ton of CO_2 in 2015 and \$26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

REFERENCES

Andronova, N., and M. Schlesinger. 2001. “Objective estimation of the probability density function for climate sensitivity.” *J. Geophys. Res.*, 106(D19), 22605–22611.

Annan, J., et al., 2005. “Efficiently constraining climate sensitivity with paleoclimate simulations.” *Scientific Online Letters on the Atmosphere*, 1, 181–184.

Anthoff D, C. Hepburn, and R. Tol. 2009a. “Equity Weighting and the Marginal Damage Costs of Climate Change.” *Ecological Economics* 68:836-849.

Anthoff, D., R. Tol, and G. Yohe. 2009b. “Risk aversion, time preference, and the social cost of carbon.” *Environmental Research Letters* 4: 024002 (7pp).

Arrow, K. 2007. “Global climate change: a challenge to policy.” *Economist’s Voice* 4(3):Article 2.

Arrow, K. 2000. “A Comment on Cooper.” *The World Bank Research Observer*. vol 15, no. 2.

Arrow, K., et al. 1996. *Benefit-Cost Analysis in Environmental, Health, and Safety Regulation: A Statement of Principles*. Washington, D.C., AEI Press. pp. 13-14.

Arrow, K.J., et al. 1996. ”Intertemporal equity, discounting and economic efficiency,” in Climate Change 1995: Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the *Second Assessment Report of the Intergovernmental Panel on Climate Change*.

Campbell, J., P. Diamond, and J. Shoven. 2001. “Estimating the Real Rate of Return on Stocks Over the Long Term.” Presented to the Social Security Advisory Board. August.

Campbell, K. et al. 2007. *The age of consequences: The foreign policy and national security implications of global climate change*. Center for Strategic & International Studies, 119 pp.

Castles, I. and D. Henderson. 2003. “The IPCC Emission Scenarios: An Economic-Statistical Critique.” *Energy and Environment* 14(2-3): 159-185.

Chetty, R. 2006. “A New Method of Estimating Risk Aversion.” *American Economic Review* 96(5): 1821–1834.

Dasgupta P. 2006. “Comments on the Stern Review’s economics of climate change.” University of Cambridge working paper.

Dasgupta P. 2008. “Discounting climate change.” *Journal of Risk and Uncertainty* 37:141-169.

Easterling, W., et al. 2007. *Climate Change 2007: Impacts, Adaptation, and Vulnerability*. Intergovernmental Panel on Climate Change, 976 pp.

Evans D., and H. Sezer. 2005. “Social discount rates for member countries of the European Union.” *J. Econ. Stud.* 32 47–59.

Forest, C., et al. 2002. “Quantifying uncertainties in climate system properties with the use of recent observations.” *Science* 295, 113.

Forest, D., P. Stone, and A. Sokolov. 2006. “Estimated PDFs of climate system properties including natural and anthropogenic forcings.” *Geophys. Res. Lett.*, 33, L01705.

Forster, P., and J. Gregory. 2006. “The climate sensitivity and its components diagnosed from Earth radiation budget data.” *J. Clim*., 19, 39–52.

Frame, D., et al. 2005. “Constraining climate forecasts: The role of prior assumptions.” *Geophys. Res. Lett*., 32, L09702.

Gingerich, P. 2006. “Environment and evolution through the Paleocene-Eocene thermal maximum.” *Trends Ecol. Evol.* 21: 246-253.

Gollier, C. 2008. “Discounting with fat-tailed economic growth.” *Journal of Risk and Uncertainty* 37:171-186.

Gollier, C. and M. Weitzman (2009). "How Should the Distant Future be Discounted When Discount Rates are Uncertain?" Harvard University, mimeo, Nov 2009.

Gregory, J., et al. 2002a. “An observationally based estimate of the climate sensitivity.” *J. Clim*., 15(22), 3117–3121.

Groom, B., Koundouri, P., Panipoulou, E., Pantelidis, T. 2006. “An econometric approach to estimating long-run discount rates.” *Journal of Applied Econometrics.*

Hall R, and C. Jones . 2007. “The value of life and the rise in health spending.” Quarterly *Journal of Economics* 122(1):39-72.

Hansen, J.,M. Sato, P. Kharecha, G. Russell, D. W. Lea and M. Siddall. 2007. “Climate change and trace gases.” *Phil. Trans. Roy. Soc. A* 365: 1925-1954.

Hegerl G, et al. 2007. “Understanding and attributing climate change.” in Solomon S, et al. (eds) *Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Hegerl, G., T. Crowley, W. Hyde, and D. Frame. 2006. “Constraints on climate sensitivity from temperature reconstructions of the past seven centuries.” *Nature* 440.

Holtsmark, B., and K. Alfsen. 2005. “PPP Correction of the IPCC Emission Scenarios – Does it Matter?” *Climatic Change* 68(1-2): 11-19.

Hope C. 2006. “The marginal impact of CO2 from PAGE2002: an integrated assessment model incorporating the IPCC’s five reasons for concern.” *The Integrated Assessment Journal* 6(1):19-56.

Hope C. 2008. “Optimal carbon emissions and the social cost of carbon under uncertainty.” *The Integrated Assessment Journal* 8(1):107-122.

Intergovernmental Panel on Climate Change (2007). “Summary for Policymakers.” In *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Just, R., D. Hueth, and A. Schmitz. 2004. *The Welfare Economics of Public Policy*. Glos UK: Edward Elgar Publishing Limited.

Knutti, R., T. Stocker, F. Joos, and G. Plattner. 2002. “Constraints on radiative forcing and future climate change from observations and climate model ensembles.” *Nature*, 416, 719–723.

Kriegler, E. et al. 2009. “Imprecise probability assessment of tipping points in the climate system.” *Proc. Natl. Acad. Sci.* 106: 5041-5046.

Kotlikoff, L. and D. Rapson. 2006. “Does It Pay, at the Margin, to Work and Save? – Measuring Effective Marginal Taxes on Americans’ Labor Supply and Saving.” National Bureau of Economic Research, Working Paper, No. 12533.

Le Treut H., et al. 2007. “Historical Overview of Climate Change.” in Solomon et al., *Climate Change 2007*.

Lenton, T., et al. 2008. “Tipping elements in the Earth’s climate system.” *Proc. Natl. Acad. Sci.* 105: 1786-1793.

Levy, M., et al. 2005. “Ecosystem conditions and human well-being.” In: *Ecosystems and Human Well-being: Current State and Trends, Volume 1*. [R. Hassan, R. Scholes, and N. Ash, eds.] Washington: Island Press. pp. 123-164.

Lind, R. 1990. “Reassessing the Government’s Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility.” *Journal of Environmental Economics and Management* 18, S-8-S-28.

Mastrandre, M. 2009. “Calculating the benefits of climate policy: Examining the assumptions of Integrated Assessment Models.” Pew Center on Global Climate Change Working Paper, 60 pp.

Meehl, G, et al. 2007. “Global Climate Projections.” in Solomon et al., *Climate Change 2007*.

National Research Council (2009). *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. National Academies Press.

Newbold S, Daigneault A. 2009. “Climate response uncertainty and the benefits of greenhouse gas emissions reductions.” *Environmental and Resource Economics* 44:351-377.

Newell, R., and W. Pizer. 2003. Discounting the distant future: how much do uncertain rates increase valuations? *Journal of Environmental Economics and Management* 46: 52-71.

Nordhaus, W. 1994. “Expert Opinion on Climate Change.” *American Scientist* 82: 45-51.

Nordhaus, W. 2007a. *Accompanying notes and documentation on development of DICE-2007 model: notes on DICE-2007.delta.v8 as of September 21, 2007.*

Nordhaus, W. 2007b. “Alternative measures of output in global economic-environmental models: Purchasing power parity or market exchange rates?” *Energy Economics* 29: 349-372.

Nordhaus W. 2008. *A Question of Balance: Weighing the Options on Global Warming Policies*. New Haven, CT: Yale University Press.

Nordhaus, W. 2009. “An Analysis of the Dismal Theorem. Cowles Foundation Discussion Paper. No. 1686. January.

Nordhaus W., and Boyer J. 2000. *Warming the World: Economic Models of Global Warming*. Cambridge, MA: MIT Press.

Pindyck, R. 2009. “Uncertain Outcomes and Climate Change Policy.” NBER Working Paper, No. 15259. August.

Ramsey, F. 1928. “A Mathematical Theory of Saving.” *The Economic Journal* 38(152): 543-559.

Roe, G. 2008. “Feedbacks, timescales, and seeing red.” *Annual Review of Earth and Planetary Sciences* 37:5.1-5.23.

Roe, G., and M. Baker. 2007. “Why is climate sensitivity so unpredictable?” *Science* 318:629-632.

Schneider von Deimling, T., H. Held, A. Ganopolski, and S. Rahmstorf. 2006. “Climate sensitivity estimated from ensemble simulations of glacial climate.” *Clim. Dyn*., 27, 149–163.

Smith, J. et al. 2009. “Transient dwarfism of soil fauna during the Paleocene-Eocene Thermal Maximum.” *Proc. Natl. Acad. Sci.* 106: 17665-17660.

Stern, N., et al. (2006), *Stern Review: The Economics of Climate Change,* HM Treasury, London.

Stern N. 2008. “The economics of climate change.” *American Economic Review* 98(2):1-37.

Sterner, T., and U. Persson. 2008. An even Sterner review: Introducing relative prices into the discounting debate. *Rev. Env. Econ. Pol.* 2: 61-76.

Summers, L., and R. Zeckhauser. 2008. “Policymaking for Prosperity.” Journal of Risk and Uncertainty 37: 115-140.

Szpiro, G. 1986. “Measuring Risk Aversion: An Alternative Approach.” *The Review of Economics and Statistics* 68(1): 156-9.

Tol, R. 2002a. “Estimates of the damage costs of climate change. Part I: benchmark estimates.” *Environmental and Resource Economics* 21:47-73.

Tol, R. 2002b. “Estimates of the damage costs of climate change. Part II: dynamic estimates.” *Environmental and Resource Economics* 21:135-160.

Tol, R. 2006. “Exchange Rates and Climate Change: An Application of FUND.” *Climatic Change* 75(1-2): 59-80.

Tol, R. 2009. “An analysis of mitigation as a response to climate change.” Copenhagen Consensus on Climate. Discussion Paper.

U.S. Department of Defense. 2010. Quadrennial Defense Review Report. February.

Warren, R., et al. 2006. “Spotlight Impact Functions in Integrated Assessment.” Tyndall Center for Climate Change Research, Working Paper 91.

Weitzman, M. 2009. “On modeling and interpreting the economics of catastrophic climate change.” *Review of Economics and Statistics* 91:1-19.

Weitzman, M. 2007. “A review of The Stern Review of the Economics of Climate Change.” *Journal of Economic Literature* 45:703-724.

Weitzman, M. 1999. In Portney P.R. and Weyant J.P. (eds.), *Discounting and Intergenerational Equity*, Resources for the Future, Washington, D.C.

Weitzman, M. 1998. “Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate.” *Journal of Environmental Economics and Management* 36 (3): 201-208.

Wing, S. et al. 2005. “Transient floral change and rapid global warming at the Paleocene-Eocene boundary.” *Science* 310: 993-996.

16-A.9 ANNEX

Table 16-A.9.1 Annual SCC Values: 2010–2050 (in 2007 dollars)

Discount Rate Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300 and shows the full distribution of 2010 SCC estimates by model and scenario combination.

16-A.9.1 Other (non-CO2) gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (e.g., aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[ee] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (e.g., DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

FUND: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_20, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

PAGE: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors[ff], decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_20, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

DICE: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was 0.48 + 0.16 + 0.34 = 0.98 W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be

---

[ee] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial, and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

[ff] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

> (1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter; and
> (2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> *Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulfur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.*[gg]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, the figure below shows that the sulfur dioxide emissions peak over the short term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[hh] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[ii] The lower-bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

[gg] AR4 Synthesis Report, p. 44, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[hh] See Smith, S.J., R. Andres, E. Conception, and J. Lurz, 2004: Historical sulfur dioxide emissions, 1850-2000: methods and results. Joint Global Research Institute, College Park, 14 pp.

[ii] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda, 2002: Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate. Environmental Science and Technology, 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen, 2001: Recent reductions in China's greenhouse gas emissions. Science, 294(5548): 1835-1837.

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

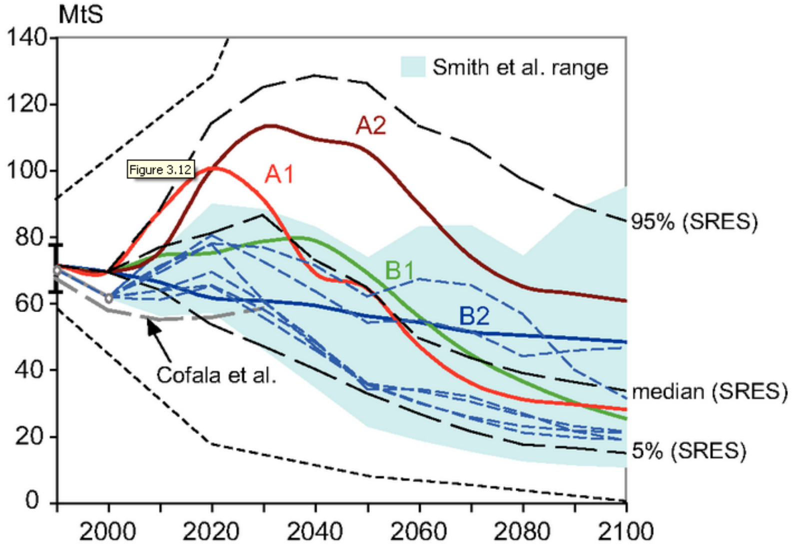


Figure 16-A.9.2 Sulfur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th, and 95th percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith et al. (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2, http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than \$2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6-7 percent (or \$0.50-\$3)–depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

16-A.9.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in the year 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in the year 2300.
3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.
4. Net land use CO_2 emissions decline linearly, reaching zero in the year 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[jj] The resulting range of EMF population trajectories (figure below) also encompass the UN medium scenario forecasts through 2300—global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090-2100 carbon intensity growth rate (i.e., CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori

---

[jj] United Nations. 2004. *World Population to 2300.*
http://www.un.org/esa/population/publications/longrange2/worldpop2300final.pdf

reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

Figures below show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

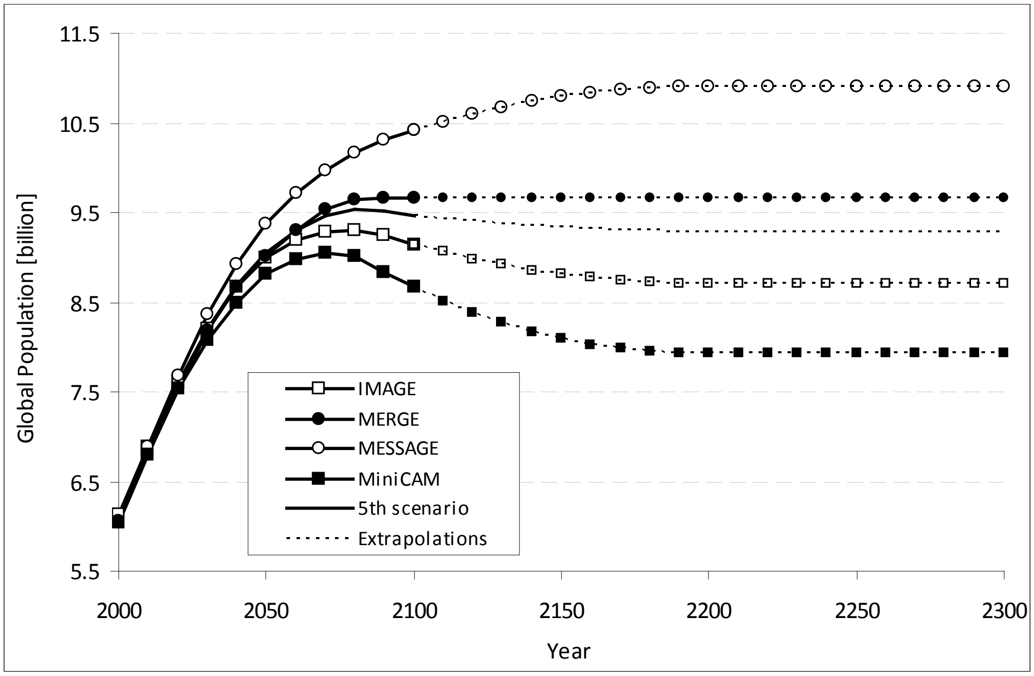


Figure 16-A.9.3 Global Population, 2000-2300 (Post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200.)

Note: In the fifth scenario, 2000-2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

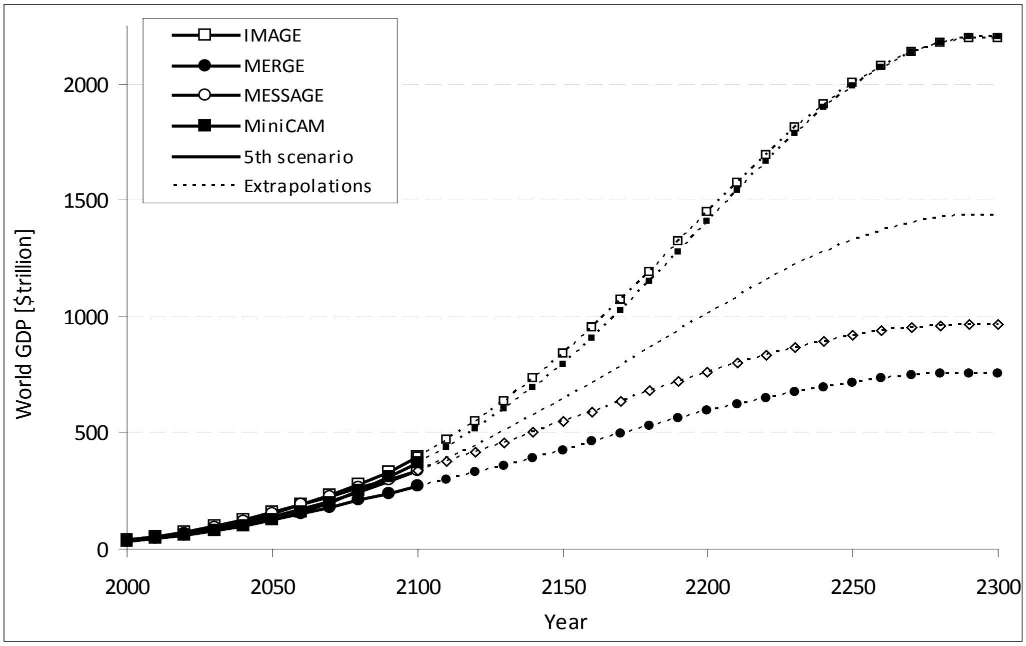


Figure 16-A.9.4 World GDP, 2000-2300 (Post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in the year 2300)

Note: In the fifth scenario, 2000-2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

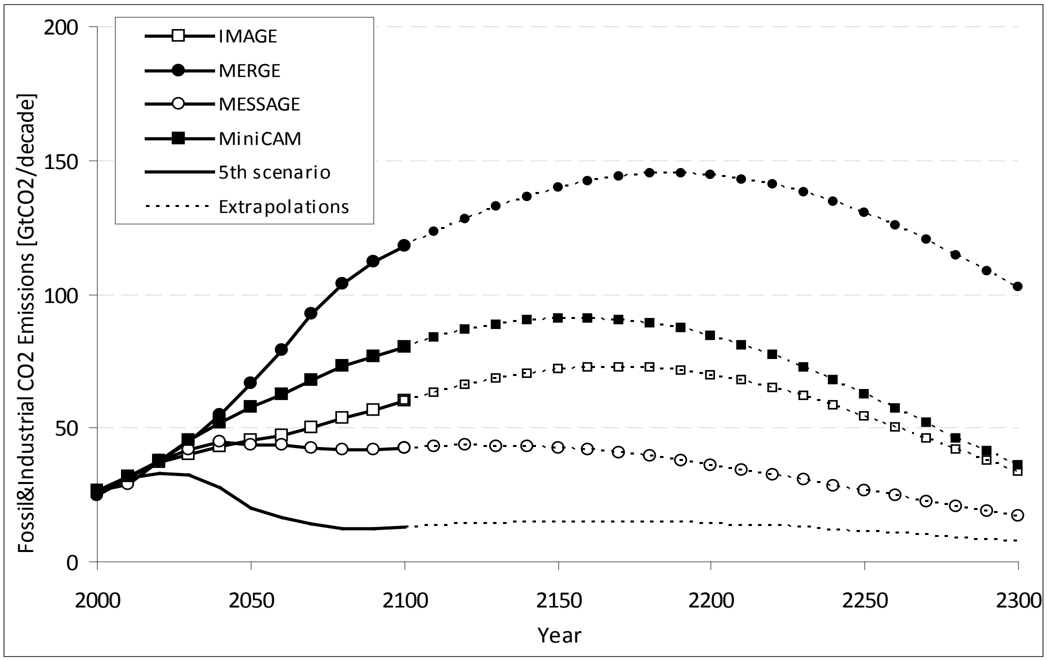


Figure 16-A.9.5 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090-2100 is maintained through 2300)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

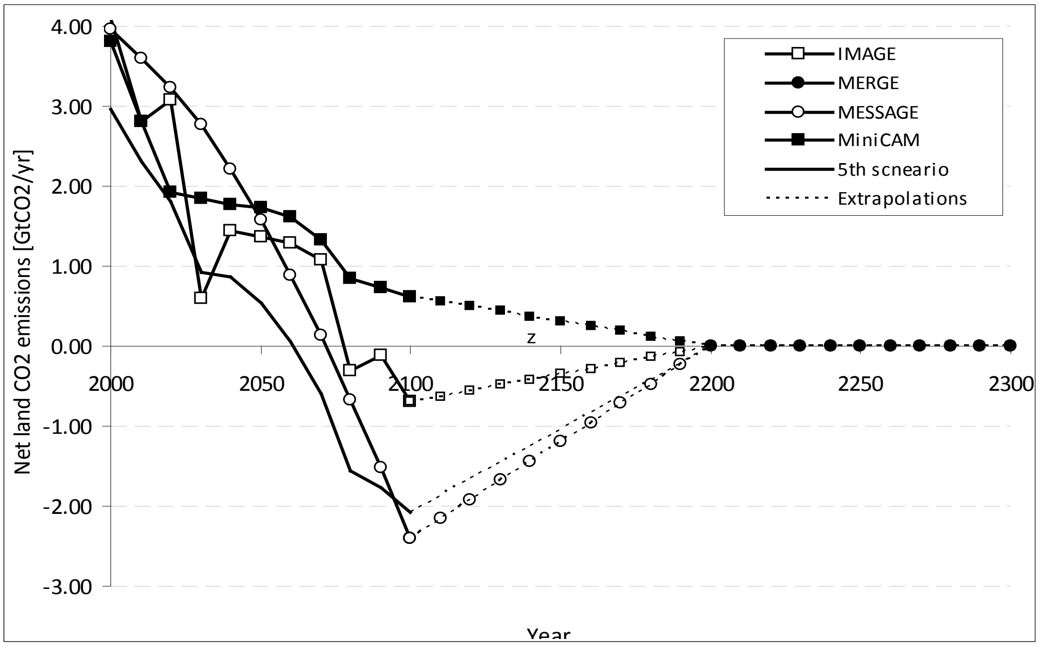


Figure 16-A.9.6 Global Net Land Use CO_2 Emissions, 2000-2300 (Post-2100 extrapolations assume emissions decline linearly, reaching zero in the year 2200)[kk]

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[kk] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (i.e., we add up the land use emissions from the other three models and divide by 4).

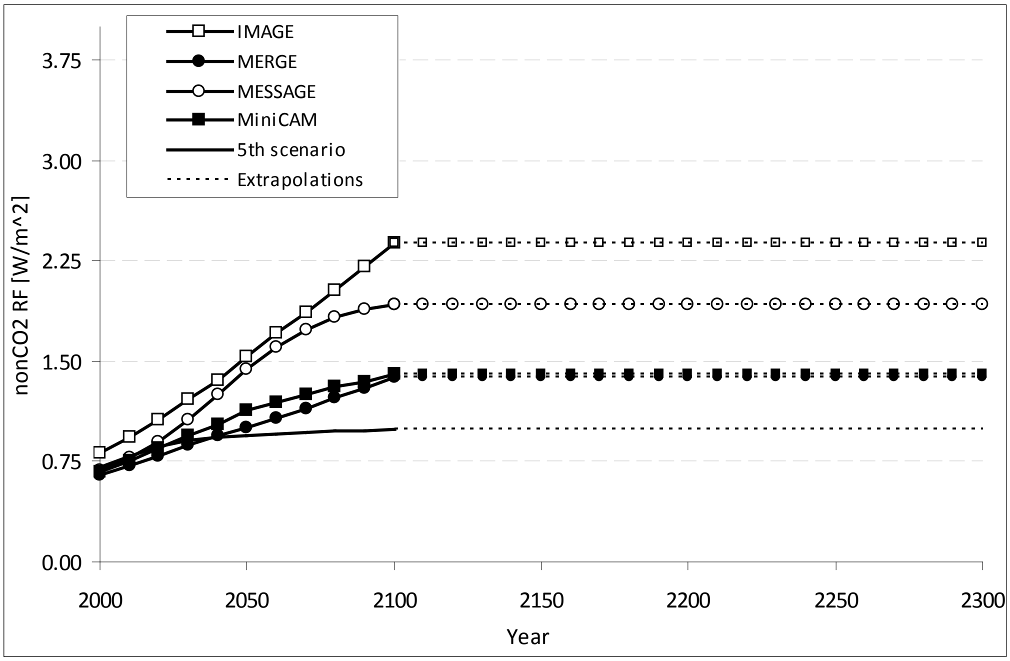


Figure 16-A.9.7 Global Non-CO_2 Radiative Forcing, 2000-2300 (Post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

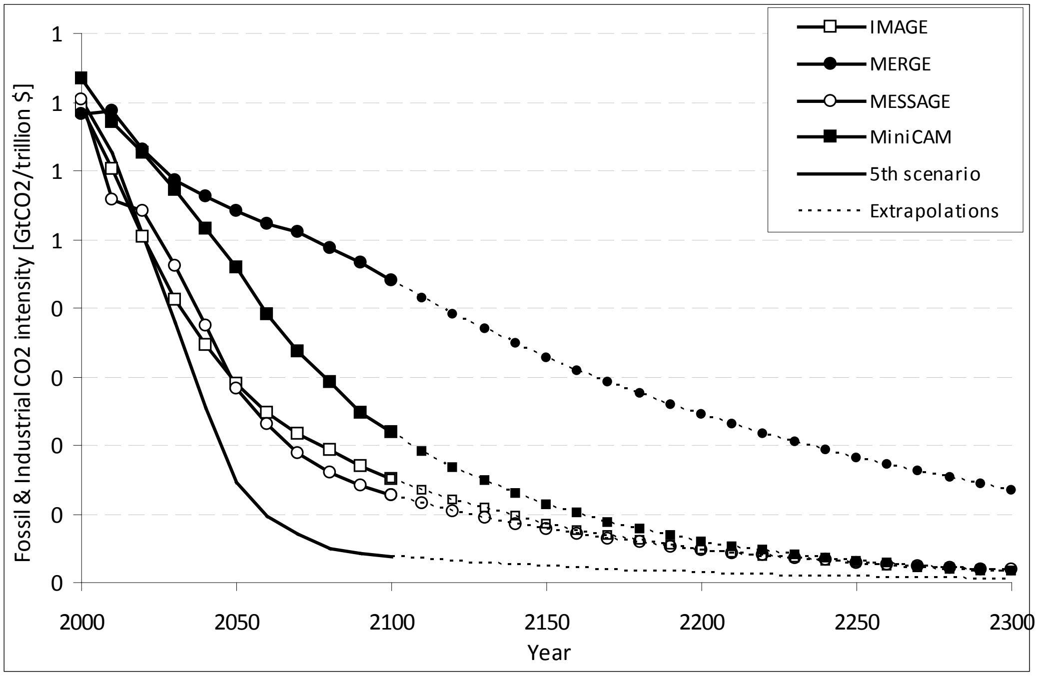


Figure 16-A.9.8 **Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000-2300 (Post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090-2100 is maintained through 2300)**

Note: In the fifth scenario, 2000-2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 16-A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	3.3	5.9	8.1	13.9	28.8	65.5	68.2	147.9	239.6	563.8
MERGE optimistic	1.9	3.2	4.3	7.2	14.6	34.6	36.2	79.8	124.8	288.3
Message	2.4	4.3	5.8	9.8	20.3	49.2	50.7	114.9	181.7	428.4
MiniCAM base	2.7	4.6	6.4	11.2	22.8	54.7	55.7	120.5	195.3	482.3
5th scenario	2.0	3.5	4.7	8.1	16.3	42.9	41.5	103.9	176.3	371.9
Scenario	**DICE**									
IMAGE	16.4	21.4	25	33.3	46.8	54.2	69.7	96.3	111.1	130.0
MERGE optimistic	9.7	12.6	14.9	19.7	27.9	31.6	40.7	54.5	63.5	73.3
Message	13.5	17.2	20.1	27	38.5	43.5	55.1	75.8	87.9	103.0
MiniCAM base	13.1	16.7	19.8	26.7	38.6	44.4	56.8	79.5	92.8	109.3
5th scenario	10.8	14	16.7	22.2	32	37.4	47.7	67.8	80.2	96.8
Scenario	**FUND**									
IMAGE	-33.1	-18.9	-13.3	-5.5	4.1	19.3	18.7	43.5	67.1	150.7
MERGE optimistic	-33.1	-14.8	-10	-3	5.9	14.8	20.4	43.9	65.4	132.9
Message	-32.5	-19.8	-14.6	-7.2	1.5	8.8	13.8	33.7	52.3	119.2
MiniCAM base	-31.0	-15.9	-10.7	-3.4	6	22.2	21	46.4	70.4	152.9
5th scenario	-32.2	-21.6	-16.7	-9.7	-2.3	3	6.7	20.5	34.2	96.8

Table 16-A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton CO$_2$)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	2.0	3.5	4.8	8.1	16.5	39.5	41.6	90.3	142.4	327.4
MERGE optimistic	1.2	2.1	2.8	4.6	9.3	22.3	22.8	51.3	82.4	190.0
Message	1.6	2.7	3.6	6.2	12.5	30.3	31	71.4	115.6	263.0
MiniCAM base	1.7	2.8	3.8	6.5	13.2	31.8	32.4	72.6	115.4	287.0
5th scenario	1.3	2.3	3.1	5	9.6	25.4	23.6	62.1	104.7	222.5
Scenario	**DICE**									
IMAGE	11.0	14.5	17.2	22.8	31.6	35.8	45.4	61.9	70.8	82.1
MERGE optimistic	7.1	9.2	10.8	14.3	19.9	22	27.9	36.9	42.1	48.8
Message	9.7	12.5	14.7	19	26.6	29.8	37.8	51.1	58.6	67.4
MiniCAM base	8.8	11.5	13.6	18	25.2	28.8	36.9	50.4	57.9	67.8
5th scenario	7.9	10.1	11.8	15.6	21.6	24.9	31.8	43.7	50.8	60.6
Scenario	**FUND**									
IMAGE	-25.2	-15.3	-11.2	-5.6	0.9	8.2	10.4	25.4	39.7	90.3
MERGE optimistic	-24.0	-12.4	-8.7	-3.6	2.6	8	12.2	27	41.3	85.3
Message	-25.3	-16.2	-12.2	-6.8	-0.5	3.6	7.7	20.1	32.1	72.5
MiniCAM base	-23.1	-12.9	-9.3	-4	2.4	10.2	12.2	27.7	42.6	93.0
5th scenario	-24.1	-16.6	-13.2	-8.3	-3	-0.2	2.9	11.2	19.4	53.6

Table 16-A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	**PAGE**									
IMAGE	0.5	0.8	1.1	1.8	3.5	8.3	8.5	19.5	31.4	67.2
MERGE optimistic	0.3	0.5	0.7	1.2	2.3	5.2	5.4	12.3	19.5	42.4
Message	0.4	0.7	0.9	1.6	3	7.2	7.2	17	28.2	60.8
MiniCAM base	0.3	0.6	0.8	1.4	2.7	6.4	6.6	15.9	24.9	52.6
5th scenario	0.3	0.6	0.8	1.3	2.3	5.5	5	12.9	22	48.7

Scenario	**DICE**									
IMAGE	4.2	5.4	6.2	7.6	10	10.8	13.4	16.8	18.7	21.1
MERGE optimistic	2.9	3.7	4.2	5.3	7	7.5	9.3	11.7	12.9	14.4
Message	3.9	4.9	5.5	7	9.2	9.8	12.2	15.4	17.1	18.8
MiniCAM base	3.4	4.2	4.7	6	7.9	8.6	10.7	13.5	15.1	16.9
5th scenario	3.2	4	4.6	5.7	7.6	8.2	10.2	12.8	14.3	16.0

Scenario	**FUND**									
IMAGE	-11.7	-8.4	-6.9	-4.6	-2.2	-1.3	0.7	4.1	7.4	17.4
MERGE optimistic	-10.6	-7.1	-5.6	-3.6	-1.3	-0.3	1.6	5.4	9.1	19.0
Message	-12.2	-8.9	-7.3	-4.9	-2.5	-1.9	0.3	3.5	6.5	15.6
MiniCAM base	-10.4	-7.2	-5.8	-3.8	-1.5	-0.6	1.3	4.8	8.2	18.0
5th scenario	-10.9	-8.3	-7	-5	-2.9	-2.7	-0.8	1.4	3.2	9.2

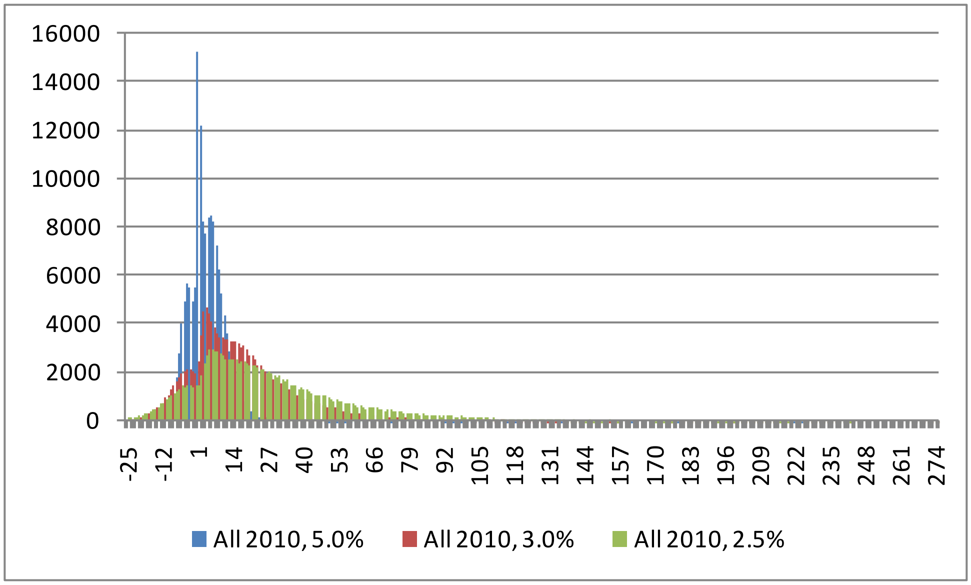


Figure 16-A.9.9 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by discount rate

* The distribution of SCC values ranges from -$5,192 to $66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

Table 16-A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates

Discount Rate		**Scenario**		
		DICE	**PAGE**	**FUND**
5%	Mean	9	6.5	-1.3
	Variance	13.1	136	70.1
	Skewness	0.8	6.3	28.2
	Kurtosis	0.2	72.4	1,479.00
3%	Mean	28.3	29.8	6
	Variance	209.8	3,383.70	16,382.50
	Skewness	1.1	8.6	128
	Kurtosis	0.9	151	18,976.50
2.50%	Mean	42.2	49.3	13.6
	Variance	534.9	9,546.00	#######
	Skewness	1.2	8.7	149
	Kurtosis	1.1	143.8	23,558.30

17-A.REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

17-A.REGULATORY IMPACT ANALYSIS

17-A.1 INTRODUCTION

This appendix provides additional details on the assumptions that feed into DOE's NIA-RIA model to estimate the impact of non-regulatory alternatives to Federal energy efficiency standards. The appendix begins with a discussion of the XENERGY penetration curves used to analyze consumer rebates, including a discussion of the revised methodology developed by DOE to estimate "interpolated" implementation curves. Additional data is then provided to support DOE's assumed rebate levels as well as DOE's assumed impact of a bulk government purchasing program on BCs and EPS.

17-A.2 DERIVATION OF THE INTERPOLATED MARKET PENETRATION CURVES

This section contains the methodology used to derive interpolated implementation curves that DOE used to analyze the consumer rebates, consumer tax credits, and manufacturer tax credits scenarios. These interpolated market penetration curves (also referred to as implementation curves) are based on market penetration curves initially developed by XENERGY, Inc.[1] In previous rulemakings, DOE, through its consultant, Lawrence Berkeley National Laboratory, consulted with the authors of the XENERGY report. Based on these consultations, DOE adjusted XENERGY's market penetration curves and developed the interpolated penetration curves for each specific product class and efficiency level in the analysis. For the BC and EPS rulemakings, DOE adopted this interpolated penetration curve methodology, which is detailed below. The resulting interpolated implementation curves for each EPS and BC product class can be found in chapter 17.

17-A.2.1 Adjustment of XENERGY Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study, DOE made some adjustments to XENERGY's original implementation curves. These reference curves are based on five market barrier levels: *No Barriers*, *Low Barriers*, *Moderate Barriers*, *High Barriers*, and *Extremely High Barriers*. Experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels.

- Moderate Barriers: 70%
- High Barriers: 60%
- Extremely High Barriers: 50%

The *low barriers* and *no barriers* curves remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves, DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds. It set another constraint such that the policy case market share cannot be greater than 100 percent, as might occur for products with high base case market shares of the target-level technology.

17-A.2.2 Interpolation of Penetration Curves

The XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates. The XENERGY report presents five referenced market implementation curves that vary according to the level of market barriers to technology penetration. Such curves have been used by DOE in the Regulatory Impact Analyses for rulemaking for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[a] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

This section presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The following describes the market implementation rate function and the reference curves; the method to calibrate the function to a given market; and the limitations of the method.

17-A.2.2.1 Market Implementation Rate Function and Curves

The XENERGY curves employ the following functional form to estimate the percentage of the informed market[b] that will accept each energy-effiency measure based on the participant's benefit/cost (b/c) ratio:

Eq. 1

where:

imp = implementation rate
bc = benefit/cost ratio
max = maximum annual acceptance rate for the technology
mid = inflection point of the curve
fit = parameter that determines the general shape (slope) of the curve.

In previous efficiency standards rulemakings, DOE adopted a slightly different functional form of equation 1, where the constant value ¼ is replaced by a parameter *r*. By introducing this

---

[a] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets can be considered proportional to the rebate impacts.

[b] The *informed market* refers to the portion of the market aware and informed about the energy efficiency measure.

parameter in equation 1 and rewriting it without the exponential and logarithmic operators, the market implementation rate of rebate programs can be evaluated using the following equation:

Eq. 2

In XENERGY’s report, the first equation is used to generate five primary (reference) curves. These curves produce initial theoretical results that are calibrated to actual measured implementation results associated with the first year of major utility energy efficiency programs. Different curves, generated using distinct values of the parameters *max*, *mid*, *fit* and *r*, reflect different levels of market barriers for different efficiency measures. The curves characterize market implementation rates for five reference levels of market barriers: *No Barriers*, *Low Barriers*, *Moderate Barriers*, *High Barriers*, and *Extremely High Barriers*. Figure 17.1 presents these five reference curves.

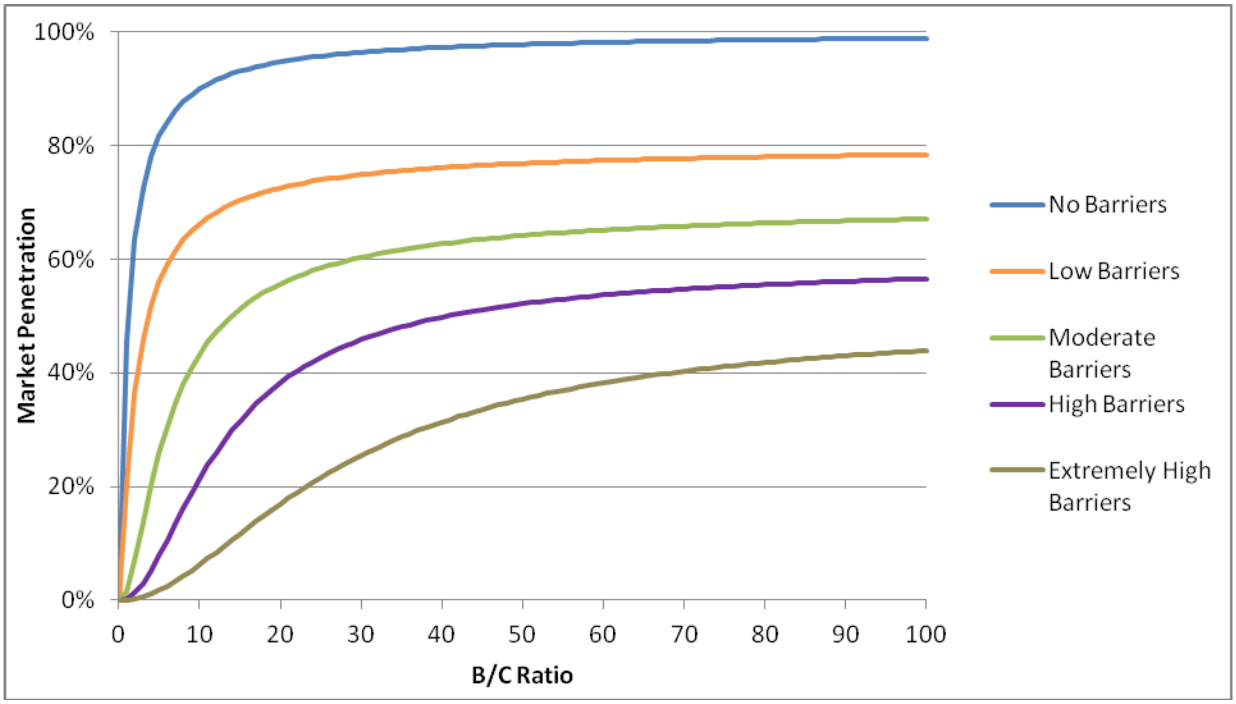


Figure 17-A.1 Market Implementation Curves for Five Market Barriers Reference Levels

They build on the following functional form:

Eq. 3

where b_d is the barrier type and $max_d(b_d)$, $mid_d(b_d)$, $fit_d(b_d)$, and $r_d(b_d)$ are as shown in Table 17.1.

Table 17-A.1 Parameter Values for Reference Curves

	Market Barriers Level				
	No Barriers	*Low Barriers*	*Moderate Barriers*	*High Barriers*	*Extremely High Barriers*
max_d	1.0	0.8	0.7[c]	0.6[c]	0.5
mid_d	10	2	0.3	0.1	0.04
fit_d	1	1.7	1.7	1.7	1.7
r_d	1	0.5	0.25	0.25	0.25

17-A.2.2.2 Calibrating the Market Implementation Rate

The procedure previously described lacks accuracy when the studied market penetration point based on the actual benefit/cost ratio does not lie close to one of the reference curves. This section presents an interpolation approach to eliminate such inaccuracy. The interpolation process provides intermediate, continuous values for the four parameters (*max*, *mid*, *fit*, and *r*) driving the market implementation curves. These intermediate values are obtained after linear interpolation of their corresponding reference values.

The four parameters (*max*, *mid*, *fit*, and *r*) were previously defined as discrete-value functions ($max(b_d)$, $mid(b_d)$, $fit(b_d)$, and $r(b_d)$) of the market barriers level. To facilitate the interpolation, it is necessary to transform the four discrete-value functions into continuous functions, the latter being thus capable of associating each of the four parameters to a real number denoting the market barrier level ($b_c \in \mathbf{R}$). A numeric, continuous scale for the market barriers level is proposed, ranging from 0 to 5 ($b_c \in [0,5]$). The correspondence between the discrete-values of market barrier levels and b_c are shown in Table 17.2.

Based on the continuous-value market barriers level, the parameters *max*, *mid*, *fit* and *r* are interpolated using the following functions:

Where and are given by Table 17.3.

The continuous-value functions defined for *max, mid, fit,* and *r,* as expressed by equations 4-7, are then substituted into equation 3, leading to the following functional form for the market implementation rate of rebate programs:

Eq. 4

---

[c] DOE adopted these parameters after consultation with the implementation curve authors.

Table 17-A.2 Correspondence between Discrete and Continuous Values of Market Barrier Levels

	Market Barriers Level				
	No Barriers	*Low Barriers*	*Moderate Barriers*	*High Barriers*	*Extremely High Barriers*
b_c	0.0	1.0	2.5	4.0	5.0

Table 17-A.3 Coefficients of Continuous-value Functions of *max*, *mid*, *fit*, and *r*

	Market Barriers Level			
	No-Low Barriers $b_c \in [0,1]$	*Low-Moderate Barriers* $b_c \in [1,2.5]$	*Moderate-High Barriers* $b_c \in [2.5,4]$	*High-High Barriers* $b_c \in [4,5]$
max_d				
	-0.200	-0.075	-0.075	-0.075
	1.000	0.875	0.875	0.875
mid_d				
	-8.000	-1.133	-0.133	-0.060
	10.000	3.133	0.633	0.340
fit_d				
	0.700	0.000	0.000	0.000
	1.000	1.700	1.700	1.700
r_d				
	-0.500	-0.167	0.000	0.000
	1.000	0.667	0.250	0.250

Hence, estimating the market effects of a rebate program relies on finding the interpolated implementation curve that best represents the studied market. In other words, it involves finding b_c, such that the pair (*imp*(b_c,*bc*), *bc*) equals the pair (base case market share, benefit/cost ratio) of the technology corresponding to the mandatory standard's efficiency level. Once the appropriate value of b_c is found (e.g. $b_c = b_c*$), the market penetration of the technology under a rebate program can be calculated by the following equation:

Eq. 5

Where:

= market barriers level corresponding to the studied market

= benefit/cost ratio with rebate

17-A.2.2.3 Limits to the Interpolation Approach

The approach presented above increases the accuracy of the estimate of the market implementation rate resulting from a rebate program. Consequently, it improves the analysis of the market effects of rebate programs. However, whereas it is feasible to develop interpolated implementation curves between the reference ones, there is no empirical support to extrapolate them beyond the *No Barriers* and the *Extremely High Barriers* curves. In fact, the theoretical boundaries for the market barriers level would be:

- Zero Barriers (b_0): With the assumption of the rational consumer, a tiny increase in the benefit/cost ratio of a technology with that ratio greater than 1 would be sufficient to make the technology widely adopted.[d] This would result in the following implementation rate function:

- Infinite Barriers (b_∞): In this case, even an extremely high benefit/cost ratio would not be sufficient to cause the market to adopt a technology. This would result in the following implementation rate function:

However, notwithstanding the existence of such theoretical boundaries, the analysis of market implementation rates in cases of markets where the base case market share is either higher than the market share in the *No Barriers* curve, or lower than the one in the *Extremely High Barriers* curve, should follow the analytical approach described in this appendix. It should rely, respectively on the *No Barriers* or the *Extremely High Barriers* curves to estimate a relative market increase due to the rebate program.

17-A.3 UTILITY REBATE PROGRAMS

To determine the impact of a consumer rebate program, DOE first derived the interpolated market penetration curve for each product class using the methodology described in section 17-A.2. Once the market barrier level was determined and the market penetration curve derived, DOE then determined the rebate level for each product class and assumed that the incremental cost of an efficient product would be reduced by the amount of the rebate. By dividing the estimated cost savings at the target efficiency level by this reduced incremental cost, DOE was able to derive the b/c ratio of BCs and EPSs in a rebate program.

As discussed in chapter 17, DOE was unable to find utility rebate programs for BCs and EPSs. To determine how a theoretical rebate program would shift the market efficiency distribution of BCs and EPSs, DOE relied on data gathered for other consumer products in

---

[d] When the benefit/cost ratio is one, the consumer is indifferent between adopting the technology or not, and the implementation rate is undetermined.

previous regulatory impact analyses. For each product, DOE calculated the share of incremental cost covered by the average rebate offered for that product. DOE then used the median value across all the products analyzed to approximate the percent of incremental cost that would be offset by BC and EPS rebates. DOE used the median rather than the mean value due to the presence of several outliers that significantly skewed the mean rebate level.

DOE considered basing its rebate levels on the rebate levels for residential products or a combination of the rebate levels for residential and commercial products, since BCs and EPSs power many applications that are used in both the residential and commercial sectors. Ultimately, DOE based its theoretical BC and EPS rebate levels on the actual rebate levels of other residential products, since the BCs and EPSs in this rulemaking are primarily intended to be used in the residential sector and, thus, a rebate program would target this sector. Table 17.4 displays the results of these calculations.

Table 17-A.4 Rebate Levels for Residential Appliances

Product	Incremental Cost	Average Rebate	Incremental Cost After Rebate	Rebate Share of Incremental Cost
Water Heaters:[2]				
Gas-Fired	$101	$57	$44	56%
Electric	$132	$97	$35	73%
Pool Heaters:[2]				
Gas-Fired	$359	$199	$160	55%
Refrigerator-Freezers:[3, 4]				
Top-Mount Freezer	$124	$52	$72	42%
Bottom-Mount Freezer	$10	$52	($42)	520%
Side-by-Side	$92	$52	$40	57%
Standard-Size Freezers:[3, 4]				
Upright	$167	$43	$124	26%
Chest	$97	$43	$54	44%
Compact Refrigerators:[3, 4]				
Compact Refrigerator	$38	$38	$0	100%
Compact Freezer	$21	$31	($10)	148%
Built-In Refrigerators:[3, 4]				
Refrigerator	$150	$52	$98	35%
Bottom-Mount Freezer	$15	$52	($37)	347%
Side-by-Side	$191	$52	$139	27%
Upright Freezer	$274	$43	$231	16%
Furnaces and Boilers:[5]				
Non-Weatherized Gas Furnace	$698	$180	$518	26%
Gas Boiler	$168	$101	$67	60%
Cooking Products:[6]				
Gas Cooktops, No Outlet	$18	$18	$0	100%
Gas Cooktops, With Outlet	$135	$68	$67	50%
Gas Standard Ovens, No Outlet	$22	$22	$0	100%
Gas Standard Ovens, With Outlet	$139	$70	$69	50%
			Median Residential Rebate Level:	**55.9%**

17-A.4 PRODUCTS AFFECTED BY A BULK GOVERNMENT PURCHASING PROGRAM

Table 17.5 through Table 17.8 display the applications that DOE believes would be impacted by a bulk government purchasing program. As discussed in chapter 17, each affected application was categorized and assumptions were made about the share of purchases that are influenced by Federal, state, and local governments.

Table 17-A.5 Government Market Share for Transportation Applications

Application	Sector	BC Shipments	EPS Shipments	Government Market Share[7]	Compliance	Affected BC Shipments	Affected EPS Shipments
Golf Carts	Comm.	210,620	--	1.70%	80%	2,860	--

Table 17-A.6 Government Market Share for Medical Devices

Application	Sector	BC Shipments	EPS Shipments	Government Market Share[8]	Compliance	Affected BC Shipments	Affected EPS Shipments
Sleep Apnea Machines	Res.	500,000	1,000,000	22.70%	80%	90,800	181,600
Medical Nebulizers	Res.	450,000	900,000	22.70%	80%	81,720	163,440
Portable 02 Concentrators	Res.	9,000	9,000	22.70%	80%	1,634	1,634
Blood Pressure Monitors	Res.	--	100,000	22.70%	80%	--	18,160
Wheelchairs	Res.	166,057	--	22.70%	80%	30,156	--
Mobility Scooters	Res.	192,274	--	22.70%	80%	34,917	--

Table 17-A.7 Government Market Share for Office Equipment

Application	Sector	BC Shipments	EPS Shipments	Government Market Share[9]	Compliance	Affected BC Shipments	Affected EPS Shipments
Personal Digital Assistants	Comm.	525,000	367,500	8.87%	80%	37,237	26,066
Netbooks	Comm.	4,771,635	4,771,635	8.87%	80%	338,437	338,437
Notebooks	Comm.	15,425,300	15,425,300	8.87%	80%	1,094,067	1,094,067
Media Tablets	Comm.	737,126	700,269	8.87%	80%	52,282	49,668
Computer Speakers	Comm.	--	2,623,118	8.87%	80%	--	186,049
External Hard Drives	Comm.	--	164,553	8.87%	80%	--	11,671
Uninterruptible Power Supplies	Comm.	2,936,000	--	8.87%	80%	208,241	--
LED Monitors	Comm.	--	1,306,098	8.87%	80%	--	92,637
Image Scanners	Comm.	--	1,151,790	8.87%	80%	--	81,693
Handheld Image Scanners	Comm.	--	--	8.87%	80%	--	--
Ink Jet Imaging Equipment	Comm.	--	694,378	8.87%	80%	--	49,250
Portable Printers	Comm.	527,187	702,916	8.87%	80%	37,392	49,856
Mobile Internet Hotspots	Comm.	787,597	787,597	8.87%	80%	55,862	55,862
LAN Equipment	Comm.	218,016	3,167,386	8.87%	80%	15,463	224,653
Bluetooth Headsets	Comm.	2,085,000	--	8.87%	80%	147,882	--
Consumer Two-Way Radios	Comm.	7,396,800	3,698,400	8.87%	80%	524,631	262,316
Mobile Phones	Comm.	9,423,900	4,240,755	8.87%	80%	668,407	300,783
Smartphones	Comm.	6,174,450	2,161,058	8.87%	80%	437,934	153,277
Cordless Phones	Comm.	2,248,930	2,248,930	8.87%	80%	159,509	159,509
Answering Machines	Comm.	2,876,230	2,876,230	8.87%	80%	204,002	204,002
Wireless Charging Stations	Comm.	--	71,352	8.87%	80%	--	5,061

Table 17-A.8 Government Market Share for Power Tools

Application	Sector	BC Shipments	EPS Shipments	Government Market Share[9]	Compliance	Affected BC Shipments	Affected EPS Shipments
DIY Power Tools (Integral)	Comm.	233,750	--	8.03%	80%	15,008	--
DIY Power Tools (External)	Comm.	1,051,875	--	8.03%	80%	67,535	--
Professional Power Tools	Comm.	4,090,625	--	8.03%	80%	262,635	--

REFERENCES

---

[1] Rufo, M. and Fred Coito. *California's Secret Energy Surplus: The Potential for Energy Efficiency*. 2002. XENERGY Inc. Oakland, CA. Prepared for The Energy Foundation and The Hewlett Foundation. (Last accessed March 2011) <http://www.ef.org/documents/Secret_Surplus.pdf>

[2] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Heating Products: Regulatory Impact Analysis. April 2010. Washington, D.C. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch15.pdf>

[3] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for Consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-Freezers and Freezers: Regulatory Impact Analysis. September 2010. Washington, D.C. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/refrig_nopr_tsd_2010-09-23.pdf>

[4] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program: Energy Conservation standards for Residential refrigerators, Refrigerator-Freezers, and Freezers; Proposed Rule. *Federal Register*. September 27, 2010. vol. 75, no. 186: pp. 59470-59577.

[5] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Furnaces and Boilers: Regulatory Impact Analysis. September 2007. Washington, D.C. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/ria.pdf>

[6] U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy. Energy Conservation Program for consumer Products: Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Dishwashers, Dehumidifiers, and Cooking Products, and Commercial Clothes Washers: Regulatory Impact Analysis. April 2009. Washington, D.C. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/cooking_products_tsd_ch17.pdf>

[7] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 1095. State Motor Vehicle Registrations: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/trans.pdf>

[8] U.S. Census Bureau, *Statistical Abstract of the United States: 2011, Table 168. Hospitals – Summary Characteristics: 1990 to 2008*, Washington, D.C. (Last accessed April 2011). <http://www.census.gov/prod/2011pubs/11statab/health.pdf>

[9] U.S. Bureau of Labor Statistics, *Occupational Employment and Wage Estimates: May 2009 Occupational Employment and Wage Estimates*, May 2009, Washington, D.C. (Last accessed April 2011). <http://www.bls.gov/oes/oes_dl.htm>