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Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry

Final Report

Prepared for

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Office of Air Quality Planning and Standards (OAQPS)
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RTI International is a trade name of Research Triangle Institute.

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SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is proposing amendments to the current National Emission Standards for Hazardous Air Pollutants (NESHAP) for the Portland cement manufacturing industry. The proposed amendments add or revise, as applicable, emission limits for mercury, total hydrocarbons, hydrogen chloride, and particulate matter from kilns and in-line/raw mills located at a major or area sources. The proposed amendments also remove the operating limit for the average hourly recycle rate for cement kiln dust and remove the work practice requirement for using certain mercury-containing fly ash in cement kilns. EPA developed these proposed amendments in response to the notice of reconsideration published on December 20, 2006, and other requirements. As part of the regulatory process of preparing these amendments, EPA is required to develop a regulatory impact analysis (RIA). This RIA includes an economic impact analysis (EIA) and a small entity impacts analysis. This report documents the RIA methods and results.

1.1 Executive Summary

The key results of the RIA are as follows:

- **Engineering Cost Analysis:** EPA estimates total annualized costs with the NESHAP will be $368 million (2005$).
- **Market Analysis:** The partial-equilibrium economic model suggests the average national price for Portland cement could be 4% higher with the NESHAP, or $3.30 per metric ton, while annual domestic production may fall by 8%, or 7 million tons per year. Because of higher domestic prices, imports rise by 2 million metric tons per year.
- **Industry Analysis:** As domestic production falls, cement industry revenues are projected to decline by 4%, or $341 million. Overall, net production costs also fall by $137 million with compliance cost increases ($235 million) offset by cost reductions associated with lower cement production. Operating profits fall by $204 million, or 16%. Other consequences include reduced demand for labor. Employment falls by approximately 8%, or 1,167 employees. EPA identified six domestic plants with negative operating profits and significant utilization changes that could temporarily idle until market demand conditions improve. The plants are small capacity plants with unit compliance costs close to $5 per ton and $50 million total change in operating profits. Since these plants account for approximately 2.5% of domestic capacity, a decision to permanently shut down these plants would reduce domestic supply and lead to additional projected market price increases.
- **Social Cost Analysis:** The estimated social cost of the proposed amendments is $605 million (2005$). This estimate includes: the results for existing kilns included in the partial-equilibrium analysis ($606 million surplus loss in domestic surplus and $89

million surplus gain for other countries producing cement); the direct compliance costs for white cement kilns ($2 million); and the direct compliance costs for 20 additional kilns projected to come on line in 2013 ($86 million). The social cost estimates are significantly higher than the engineering analysis estimates, which estimated annualized costs of $368 million. This is a direct consequence of EPA's assumptions about existing domestic plants' pricing behavior discussed extensively in previous cement industry rulemakings, Section 2, Appendix A, and Appendix B of this RIA. Under baseline conditions without regulation, the existing domestic cement plants are assumed to choose a production level that is less than the level produced under perfect competition. As a result, a preexisting market distortion exists in the markets covered by the proposed rule (i.e., the observed baseline market price is higher than the [unobserved] market price that a model of perfect competition would predict). The imposition of additional regulatory costs tends to widen the gap between price and marginal cost in these markets and contributes to additional social costs.

- **Energy Impacts:** EPA concludes that the rule when implemented will not have a significant adverse effect on the supply, distribution, or use of energy. The cement industry accounts for less than 0.3% of the U.S. total energy consumption. Although EPA estimates the additional add-on controls may increase electricity consumption by 926 million kWh, this is less than 0.1% of the *Annual Energy Outlook* (*AEO*) *2009* (Department of Energy [DOE], 2008) 2013 electricity forecasts of total electricity use (4,091 billion kWh).
- **Small Business Analysis:** EPA performed a screening analysis for impacts on small entities by comparing compliance costs to average company revenues. EPA's analysis found that the ratio of compliance cost to company revenue falls below 1% for one of the four small entities included in the screening analysis. Two small entities (including a tribal government) would have an annualized cost of between 1% and 3% of sales. One small business would have an annualized cost greater than 3% of sales. In addition to the screening analysis, EPA also examined small entity effects after accounting for market adjustments. Under this assumption, the entities recover some of the regulatory program costs as the market price adjusts in response to higher cement production costs. Even after accounting for these adjustments, small entity operating profits fall by $4 million, or 9%. As cement production falls, employment may decline by up to 23 employees, a 5% reduction.
- **Benefits Analysis:** In the year of full implementation (2013), EPA estimates the benefits of this proposal are $4.4 billion to $11 billion and $4.0 billion to $9.7 billion, at 3% and 7% discount rates respectively.[1] Annualized domestic social costs are $694 million at a 7% discount rate as mentioned in Section 4 of this RIA.[2] Thus, the net benefits (i.e., benefits in 2013 minus annualized costs) are $3.7 billion to $11 billion and $3.3 billion to $9.0 billion, at 3% and 7% discount rates respectively.

[1] The benefits are discounted to account for the cessation lag in $PM_{2.5}$ benefits from premature mortality and acute myocardial infarctions (AMIs), rather than a discounted stream of future benefits; whereas discounting the costs reflects the lifetime costs of the equipment. For this reason, it is appropriate in this context to use two different discount rates for the benefits and costs.

[2] The domestic cost does not include the estimated $89 million surplus gain for foreign producers.

1.2 Organization of this Report

The remainder of this report supports and details the methodology and the results of the EIA:

- Section 2 presents a profile of the affected industry.
- Section 3 describes the economic impact analysis and energy impacts.
- Section 4 describes the small business impact analysis.
- Section 5 presents the benefits estimates.
- Appendix A describes the regional Portland cement markets and the economic model.
- Appendix B discusses the model of the cement plant’s production decision.
- Appendix C presents the social cost methodology.

SECTION 2
INDUSTRY PROFILE

Hydraulic cement (primarily Portland cement) is a key component of an important construction material: concrete. Concrete is used in a wide variety of applications (e.g., residential and commercial buildings, public works projects), and cement demand is influenced by national and regional trends in these sectors. Recent data for 2007 show that the U.S. cement industry produced over 90 million metric tons of Portland cement (Department of Interior [DOI], U.S. Geological Survey [USGS], 2008b). The value of total U.S. sales, including imported cement, was about $11.8 billion, with an average value of approximately $100 per metric ton. The vast majority of cement sales went to ready-mixed concrete producers and concrete product manufacturers (88%). Since 2003, the United States has relied on cement imports to meet approximately 20% to 23% of its consumption needs. However, this share dropped to approximately 17% in 2007 as overall construction demand for cement fell (DOI, USGS, 2008b).

The remainder of this section provides an introduction to the Portland cement industry. The purpose is to give the reader a general understanding of the technical and economic aspects of the industry that must be addressed in the economic impact analysis. Section 2.1 provides an overview of the production processes and costs data. Section 2.2 discusses the uses, consumers, and substitutes for cement. Section 2.3 summarizes the organization of the Portland cement industry. The industry profile concludes with a discussion of historical market data and the current industry outlook.

2.1 The Supply Side

2.1.1 Production Process

As shown in Figure 2-1, the manufacturing process of an integrated cement plant includes

- quarrying and crushing the raw materials,
- grinding the carefully proportioned materials to a high degree of fineness,
- firing the raw materials mixture in a rotary kiln to produce clinker, and
- grinding the resulting clinker to a fine powder and mixing with gypsum to produce cement.

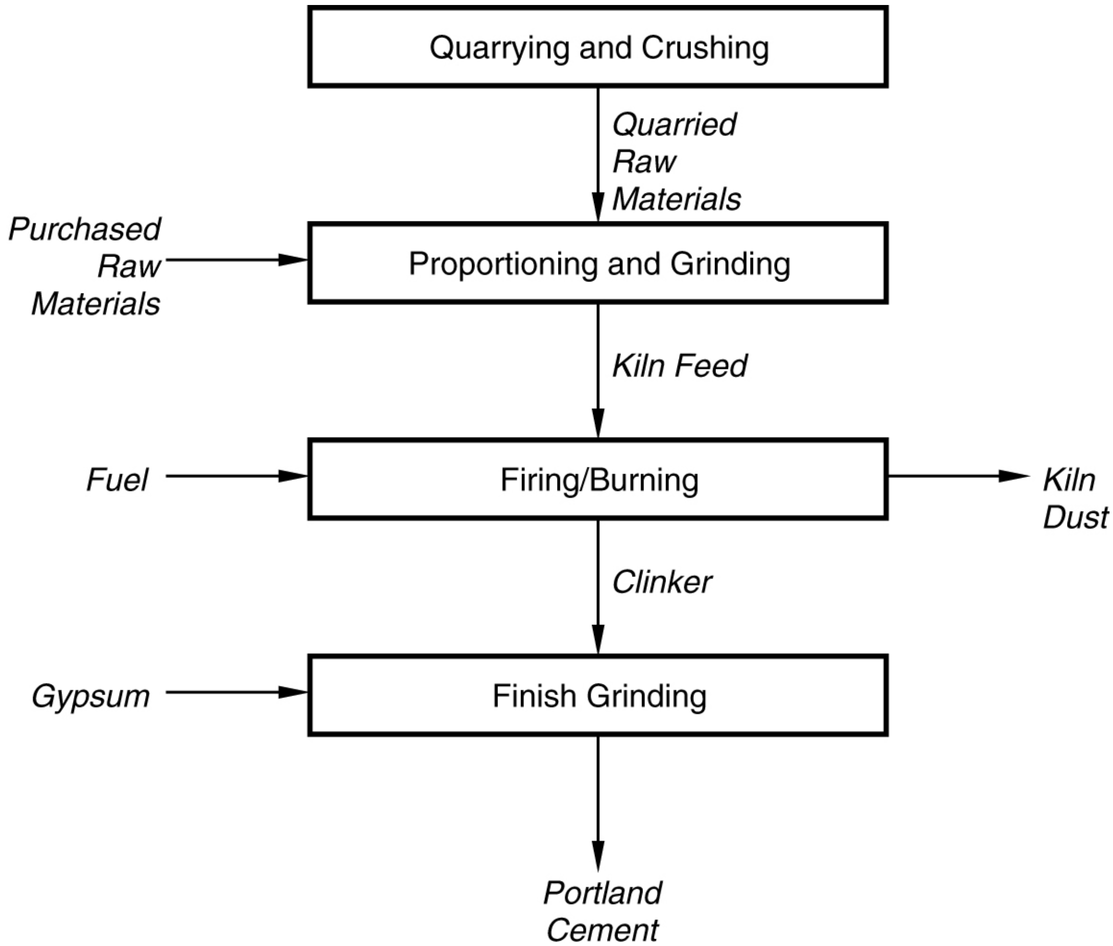

Figure 2-1. Simplified Flow Sheet of Clinker and Cement Manufacture

There are two processes for manufacturing cement: the wet process and the dry process. In the wet process, water is added to the raw materials during the blending process and before feeding the mixture into the rotary kiln. In contrast, the dry process feeds the blended materials directly into the rotary kiln in a dry state. Newer dry process plants also use preheater and precalciner technologies that partially heat and calcine the blended raw materials before they enter the rotary kiln. These technologies can increase the overall energy efficiency of the cement plant and reduce production costs.

The fuel efficiency differences between the wet and dry processes have led to a substantial decline in clinker capacity provided by the wet process over the last 3 decades. Historical data show capacity shares falling from 52% in 1980 to approximately 22% in 2000 (Van Oss and Padovani, 2002). Data also show that the number of wet process plants fell from 32 in 2000 to 23 in 2005 (Van Oss and Padovani, 2002; DOI, USGS, 2007).

2.1.2 *Types of Portland Cement*

Portland cement manufacturers produce a variety of types of cement in the United States designed to meet different requirements. The American Society for Testing Materials (ASTM) specification C-150 provides for eight types of Portland cement: five standard types (I, II, III, IV, V) and three additional types that include air-entraining properties (IA, IIA, IIIA) (PCA, 2008a). We describe these below.

Types I and IA: These types are the usual product used in general concrete construction, most commonly known as gray cement because of its color.

Types II and IIA: These types are intended for use when moderate heat of hydration is required or for general concrete construction exposed to moderate sulfate action.

Type III and IIIA: These types are made from raw materials with a lime-to-silica ratio higher than that of Type I cement and are ground finer than Type I cements. They contain a higher proportion of tricalcium silicate than regular Portland cements.

Type IV: This type contains a lower percentage of tricalcium silicate and tricalcium aluminate than Type I, thus lowering the heat evolution. Consequently, the percentage of tetracalcium aluminoferrite is increased. Type IV cements are produced to attain a low heat of hydration.

Type V: This type resists sulfates better than the other four types.

As shown in Table 2-1, the vast majority of Portland cement shipments[1] in 2005 were Types I and II grey cement. However, Type V (sulfate-resisting) is a growing market (DOI, USGS, 2007a); since 2000, Type V cement has increased its share of shipments from 4% to 15%. Shipment shares for other types of cement remained constant during this period.

2.1.3 *Production Costs*

Portland cement is produced using a combination of variable inputs such as raw materials, labor, electricity, and fuel. U.S. Census data for the cement industry (North American Industry Classification System [NAICS] 32731: cement manufacturing) provides an initial overview of aggregated industry expenditures on these inputs (Department of Commerce [DOC], Bureau of the Census, 2008). In 2006, the total value of shipments was $10.7 billion, and the industry spent approximately $2.1 billion on materials, parts, and packaging, or 20% of the value of shipments. Total compensation for all employees (includes payroll and fringe benefits)

[1] USGS notes these shipment data include cement imports (primarily Types I, II, and V).

Table 2-1. Portland Cement Shipped from Plants in the United States to Domestic Customers, by Type[a, b]

Type	2000	Share	2005	Share
General use and moderate heat (Types I and II) (gray)[c]	90,644	88%	93,900	77%
High early strength (Type III)	3,815	4%	3,960	3%
Sulfate resisting (Type V)[c]	4,453	4%	18,100	15%
White[d]	894	1%	1,190	1%
Blended	1,296	1%	3,160	3%
Expansive and regulated fast setting	60	0%	6	0%
Other[e]	1,786	2%	1,997	2%
Total[f]	102,947	100%	122,000	100%

[a] Includes imported cement.

[b] Data are rounded to no more than three significant digits; may not add to totals shown.

[c] Cements classified as Type II/V hybrids are now commonly reported as Type V.

[d] Mostly Types I and II but may include Types III through V and block varieties.

[e] Includes block, oil well, low heat (Type IV), waterproof, and other Portland cements.

[f] Data are based on an annual survey of plants and importers.

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Washington, DC: U.S. Department of the Interior. Table 15.

U.S. Department of the Interior, U.S. Geological Survey. 2002. *2001 Minerals Yearbook, Cement*. Washington, DC: U.S. Department of the Interior. Table 15.

Amounted to $1.3 billion (12%).[1] Fuels and electricity expenditures were approximately $1.6 billion (15%).

2.1.3.1 Raw Material Costs

According to the USGS, approximately 159.7 million tons of raw materials were required to produce approximately 95.5 million tons of cement in 2005 or 1.67 tons of raw materials per ton of cement. Table 2-2 summarizes the amount of raw material inputs used per ton of cement produced in the United States between 2000 and 2005. As the data show, the amount of raw materials required to produce one ton of cement has remained essentially constant during this 6-year period.

[1] Wages paid to production workers were $0.7 billion (6% of the value of shipments) at an average hourly rate of $25.

Table 2-2. Raw Material Input Ratios for the U.S. Cement Industry: 2000 to 2005

	2000	2001	2002	2003	2004	2005
Raw material input (10^3 metric tons)	144,949	147,300	153,100	150,500	158,200	159,700
Cement production (10^3 metric tons)	85,178	86,000	86,817	89,592	94,014	95,488
Metric tons of raw material input per ton of cement	1.70	1.71	1.76	1.68	1.68	1.67

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2002–2007a. *2001–2005 Minerals Yearbook, Cement*. Table 6. Washington, DC: U.S. Department of the Interior.

U.S. Department of the Interior, U.S. Geological Survey. 2002–2007a. *2001–2005 Minerals Yearbook, Cement*. Table 3. Washington, DC: U.S. Department of the Interior.

The price of these raw materials varies across regions. Table 2-3 lists the average price of raw materials per metric ton by state. In 2005, the prices of raw materials were highest in Hawaii where they sold for an average of $13.34 per metric ton. The prices of raw materials were lowest in Michigan, where they sold for an average of $3.89 per metric ton.

2.1.3.2 Labor Costs

In 2005, the Portland Cement Association (PCA) reported labor productivity measures (in terms of metric tons of cement per employee hour)[1] for 2000 to 2005 in its U.S. and Canadian Labor-Energy Input Survey. Using these data, we computed a measure of labor hour requirements to produce cement (see Table 2-4). As these data show, wet process plants are typically more labor intensive, requiring approximately 45% more labor hours to produce a metric ton of cement than dry process plants.

In addition, labor productivity has been improving more quickly in dry process plants than in those using a wet manufacturing process. Between 2000 and 2005, labor requirements decreased by 15% in dry process plants, while in wet process plants labor requirements remained constant. As a result, the wet process labor costs relative to dry process plants labor costs have risen in recent years (Figure 2-2).[2]

[1] Throughout this report, we use PCA's method to calculate labor and energy efficiency. This measure is a weighted sum of clinker and finished cement production. Weights for labor are 85% clinker and 15% finished cement production. Weights for energy are 92% clinker and 8% finished cement production (PCA, 2005).

[2] The labor costs reported in Figure 2-3 were calculated by first multiplying the number of employee hours per metric ton of cement reported in Table 2-4 by the average hourly earnings of production workers for each year (BLS, 2007). Next, these cost estimates were adjusted for inflation and expressed in 2005 dollars by using the consumer price index (CPI) (DOC, BLS, 2008).

Table 2-3. Raw Material Costs by Market and State: 2005

State(s)	Price of Raw Materials ($/metric ton)[a]	State(s)	Price of Raw Materials ($/metric ton)[a]
AK	6.60	MT	$4.76
AL	6.57	NC	$8.59
AR	$6.29	ND	$4.45
AZ	$5.75	NE	$7.10
CA	$8.37	NH	$8.02
CO	$6.85	NJ	$7.04
CT	$9.19	NM	$6.67
DE	$6.89	NV	$7.17
FL	$8.67	NY	$8.44
GA	$7.63	OH	$5.82
HI	$13.34	OK	$5.67
IA	$7.27	OR	$6.01
ID	$5.37	PA	$6.67
IL	$7.16	RI	$7.74
IN	$5.40	SC	$7.61
KS	$7.20	SD	$4.60
KY	$7.24	TN	$7.55
LA	$8.18	TX	$6.15
MA	$9.19	UT	$5.58
MD	$8.28	VA	$9.03
ME	$6.85	VT	$6.75
MI	$3.89	WA	$6.92
MN	$8.30	WI	$5.83
MO	$7.37	WV	$6.86
MS	$11.90	WY	$5.68

Source: U.S. Department of the Interior, U.S. Geological Survey. 2006b. *2005 Minerals Yearbook, Crushed Stone.* Table 4. Washington, DC: U.S. Department of the Interior.

Table 2-4. Labor Productivity Measures for the U.S. Cement Industry by Process Type: 2000 to 2005 (employee hours per metric ton)

Year	2000	2001	2002	2003	2004	2005
All plants	0.394	0.388	0.360	0.347	0.338	0.338
Wet process	0.469	0.457	0.450	0.465	0.452	0.463
Dry process	0.376	0.375	0.342	0.328	0.318	0.318

Source: Portland Cement Association. December 2005. U.S. and Canadian Labor-Energy Input Survey 2005. Skokie, IL: PCA’s Economic Research Department.

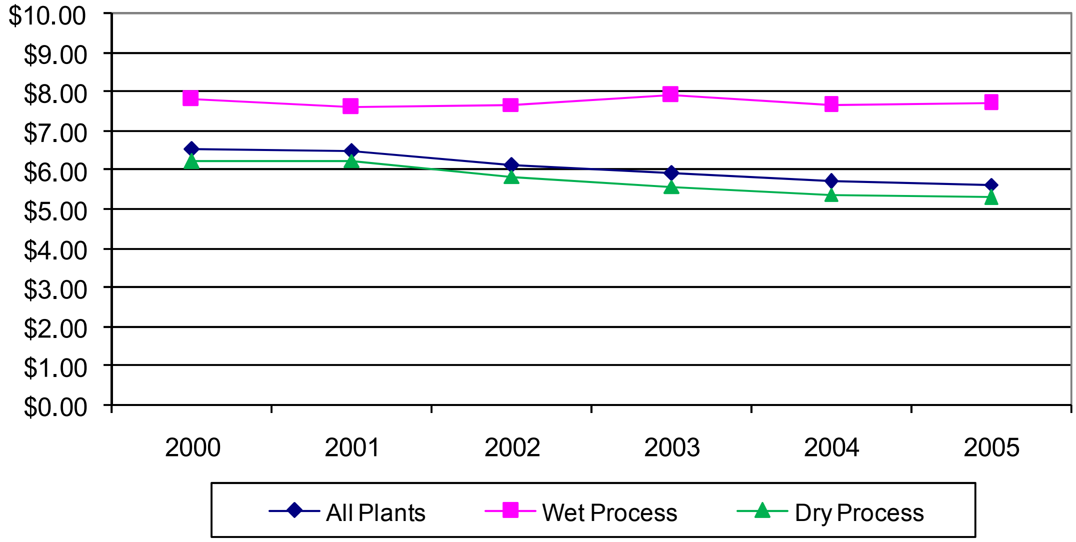

Figure 2-2. Labor Costs per Metric Ton of Cement ($2005)

Sources: Portland Cement Association. December 2005. *U.S. and Canadian Labor-Energy Input Survey 2005*. Skokie, IL: PCA's Economic Research Department.

U.S. Department of Labor, Bureau of Labor Statistics (BLS). 2007a. "Current Employment Statistics (National): Customizable Data Tables" Available at <http://www.bls.gov/ces/>. As obtained on March 14, 2008.

U.S. Department of Labor, Bureau of Labor Statistics (BLS). 2008. "Consumer Price Index All Items – U.S. City Average Data: Customizable Data Tables." Available at <http://www.bls.gov/cpi/>. As obtained on March 14, 2008.

2.1.3.3 Energy Costs

Figure 2-3 provides a detailed breakdown of U.S. energy consumption in 2005. As this figure shows, the vast majority of energy in U.S. cement plants is derived from coal and coke (75%). The remaining 25% of energy consumption is derived from electricity, waste, natural gas, and petroleum products.

PCA also reported energy consumption data by type of U.S. cement plant (in terms of millions of BTUs per metric ton of cement) (see Table 2-5). As these data show, wet process plants are typically more energy intensive, consuming approximately 44% more energy per ton of cement than dry process plants. In addition, the trends in energy consumption continue to show that dry plants have become more energy efficient than wet process plants. Between 2000 and 2005, energy consumption per ton of cement in dry process plants *decreased* by 5%; in contrast, wet process plants' energy consumption increased slightly during this period.

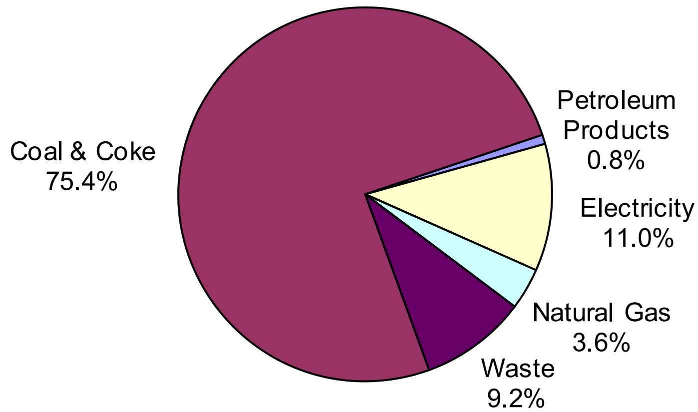

Figure 2-3. Distribution of Energy Consumption

Source: Portland Cement Association. December 2005. *U.S. and Canadian Labor-Energy Input Survey 2005*. Skokie, IL: PCA's Economic Research Department.

Table 2-5. Energy Consumption by Type of U.S. Cement Plant (million BTU per metric ton)

Year	2000	2001	2002	2003	2004	2005
All plants	4.982	4.93	4.858	4.762	4.755	4.699
Wet process	6.25	6.442	6.676	6.647	6.807	6.387
Dry process	4.673	4.655	4.498	4.433	4.407	4.433

Source: Portland Cement Association. December 2005. *U.S. and Canadian Labor-Energy Input Survey 2005*. Skokie, IL: PCA's Economic Research Department.

2.2 The Demand Side

The demand for Portland cement is considered a "derived" demand because it depends on the construction demands for its end product—concrete. A recent study by the U.S. International Trade Commission suggests that 0.192 metric tons of grey Portland cement were used per $1,000 of construction in 1998 (USITC, 2006). Given cement prices at this time (approximately $75 per metric ton), Portland cement costs represented only a small share of the total value of construction expenditures (less than 2%).

Concrete is used in a wide variety of construction applications, including residential and commercial buildings, and public works projects such as the national highway system. As shown in Figure 2-4, ready-mixed concrete producers have historically accounted for over half of the Portland cement consumption. Although government and miscellaneous expenditures saw substantial increases in the early 1990s, their consumption share returned to pre-1990s levels after 1996. The latest USGS use data show that ready-mixed concrete producers accounted for

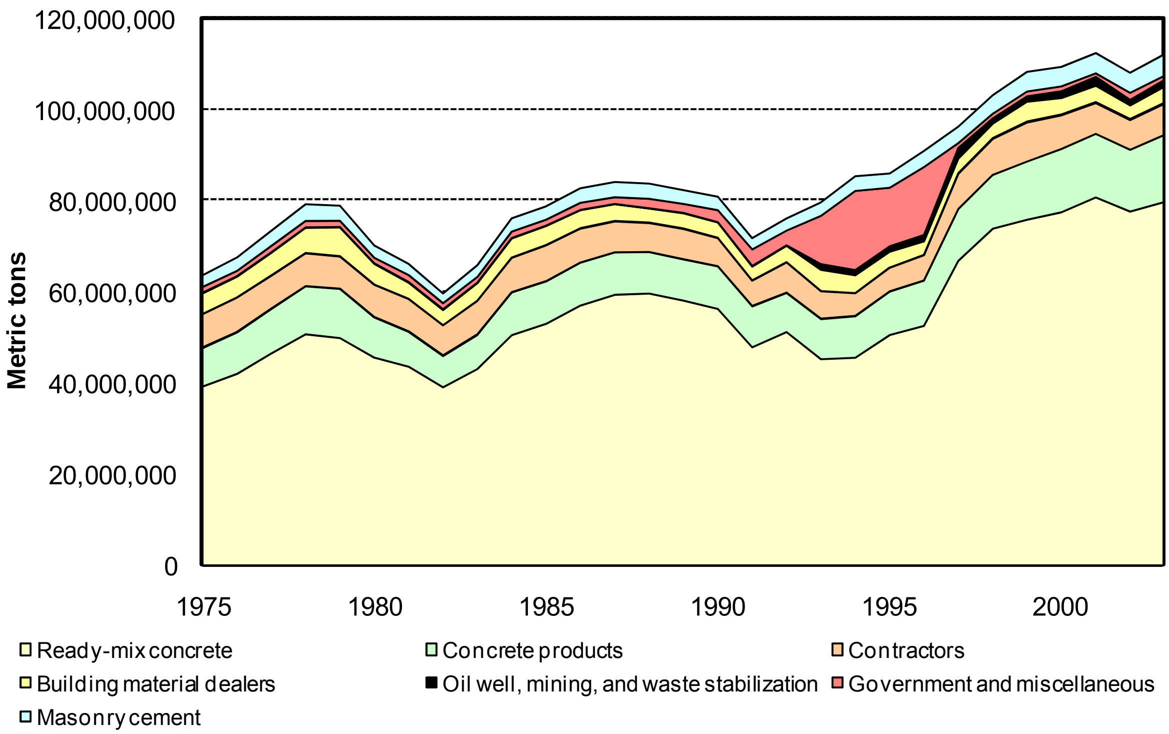

Figure 2-4. End Uses of Cement: 1975 to 2003

Source: Kelly, T. and G. Matos. 2007a. "Historical Statistics for Mineral and Material Commodities in the United States: Cement End Use Statistics." U.S. Geological Survey Data Series 140, Version 1.2. Available at http://minerals.usgs.gov/ds/2005/140/.

74% of cement sales in 2005, followed by concrete product manufacturers (14%), contractors (6%), and other (6%) (Kelly and Matos, 2007a).

Cement competes with other construction materials such as steel, asphalt, and lumber. Lumber is the primary substitute in the residential construction market, while steel is the primary substitute in commercial applications. Asphalt is a key substitute in transportation projects such as road and parking lot surfacing. However, concrete has advantages over these substitutes because it tends to be available locally and has lower long-term maintenance costs (Van Oss and Padovani, 2002).

The PCA regularly reports price trends for these competing building materials (PCA, 2008b). As shown in Figure 2-5, steel and asphalt have risen sharply relative to cement since 2003 while lumber has declined.

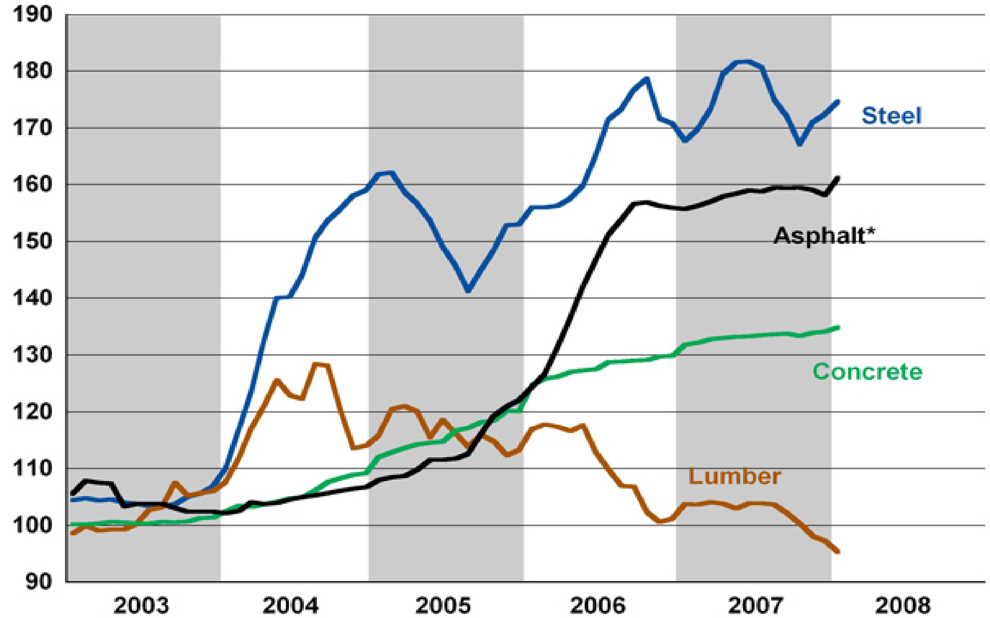

Figure 2-5. Producer Price Indices for Competitive Building Materials: 2003 to 2008

Source: Portland Cement Association. 2008b. "Market Research: Producer Price Indices—Competitive Building Materials." Available at <http://www.cement.org/market/>.

2.3 Industry Organization

2.3.1 Market Structure

A review and description of market characteristics (i.e., degree of concentration, entry barriers, and product differentiation) can enhance our understanding of how U.S. cement markets operate. These characteristics provide indicators of a firm's ability to influence market prices by varying the quantity of cement it sells. For example, in markets with large numbers of sellers and identical products, firms are unlikely to be able to influence market prices via their production decisions (i.e., they are "price takers"). However, in markets with few firms, significant barriers to entry (e.g., licenses, legal restrictions, or high fixed costs), or products that are similar but can be differentiated, the firm may have some degree of market power (i.e., set or significantly influence market prices).

Cement sales are often concentrated locally among a small number of firms for two reasons: high transportation costs and production economies of scale.[1] Transportation costs significantly influence where cement is ultimately sold; high transportation costs relative to unit value provide incentives to produce and sell cement locally in regional markets (USITC, 2006).

[1] The 2002 Economic Census reports that the national Herfindahl-Hirschman Index (HHI) for cement (North American Industry Classification System [NAICS] 32731) is 568. However, this measure is likely not representative of actual concentration that exists in regional markets.

To support this claim, the empirical literature has typically pointed to Census of Transportation data showing over 80% of cement shipments were made within a 200-mile radius (Jans and Rosenbaum, 1997)[1] and reported evidence of high transportation costs per dollar of product value from case studies (Ryan, 2006). The cement industry is also very capital intensive and entry requires substantial investments. In additional, large plants are typically more economical because they can produce cement at lower unit costs; this reduces entry incentives for small-sized cement plants. Using recent data for planned capacity expansions between 2008 and 2012, the PCA reports these expansions will cost $5.9 billion and add 25 million metric tons (PCA, 2007), or $240 per metric ton, of new capacity.

For a given construction application, consumers are likely to view cement produced by different firms as very good substitutes. American Society for Testing and Materials (ASTM) specifications tend to ensure uniform quality, and recent industry reviews (USITC, 2006) suggest that there is little or no brand loyalty that allows firms to differentiate their products.

2.3.2 Manufacturing Plants

During 2005, 107 cement manufacturing plants with 186 cement kilns were operating in the United States. This section describes the location, age, production capacity, and employment of these manufacturing facilities. Section 2.3.2 concludes with a discussion of future trends. Section 2.3.3 provides a detailed discussion of the characteristics of the firms owning these facilities.

2.3.2.1 Location

Table 2-6 summarizes the geographic location of cement kilns in the United States and clinker capacity. The top five states in order of clinker capacity are California, Texas, Pennsylvania, Florida, and Alabama. Together these states account for 75 (40%) of the kilns in the United States and 41 million metric tons (44%) of clinker capacity. Figure 2-6 provides a graphical depiction of the number of kilns distributed by state.

Fourteen states (Alaska, Hawaii, Connecticut, Louisiana, New Hampshire, North Dakota, Wisconsin, Delaware, Massachusetts, New Jersey, Rhode Island, Minnesota, North Carolina, and Vermont) and the District of Columbia had no clinker-producing facilities in 2005.

[1] A recent USITC study of California cement markets found more than 75% of gray Portland cement shipments in the state were shipped to customers within 200 miles of the cement producer (USITC, 2006).

Table 2-6. Number of Kilns and Clinker Capacity by State: 2005

	No. Kilns	Clinker Capacity (10^3 metric tons per year)
AK	0	
AL	5	5,375
AR	3	831
AZ	8	2,809
CA	20	12,392
CO	2	2,117
CT	0	
DE	0	
FL	7	5,489
GA	2	1,020
HI	0	
IA	4	2,672
ID	2	260
IL	8	2,770
IN	8	3,191
KS	9	2,835
KY	1	1,365
LA	0	
MA	0	
MD	4	2,538
ME	1	392
MI	8	4,243
MN	0	
MO	6	5,169
MS	1	419
MT	2	573
NC	0	
ND		
NE	2	845
NH	0	
NJ	0	
NM	2	432
NV	2	452
NY	4	2,886
OH	3	1,115
OK	7	1,869
OR	1	816

(continued)

Table 2-6. Number of Kilns and Clinker Capacity by State: 2005 (continued)

	No. Kilns	Clinker Capacity (10^3 metric tons per year)
PA	21	6,414
RI	0	
SC	6	3,480
SD	3	851
TN	2	1,438
TX	22	11,688
UT	2	1,514
VA	1	1,120
VT	0	
WA	2	1,100
WI	0	
WV	3	708
WY	2	597
Total	186	93,785

Source: Portland Cement Association (PCA). 2004. U.S. and Canadian Portland Cement Industry: Plant Information Summary. Skokie, IL: PCA's Economic Research Department.

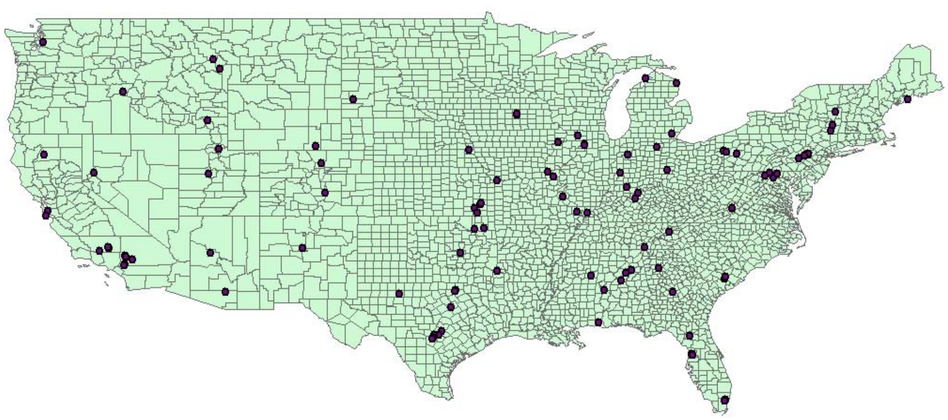

Figure 2-6. Distribution of Cement Kilns in the United States

Source: Portland Cement Association (PCA). December 2004. *U.S. and Canadian Portland Cement Industry: Plant Information Summary*. Skokie, IL: Portland Cement Association Economic Research Department.

2.3.2.2 Age

In 2005, 72% (134) of all kilns in the United States used the dry manufacturing process, and it accounted for 83% (78 million metric tons) of national clinker capacity. The growing prevalence of the dry process among cement manufacturers is part of a long-term trend. As the data in Table 2-7 indicate, no new wet clinker capacity has been added within the past 30 years.

Table 2-7. Number of Kilns and Clinker Capacity by Age and Process Type

	No. Kilns	Clinker Capacity (10^3 metric tons per year)	Average Annual Capacity per Kiln
Total			
0–10	26	28,144	1,082.5
11–15	3	2,176	725.3
16–20	5	3,345	669.0
21–25	16	14,982	936.4
26–30	18	11,843	657.9
31–35	16	5,786	361.6
36–40	21	9,285	442.1
41–45	29	8,971	309.3
46–50	32	6,564	205.1
51–55	6	991	165.2
56–60	6	800	133.3
60+	8	898	112.3
Total	186	93,785	504.2
Dry Process			
0–10	26	28,144	1,082.5
11–15	3	2,176	725.3
16–20	5	3,345	669.0
21–25	16	14,982	936.4
26–30	18	11,843	657.9
31–35	10	3,962	396.2
36–40	12	5,498	458.2
41–45	14	3,800	271.4
46–50	16	2,651	165.7
51–55	4	682	170.5
56–60	6	800	133.3
60+	4	328	82.0
Total	134	78,211	583.7
Wet Process			
0–10	0		
11–15	0		
16–20	0		
21–25	0		
26–30	0		
31–35	6	1,824	304.0
36–40	9	3,787	420.8
41–45	15	5,171	344.7

(continued)

Table 2-7. Number of Kilns and Clinker Capacity by Age and Process Type (continued)

	No. Kilns	Clinker Capacity (10^3 metric tons per year)	Average Annual Capacity per Kiln
Wet Process (cont.)			
46–50	16	3,913	244.6
51–55	2	309	154.5
56–60	0		
60+	4	570	142.5
Total	52	15,574	299.5

Source: Portland Cement Association (PCA). 2004. U.S. and Canadian Portland Cement Industry: Plant Information Summary. Skokie, IL: PCA's Economic Research Department.

All 68 kilns that have become operational within the past 30 years use the dry manufacturing process. These new kilns account for 64% (60 million metric tons) of national clinker capacity.

2.3.2.3 Production Capacity and Utilization

Between 2000 and 2005, apparent annual clinker capacity grew approximately 17%, while clinker production grew by approximately 14% (Table 2-8). Because capacity tends to grow more rapidly than production, total capacity utilization decreased slightly in this period from 87.5% in 2000 to 85.4% in 2005.

Table 2-8. Clinker Capacity, Production, and Capacity Utilization in the United States: 2000 to 2005

	2000	2001	2002	2003	2004	2005
Apparent annual capacity (10^3 metric tons)	89,264	100,360	101,000	102,000	105,000	104,000
Production (10^3 metric tons)	78,138	79,979	82,959	83,315	88,190	88,783
Capacity utilization (%)	87.5%	79.7%	82.1%	81.7%	84.0%	85.4%

Source: U.S. Department of the Interior, U.S. Geological Survey. 2000–2005. *Minerals Yearbook, Cement.* Table 5. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.usgs.gov/minerals/pubs/commodity/cement/>. As obtained on March 14, 2008.

Much of the vast majority of the growth in clinker capacity came in 2001 when existing Portland cement plants completed major capacity upgrade projects, resulting in a 12% increase in clinker capacity over the previous year (USGS, 2002). As a result, capacity utilization fell to 79.7% that year. After 2001, clinker capacity grew an average of 1% each year, while production grew an average of 2%. As a result, capacity utilization has risen slowly since 2001. However, throughout these movements in clinker capacity and production, capacity utilization tended to remain between 80% and 85%.

Capacity utilization often varies by geographic region as a result of fluctuations in regional construction activity. For example, 2005 data show that Idaho, Montana, and Nevada shared a capacity utilization rate of 95.5%—well above the national average. In contrast, South Carolina used only 64.5% of its clinker capacity. Table 2-9 provides a complete listing of capacity utilization rates by state in 2005.

2.3.2.4 Employment

Each year, the Annual Survey of Manufactures (ASM) collects employment, payroll, sales, and other data for all manufacturing establishments. Table 2-10 summarizes the employment data collected by the ASM for the cement manufacturing industry (NAICS 327310) from 2000 to 2005. As these data indicate, total employment fell approximately 2% over this 6-year period, from approximately 17,000 employees in 2000 to 16,900 in 2005.

2.3.2.5 Trends

As previously discussed, clinker capacity has been increasing at a slower pace since 2001. However, according to the PCA, the cement industry has announced that it will increase clinker capacity by nearly 25 million metric tons between 2007 and 2012. This represents a 27% increase over U.S. 2006 clinker capacity and amounts to a $5.9 billion investment (PCA, 2007).

In addition to these expected capacity expansions, likely changes in U.S. specifications allowing the use of limestone in Portland cement could also increase production capacity. According to the PCA, domestic cement supply could increase by as much as 2 million additional tons by 2012. Increases in EPA production variances could also add another 1.1 million metric tons of domestic supply (PCA, 2007).

2.3.3 Firm Characteristics

EPA has reviewed industry information and publicly available sales and employment databases to identify the chain of ownership by accounting for subsidiaries, divisions, and joint ventures to appropriately group companies by size. Table 2-11 provides sales and employment data for 27 ultimate parent companies operating Portland cement manufacturing plants in 2005.

Table 2-9. Capacity Utilization Rates by State: 2005

State	USGS Geographic Area	Utilization Rate (percent)
AL	Alabama	86.7
AR	Arkansas and Oklahoma	90.9
AZ	Arizona and New Mexico	87
CA	California, northern and southern	88.8
CO	Colorado and Wyoming	79.5
FL	Florida	85.9
GA	Georgia, Virginia, West Virginia	78.4
IA	Iowa, Nebraska, South Dakota	85.5
ID	Idaho, Montana, Nevada, Utah	95.5
IL	Illinois	91.4
IN	Indiana	86.8
KS	Kansas	89.1
KY	Kentucky, Mississippi, Tennessee	87.4
MD	Maryland	89.1
ME	Maine and New York	83.6
MI	Michigan	85.5
MO	Missouri	90.3
MS	Kentucky, Mississippi, Tennessee	87.4
MT	Idaho, Montana, Nevada, Utah	95.5
NE	Iowa, Nebraska, South Dakota	85.5
NM	Arizona and New Mexico	87
NV	Idaho, Montana, Nevada, Utah	95.5
NY	Maine and New York	83.6
OH	Ohio	84.7
OK	Arkansas and Oklahoma	90.9
OR	Oregon and Washington	83.3
PA	Pennsylvania, eastern and western	83.7
SC	South Carolina	64.5

Source: U.S. Department of the Interior, U.S. Geological Survey. 2007b. *2005 Minerals Yearbook, Cement*. Table 5. Washington, DC: U.S. Department of the Interior.

Table 2-10. Cement Manufacturing Employment (NAICS 327310): 2000 to 2005

Year	Number of Employees
2000	17,175
2001	17,220
2002	17,660
2003	17,352
2004	16,883
2005	16,877

Sources: U.S. Department of Commerce, Bureau of the Census. 2006. *2005 Annual Survey of Manufacture*s. M05(AS)-1. Washington, DC: Government Printing Office. Available at <http://www.census.gov/prod/2003pubs/m01as-1.pdf>. As obtained on March 14, 2008.

U.S. Department of Commerce, Bureau of the Census. 2003. *2001 Annual Survey of Manufacture*s. M05(AS)-1. Washington, DC: Government Printing Office. Available at <http://www.census.gov/prod/2003pubs/m01as-1.pdf>. As obtained on March 14, 2008.

2.3.3.1 Distribution of Small and Large Companies

Firms are grouped into small and large categories using Small Business Administration (SBA) general size standard definitions for NAICS codes. These size standards are presented either by number of employees or by annual receipt levels, depending on the NAICS code. The manufacture of Portland cement is covered by NAICS code 327310 for cement manufacturing. Thus, according to SBA size standards, firms owning Portland cement manufacturing plants are categorized as small if the total number of employees at the firm is less than 750; otherwise, the firm is classified as large. As shown in Table 2-11, potentially affected firms range in size from 160 to 71,000 employees. A total of 4 firms, or 15%, are categorized as small, while the remaining 23 firms, or 75%, are large.[1]

2.3.3.2 Capacity Share

As shown in Table 2-11, the leading companies in terms of capacity at the end of 2005 were Holcim (U.S.) Inc.; CEMEX, Inc.; Lafarge North America, Inc.; Buzzi Unicem USA, Inc.; HeidelbergCement AG (owner of Lehigh Cement Co.); Ash Grove Cement Co.; Texas Industries, Inc.; Italcementi S.p.A.; Taiheiyo Cement Corporation; Titan Cement; and VICAT. The top 5 had about 57% of total U.S. clinker capacity, and the top 10 accounted for 83% of total capacity. Small companies accounted for less than 5% of clinker capacity.

[1] In cases where no employment data were available, we used information from previous EPA analyses to determine firm size.

Table 2-11. Ultimate Parent Company Summary Data: 2005

Ultimate Parent Name	Annual Sales ($\$10^6$)	Employ-ment	Type	Small Business	Plants	Kilns	Clinker Capacity (10^3 metric tons per year)	Capacity Share
Holcim, Inc	$14,034	59,901	Public	No	14	17	13,089	14.0%
CEMEX, S.A. de C.V.	$18,290	26,679	Public	No	13	21	12,447	13.3%
Lafarge S.A.	$22,325	71,000	Public	No	13	23	12,281	13.1%
BUZZI UNICEM SpA	$3,495	11,815	Private	No	10	19	8,129	8.7%
HeidelbergCement AG	$12,182	45,958	Public	No	10	13	7,786	8.3%
Ash Grove Cement Company	$1,190	2,600	Private	No	9	15	6,687	7.1%
Texas Industries, Inc.	$944	2,680	Public	No	4	15	5,075	5.4%
Italcementi S.p.A.	$5,921	20,313	Public	No	6	16	4,442	4.7%
Taiheiyo Cement Corporation	$7,710	2,061	Private	No	3	7	3,375	3.6%
Titan Cement	$1,589	1,834	Public	No	2	2	2,612	2.8%
VICAT	$2,137	6,015	Public	No	2	2	1,933	2.1%
Eagle Materials	$922	1,600	Public	No	3	5	1,651	1.8%
Mitsubishi Cement Corporation	$1,134	NA	Joint venture	No	1	1	1,543	1.6%
Rinker Materials	$4,140	11,193	Private	No	2	2	1,533	1.6%
Hanson America Holdings	$3,000	14,872	Private	No	1	1	1,497	1.6%
Salt River Materials Group [a]	$150[b]	<750	Tribal Govern ment	Yes	1	4	1,477	1.6%
Grupo Cementos de Chihuahua, S.A. de C.V.	$663	2,591	Public	No	2	5	1,283	1.4%
Cementos Portland Valderrivas, S.A.	$1,159	2,674	Public	No	2	6	1,257	1.3%
Zachary Construction	$152	1,200	Private	No	1	2	868	0.9%
RMC Pacific Materials	$160	800	Private	No	1	1	812	0.9%

(continued)

Table 2-11. Ultimate Parent Company Summary Data: 2005 (continued)

Ultimate Parent Name	Annual Sales ($\$10^6$)	Employ-ment	Type	Small Business	Plants	Kilns	Clinker Capacity (10^3 metric tons per year)	Capacity Share
Monarch Cement Company	$154	600	Public	Yes	1	2	787	0.8%
Florida Rock Industries	$1,368	3,464	Public	No	1	1	726	0.8%
Votorantim Group and Anderson Columbia Company	$9,518	30,572	Joint venture	No	1	1	682	0.7%
Dyckerhoff AG	$1,876	6,958	Public	No	1	1	586	0.6%
Continental Cement Company, LLC	$50[b]	<750	Private	Yes	1	1	549	0.6%
Cementos Del Norte	NA	NA	Private	No	1	1	392	0.4%
Snyder Associate Companies	$29	350	Private	Yes	1	2	286	0.3%

[a] Enterprise is owned by Salt River Pima-Maricopa Indian Community.

[b] EPA estimate.

Sources: Dun & Bradstreet, Inc. 2007. D&B million dollar directory. Bethlehem, PA.
LexisNexis. LexisNexis Academic [electronic resource]. Dayton, OH: LexisNexis.

2.3.3.3 Company Revenue and Ownership Type

Cement manufacturing is a capital-intensive industry. The vast majority of stakeholders are large global companies with sales exceeding $1 billion. In 2005, ultimate parent company sales ranged from $30 million to $22.3 billion (Table 2-11), with average (median) sales of $4,565 ($1,589) million. Small companies accounted for 0.3% share by sales. Ultimate parent companies were either privately or publicly owned or jointly operated by several companies. A majority of the companies (52%) were publicly owned. Private companies had a slightly smaller share (41%), and only two (or 7%) were joint ventures.

2.4 Markets

Portland cement is produced and consumed domestically as well as traded internationally. The United States meets a substantial fraction of its cement needs through imports; in contrast, it exports only a small fraction of domestically produced cement to other countries. We provide value, quantity, and price trends over the past decade for Portland cement when detailed statistics are available. In the case of international trade, we can report data only for hydraulic cement, which includes Portland and masonry cement.

2.4.1 Market Volumes

2.4.1.1 Domestic Production

In 2007, the domestic shipments of Portland cement were 90.6 million metric tons, reflecting an 8.5% increase from 2000 and, more recently, a 3% decrease from 2006 (see Table 2-12). Year-end stocks remained relatively level during this period at 7.4 million metric tons. Stocks fell slightly by 5% since 2006 and equaled 8.9 million tons in 2007. As Table 2-12 shows, shipments to final customers increased steadily since 2000, reaching 128 million tons in 2006. However, affected by declines in the housing market, the shipments fell by 9% in 2007.

Table 2-12. Historical U.S. Cement Statistics (10^6 metric tons)

	2000	2001	2002	2003	2004	2005	2006	2007
Production								
Clinker	78.1	78.5	82.0	81.9	86.7	87.4	88.6	87.2
Portland cement	83.5	84.5	85.3	88.1	92.4	93.9	93.2	90.6
Masonry cement	4.3	4.5	4.4	4.7	5.0	5.4	5.0	4.9
Total cement	87.8	88.9	89.7	92.8	97.4	99.3	98.2	95.5
Shipments to final customers	110.0	113.1	110.0	112.9	120.7	127.4	127.9	116.0
Stocks, cement, year end	7.6	6.6	7.6	6.6	6.7	7.4	9.4	8.9

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2008b. *Minerals Commodity Summaries, Cement 2008*. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2008-cemen.pdf>.

U.S. Department of the Interior, U.S. Geological Survey. 2003. *2002 Minerals Yearbook, Cement*. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.er.usgs.gov/minerals/pubs/commodity/cement/>.

2.4.1.2 International Trade

Cement imports are a significant share of domestic consumption (approximately 20%); they also grew by 30% from 2000 to 2006 (see Table 2-13). Major importing countries in 2007 included Canada (18% of total imports in 2006), China (16%), and Thailand (11%) (DOI, USGS, 2008b). In 2007, the falling value of the dollar and construction activity declines in the housing market tempered the quantity of import demanded. As a result, the share of U.S. consumption met by imports fell to its lowest level in 10 years.

Table 2-13. U.S. Cement Trade Data: 2000 to 2007

	2000	2001	2002	2003	2004	2005	2006	2007
Exports (10^6 metric tons)	0.7	0.7	0.9	0.8	0.7	0.8	1.5	1.9
Imports (10^6 metric tons)	24.6	23.6	22.5	21.0	25.4	30.4	32.1	21.3
Net import share of apparent consumption (%)	20.0	21.0	19.0	20.0	21.0	23.0	23.0	17.0

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2008b. *Minerals Commodity Summaries, Cement 2008*. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2008-cemen.pdf>.

U.S. Department of the Interior, U.S. Geological Survey. 2003. *2002 Minerals Yearbook, Cement*. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.er.usgs.gov/minerals/pubs/>.

During the period from 2000 to 2005, U.S. exports remained relatively constant at about 800,000 tons and typically did not exceed 1% of production. However, the level of U.S. exports has increased during the last 2 years. In 2007, U.S. exports totaled 1.9 million metric tons. The vast majority of U.S. exports of hydraulic cement are supplied to Canada: U.S. producers shipped a total of 650,000 tons to Canada in 2005, or 85% of total U.S. exports. The remaining fraction of U.S. exports in 2005 went to the Bahamas, Mexico, and 33 other countries around the world (DOI, USGS, 2008b).

2.4.2 Market Prices

Correcting for the effects of inflation, we find that the real price of cement per metric ton (2005 dollars) has typically ranged between \$75 and \$95 since 1990 (see Figure 2-7). However, data for the last 2 years suggest the average price of cement is at its highest level in over 2 decades (approximately \$100). Because of transportation constraints, there are regional differences in the price of cement across states. For example, remote locations such as Alaska and Hawaii had the highest deviation from the national average (\$48 in 2005) (see Figure 2-8). In the contiguous states, prices in Arizona, New Mexico, and California were higher than the national averages, while prices in Texas, Indiana, and South Carolina were among the lowest.

2.4.3 Future Projections

Although estimates of future cement demand are not publicly available, the Energy Information Administration provides projections for the real value of shipments for the stone, clay, and glass industry in its *AEO* (DOE, 2007). The forecasted annual average growth rate for 2005 to 2030 is approximately 1.7%.

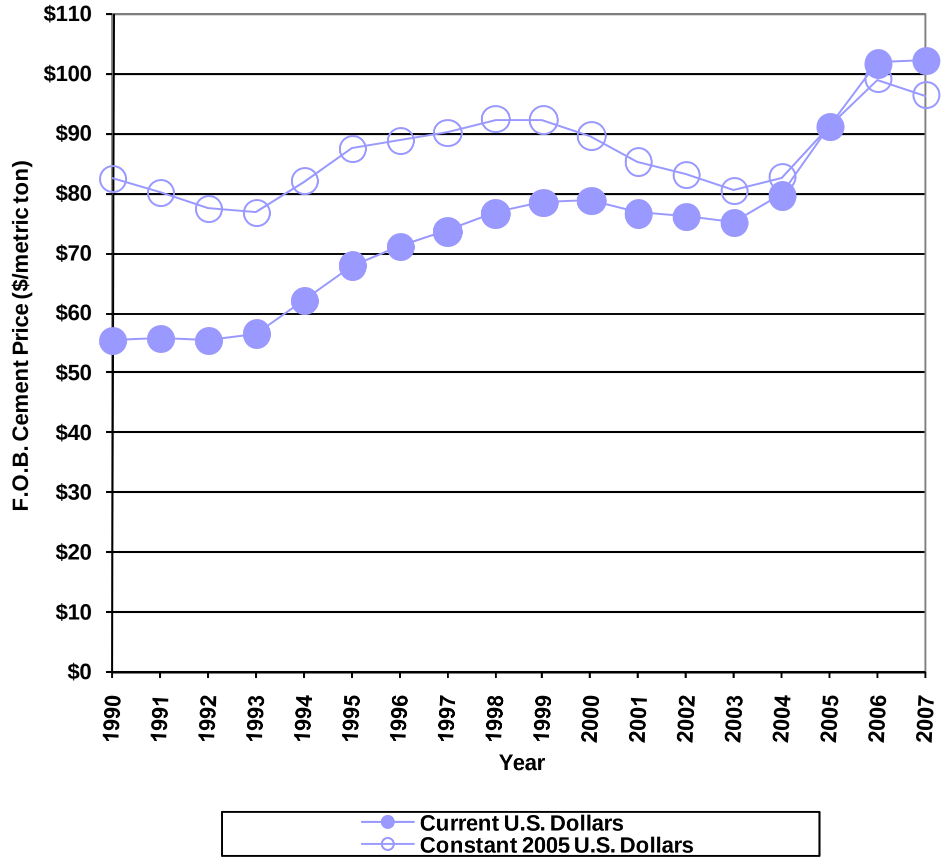

Figure 2-7. Historical U.S. Cement Price

Sources: 1990–2003: Kelly, T. and G. Matos. 2007b. “Historical Statistics for Mineral and Material Commodities in the United States: Cement Supply and Demand Statistics.” U.S. Geological Survey Data Series 140, Version 1.2. Available at <http://minerals.usgs.gov/ds/2005/140/>. Last modified April 11, 2006.

2004–2007: U.S. Department of the Interior, U.S. Geological Survey. 2008b. *Minerals Commodity Summaries, Cement 2008*. Washington, DC: U.S. Department of the Interior. Available at <http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2008-cemen.pdf>.

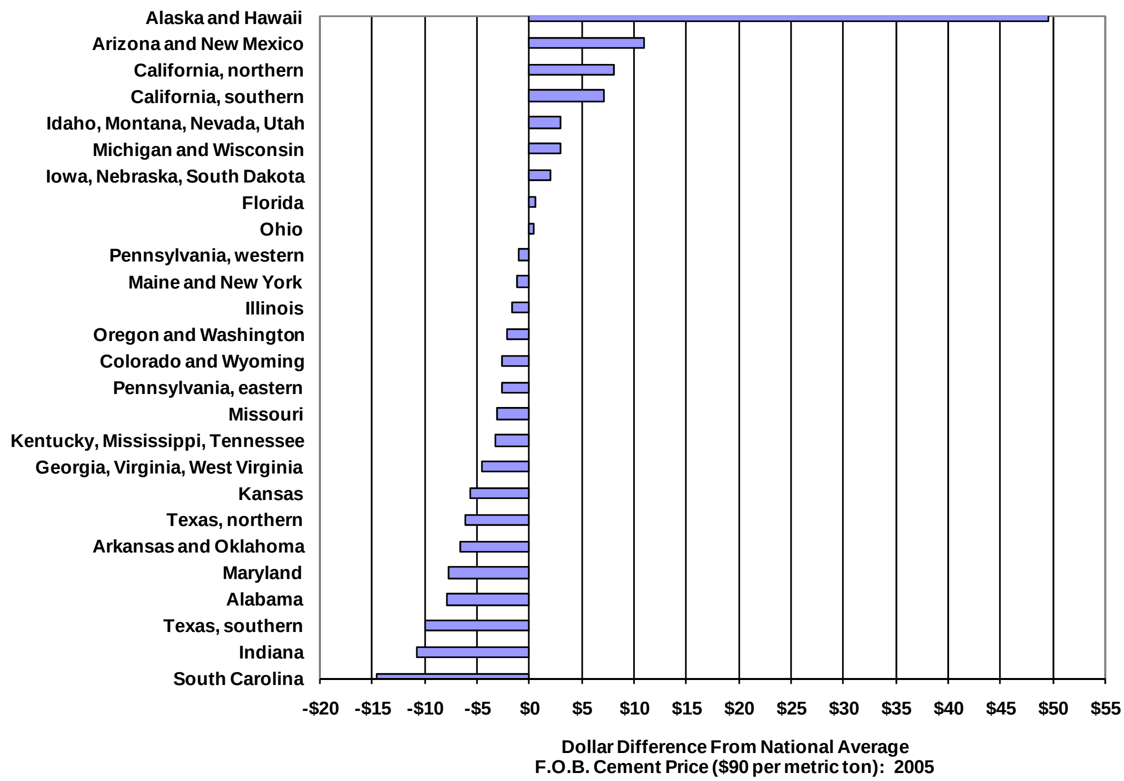

Figure 2-8. Deviation from National Average Cement Price per Metric Ton by Region: 2005

Source: U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Washington, DC: U.S. Department of the Interior. Table 11. Available at <http://minerals.er.usgs.gov/minerals/pubs/commodity/cement/>.

SECTION 3
ECONOMIC IMPACT ANALYSIS

EPA prepares an EIA to provide decision makers with a measure of the social costs of using resources to comply with a program (EPA, 2000). The social costs can then be compared with estimated social benefits (as presented in Section 5). As noted in EPA's (2000) *Guidelines for Preparing Economic Analyses*, several tools are available to estimate social costs and range from simple direct compliance cost methods to the development of a more complex market analysis that estimates market changes (e.g., price and consumption) and economic welfare changes (e.g., changes in consumer and producer surplus).

The Office of Air Quality Planning and Standards (OAQPS) has adopted the standard industry-level analysis described in the Office's resource manual (EPA, 1999a). This approach is consistent with previous EPA analyses of the Portland cement industry (EPA, 1998; EPA, 1999b) and uses a single-period static partial-equilibrium model to compare prepolicy cement market baselines with expected postpolicy outcomes in these markets. The benchmark time horizon for the analysis is the intermediate run where producers have some constraints on their flexibility to adjust factors of production. This time horizon allows us to capture important transitory impacts of the program on existing producers. Key measures in this analysis include

- market-level effects (market prices, changes in domestic production and consumption, and international trade),
- industry-level effects (changes in revenues, costs, profits, employment),
- facility-level effects (plant utilization changes), and
- social costs (changes in producer and consumer surplus).

3.1 Regulatory Program Costs

EPA is proposing the new emission limits for mercury, total hydrocarbons (THC), particulate matter, and hydrochloric acid. For the year 2013, EPA's engineering cost analysis estimates the total annualized costs of the proposed rule are $368 million (in 2005 dollars) (see Table 3-1). These costs include a variety of pollution control expenditures: equipment installation, operating and maintenance, recordkeeping, and performance-testing activities. Figure 3-1 illustrates the distribution of annualized compliance costs per metric ton of capacity for existing grey and white cement kilns. For analytical convenience, the analysis assumes the

Table 3-1. Summary of Direct Compliance Costs (10^6 2005$)

Type	Value	EIA Social Cost Method
Existing Grey Cement Kilns		
Total:	$280	
Mercury	$28	
THC	$111	Partial-equilibrium model (baseline year 2005)
PM	$17	
HCl (maximum achievable control technology [MACT] option)	$124	
Existing White Cement Kilns		
Total:	$2	
Mercury	<$1	
THC	<$1	Direct compliance cost method
PM	<$1	
HCl (MACT option)	<$1	
20 Additional New Kilns in 2013		
Total:	$86	
Mercury	$25	
THC	$20	Direct compliance cost method
PM	$5	
HCl (MACT option)	$36	
Total, All Kilns:	$368	

capital costs will take place at the beginning of 2013. However, costs may actually begin being phased in a year or two earlier.[1]

3.2 Partial-Equilibrium Analysis for Costs Applying to Existing Kilns

The partial-equilibrium analysis performed for this rule develops a cement market model that simulates how stakeholders (consumers and firms) might respond to the additional regulatory program costs. In this section, we provide an overview of the economic model. Appendix A provides additional details on the behavioral assumptions, data, parameters, and model equations.

[1] These costs are actually draft compliance costs. The final compliance cost estimate for this rule are somewhat lower, at $317 million; this difference is not expected to have an impact on the results of the market analysis, emissions reductions, or on the expected distribution of social costs among stakeholders.

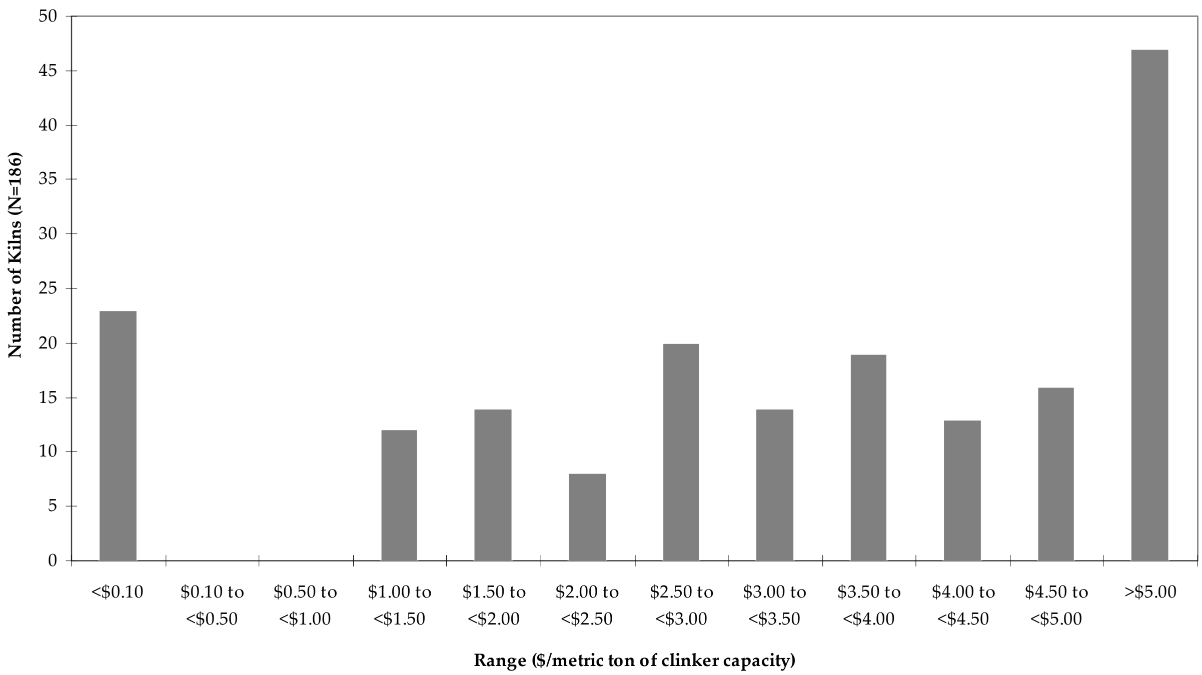

Figure 3-1. Distribution of Annualized Direct Compliance Costs per Metric Ton of Clinker Capacity: Existing Grey and White Cement Kilns (2005$)

3.2.1 Regional Structure and Baseline Data

Cement sales are often concentrated locally among a small number of firms for two reasons: high transportation costs and production economies of scale.[2] Transportation costs significantly influence where cement is ultimately sold; high transportation costs relative to unit value provide incentives to produce and sell cement locally in regional markets (USITC, 2006). To support this claim, the empirical literature has typically pointed to Census of Transportation data showing over 80% of cement shipments were made within a 200-mile radius (Jans and Rosenbaum, 1997)[3] and reported evidence of high transportation costs per dollar of product value from case studies (Ryan, 2006). Based on this literature, the Agency assumes that the U.S. Portland cement industry is divided into a number of independent regional markets with each having a single market-clearing price.

[2] The 2002 Economic Census reports that the national Herfindahl-Hirschman Index (HHI) for cement—North American Industry Classification System (NAICS) 32731—is 568. However, this measure is likely not representative of actual concentration that exists in regional markets.

[3] A recent USITC study of California cement markets found more than 75% of gray Portland cement shipments in the state were shipped to customers within 200 miles of the cement producer (USITC, 2006).

The need for a complete set of statistics makes the use of a 2005 baseline the best choice; it was the latest year for which the PCA had published their plant information summary and complete statistics for updating variable cost functions were available. However, EPA recognizes that the demand for cement is a derived demand because it is dependent on demand for sectors such as housing and construction. As a result, business cycles also influence the cement industry. If 2013 is more or less favorable for the cement industry than 2005, then impacts would be expected to change accordingly.

The freight-on-board (f.o.b.) price of Portland cement for each regional market is derived as the production weighted average of the state level f.o.b. prices reported by the USGS for cement (see Table 3-2). The production of Portland cement within each market is the sum of estimated individual kiln production levels (see Appendix A for additional details) (see Table 3-3). We obtained estimates of Portland cement imports from the USGS and mapped them to each market based on the port of entry.

Table 3-2. Portland Cement Prices by Market ($/metric tons): 2005

Market	Price ($/metric ton)
Atlanta	$81
Baltimore/Philadelphia	$86
Birmingham	$83
Chicago	$86
Cincinnati	$84
Dallas	$83
Denver	$89
Detroit	$93
Florida	$91
Kansas City	$86
Los Angeles	$97
Minneapolis	$92
New York/Boston	$89
Phoenix	$99
Pittsburgh	$88
St. Louis	$87
Salt Lake City	$91
San Antonio	$82
San Francisco	$97

Seattle	$88

Table 3-3. Portland Cement Markets (10^6 metric tons): 2005

		Imports[a]		
Market	**U.S. Production**	**Canada**	**Rest of World**	**Total**
Atlanta	6.1	—	2.3	8.4
Baltimore/Philadelphia	8.0	—	0.6	8.6
Birmingham	5.9	—	2.2	8.1
Chicago	4.3	0.2	<0.1	4.5
Cincinnati	3.7	—	—	3.7
Dallas	8.2	—	2.4	10.6
Denver	3.4	—	—	3.4
Detroit	4.8	1.3	0.1	6.1
Florida	5.6	—	5.8	11.4
Kansas City	5.3	—	0.0	5.3
Los Angeles	9.6	—	3.8	13.4
Minneapolis	1.7	0.4	—	2.1
New York/Boston	3.2	0.6	2.1	6.0
Phoenix	4.1	—	—	4.1
Pittsburgh	1.5	1.6	<0.1	3.1
St. Louis	5.4	—	—	5.4
Salt Lake City	2.4	0.1	—	2.4
San Antonio	5.7	—	4.6	10.3
San Francisco	3.4	—	2.8	6.2
Seattle	1.1	1.3	1.2	3.6
Total, Grey	93.6	5.4	27.9	126.8
Total, White	0.3	0.3	1.5	2.1
Total	93.9	5.7	29.4	129.0

[a] Hydraulic cement. The vast majority of these imports are Portland cement (approximately 29 million metric tons, or 86%). Excludes Puerto Rico.

3.2.2 *Seller Pricing Behavior*

Once the markets were defined, we examined the evidence supporting the appropriate supplier pricing behavior assumptions in these markets. For example, the degree of concentration, entry barriers, and product differentiation can indicate a firm's ability to influence market prices by varying the quantity of cement it sells. In markets with large numbers of sellers and identical products, firms are unlikely to be able to influence market prices via their production decisions (i.e., they are "price takers"). However, in markets with few firms, significant barriers to entry (e.g., licenses, legal restrictions, or high fixed costs) or with products that are similar but can be differentiated, the firm may have some degree of market power (i.e., set or significantly influence market prices).

Although perfect competition on the supply side (and demand side) is widely accepted for modeling many industries (EPA, 2000), the cement industry has unique characteristics that lead us to use an alternative assumption about supplier pricing behavior. First, high transportation costs and other production economics limit the number of sellers, so each seller has a substantial market share. Potential entry is constrained by the high capital costs that involve purchases and construction of large rotary kilns that are not readily movable or transferable to other uses. In addition, large plants are typically more economical because they can produce cement at lower unit costs; this reduces entry incentives for small-sized cement plants. Second, cement producers offer very similar or identical products. American Society for Testing and Materials (ASTM) specifications tend to ensure uniform quality, and recent industry reviews (USITC, 2006) suggest that there is little or no brand loyalty that allows firms to differentiate their products. Given this evidence, EPA continued to use the oligopoly framework used in previous economic analyses (1998, 1999b).

One consequence of this assumption is that the seller individually chooses an output level that is less than the level produced under perfect competition. As a result, the baseline market price will be higher than a model of perfect competition, and there is a preexisting market distortion in the industry being regulated.[4] The size of the existing distortion depends on the seller's market share and how responsive cement consumers are to changes in the cement price. Economic theory suggests that in the model EPA selected for this analysis, the market distortion

[4] This ultimately influences the partial-equilibrium model's estimates of the social cost of the regulatory program since bigger existing market distortions tend to widen the gap between price and marginal cost in these markets and lead to higher deadweight loss estimates than under the case of perfectly competitive markets. The Office of Management and Budget (OMB) explicitly mentions the need to consider market power–related welfare costs in evaluating regulations under Executive Order 12866 (EPA, 1999a).

will typically be higher the smaller the number of sellers and in markets where the quantity demanded is less sensitive to price (i.e., the demand elasticity is inelastic) (see Appendix A).

3.2.3 Economic Impact Analysis Results

3.2.3.1 Market-Level Results

Market-level impacts include the regional price and quantity adjustments for Portland cement, including the changes in imports for the appropriate regions. As shown in Table 3-4, the average national price for Portland cement increases by 4% higher, or \$3.30 per metric ton, while domestic production falls by 8%, or 7 million tons per year.

Table 3-4. National-Level Market Impacts: 2005

		Changes from Baseline	
	Baseline	**Absolute**	**Percent**
Market Price (\$/metric ton)	\$88.35	\$3.30	3.7%
Market Output (10^6 metric tons)	127	−4	−3.3%
Domestic production	94	−7	−7.8%
Imports	33	2	7.1%

As shown in Table 3-5, price increases are the highest in regions with high compliance costs per metric ton. For example, the Cincinnati market price increase (\$8.00 per metric ton) also includes kilns with higher average compliance costs and a kiln with the highest per-unit compliance costs (\$15.10 per metric ton).

Imports of Portland cement increase in response to higher domestic cement prices. As shown in Table 3-4, imports increase by 7%, or 2 million metric tons. Imports also tend to limit price increases in certain regions. Cement plants in these regions have more difficulty passing on compliance costs in the form of higher prices when compared with similar plants operating in regions without import competition. As shown in Table 3-6, median price increases in regions with imports are approximately 17% lower than the median price increases in regions without import competition.

Table 3-5. Regional Compliance Costs and Market Price Changes ($/metric ton of cement): 2005

Market	Compliance Costs			Market Price Change	
	Mean	Minimum	Maximum	Absolute	Percent
Atlanta	$3.20	$0.00	$6.50	$2.10	2.6%
Baltimore Philadelphia	$4.70	$0.00	$8.10	$4.60	5.3%
Birmingham	$2.30	$0.00	$4.50	$2.50	3.1%
Chicago	$3.40	$0.00	$7.10	$3.50	4.1%
Cincinnati	$7.30	$2.40	$15.10	$8.00	9.5%
Dallas	$2.70	$0.00	$6.40	$4.30	5.2%
Denver	$2.90	$1.30	$4.90	$4.80	5.4%
Detroit	$3.50	$0.00	$6.20	$3.80	4.1%
Florida	$2.30	$1.10	$3.10	$1.90	2.1%
Kansas City	$4.90	$0.00	$9.30	$4.90	5.7%
Los Angeles	$4.00	$2.30	$6.20	$2.80	2.9%
Minneapolis	$3.60	$2.40	$5.60	$4.80	5.2%
New York Boston	$2.50	$1.30	$4.20	$1.60	1.8%
Phoenix	$2.80	$1.20	$5.60	$3.30	3.3%
Pittsburgh	$4.90	$4.50	$5.30	$3.40	3.9%
St Louis	$2.10	$0.00	$4.10	$2.40	2.7%
Salt Lake City	$4.60	$2.90	$6.60	$5.50	6.0%
San Antonio	$4.00	$1.50	$7.50	$3.10	3.8%
San Francisco	$2.40	$1.60	$3.20	$2.00	2.1%
Seattle	$1.60	$1.20	$2.00	$0.80	0.9%
National	$3.00	$0.00	$15.10	$3.30	3.7%

3.2.3.2 Industry-Level Results

As domestic production falls, cement industry revenues are projected to decline by 4%, or $341 million (see Table 3-7). Overall, net production costs also fall by $137 million with compliance cost increases ($235 million) offset by cost reductions associated with lower cement production. Operating profits fall by $204 million, or 16%. Other consequences include reduced demand for labor. Employment falls by approximately 8%, or 1,167 employees.

Table 3-6. Summary of Regional Market Impacts: 2005

	Regional Markets		
	With Imports	Without Imports	All Markets
Change in Market Price			
Absolute ($/metric ton)			
Mean	$3.20	$4.60	$3.30
Median	$3.30	$4.00	$3.30
Minimum	$0.80	$2.40	$0.80
Maximum	$5.50	$8.00	$8.00
Percentage of baseline price			
Mean	3.7%	5.2%	3.7%
Median	3.8%	4.4%	3.8%
Minimum	0.9%	2.7%	0.9%
Maximum	6.0%	9.5%	9.5%
Change in Domestic Production			
Absolute (10^3 metric tons)			
Mean	−408.6	−189.8	−207.5
Median	−333.1	−160.5	−179.4
Minimum	−79.9	−129.1	−27.2
Maximum	−931.5	−309.0	−486.7
Percentage of baseline production			
Mean	−8.7%	−4.8%	−8.0%
Median	−7.8%	−4.3%	−7.4%
Minimum	−3.8%	−2.4%	−2.4%
Maximum	−21.8%	−8.4%	−21.8%

As shown in Table 3-8, compliance costs vary by cement plant, and this variation suggests some plants will be more adversely affected than others. To assess these differences, EPA collected industry operating profit data and identified plants with operating profit increases and losses. Absent plant-specific data, EPA assumed each plant's baseline profits were consistent with the median operating profit margin reported by the PCA (2008c, Table 44). In 2005, this value was $18 per metric ton, or 15.7%. Using this assumption, total operating profits for 67 plants (64%) decrease by $328 million with regulation. These plants tend to be larger major sources and have higher unit compliance costs. The remaining plants' compliance burden is

Table 3-7. National-Level Industry Impacts: 2005

	Baseline	Changes from Baseline: Absolute	Changes from Baseline: Percent
Revenues ($\$10^6$)	\$8,261	−\$341	−4.1%
Costs ($\$10^6$)	\$6,966	−\$137	−2.0%
Cement production	\$6,966	−\$372	−5.3%
Regulatory program	\$0	\$235	NA
Operating Profits ($\$10^6$)	\$1,294	−\$204	−15.8%
Employment	15,440	−1,167	−7.6%

NA = Not available.

Table 3-8. Distributional of Industry Impacts: 2005

	Changes in Total Operating Profit: Plants with Loss	Changes in Total Operating Profit: Plants with Gain	Changes in Total Operating Profit: All Plants
Number	67	38	105
Cement Capacity (10^6 metric tons)			
Total	64,757	35,668	100,424
Average per plant	967	939	956
Compliance Costs			
Total ($\$10^3$)	\$230,894	\$46,829	\$277,722
Average (\$/metric cement)	\$3.57	\$1.31	\$2.77
Capacity Utilization (%)			
Baseline	93.4%	92.9%	93.2%
With regulation	80.4%	95.9%	85.9%
Change in total operating profits ($\$10^6$)	−\$329	\$125	−\$204
Change in Employees	−1,345	178	−1,167

offset by higher cement prices, and total plant operating profits increase by \$125 million. These plants are typically smaller area sources and have lower unit compliance costs compared with their competitors.

Within the group of plants with operating losses, EPA identified six domestic plants with negative operating profits and significant utilization changes that could temporarily idle until market demand conditions improve (see Table 3-9). The plants are small capacity plants with unit compliance costs close to \$5 per ton; they account for approximately 2.5% of domestic

Table 3-9. Cement Plants with Significant Utilization Changes: 2005

	Total
Number	6
Cement Capacity (10^6 metric tons)	
Total	2,860
Average per plant	477
Compliance Costs	
Total ($\$10^3$)	$14,185
Average ($/metric cement)	$4.96
Capacity Utilization (%)	
Baseline	94.7%
With regulation	39.3%
Change in Operating Profit ($\$10^6$)	−$50
Change in Employees	−208

capacity. If the plant owners did decide to permanently shut down these plants, the reduction in domestic supply would lead to additional projected market price increases. Reducing national supply by an additional 2 million metric tons and holding other domestic and foreign supply fixed, EPA calculations suggest the national cement price could rise by 6.5% ($5.80 per metric ton).

3.3 Direct Compliance Cost Method for White Cement Kilns and Kilns Coming On Line in 2013

The partial-equilibrium analysis is an illustrative example of the economic impacts associated with the engineering cost analysis for existing kilns ($280 million in direct compliance costs). In addition, EPA developed a separate engineering cost analysis for four white cement kilns and an additional 20 kilns that are likely to come on line by 2013. These costs were not included in the EIA because of uncertainties associated with cement market conditions in 2013.

The total annualized costs for white cement kilns are $1.5 million, or $4.90 per metric ton of clinker capacity. Using reported 2005 data from the USGS on the average mill net value of white cement ($176 per metric ton), this cost represents between 2.5 and 2.8% of the product value.

Using a model kiln with a clinker capacity of 1.2 million metric tons, EPA estimates the total annualized costs for 20 additional kilns coming on line in 2013 to be \$86 million. The average cost per ton of clinker capacity is approximately \$4.00.[5]

Using a range of historical national price data and unit cost data, EPA conducted sales tests for a representative kiln:

Sales Test Ratio = Control Costs (\$/ton)/F.O.B Cement Prices (\$/ton).

The USGS reports that the real price of cement per metric ton (2005 dollars) has typically ranged between \$75 and \$100 since 1990. A sales test using these data shows cost-to-sales ratios (CSRs) between 3 and 5% (see Figure 3-2).

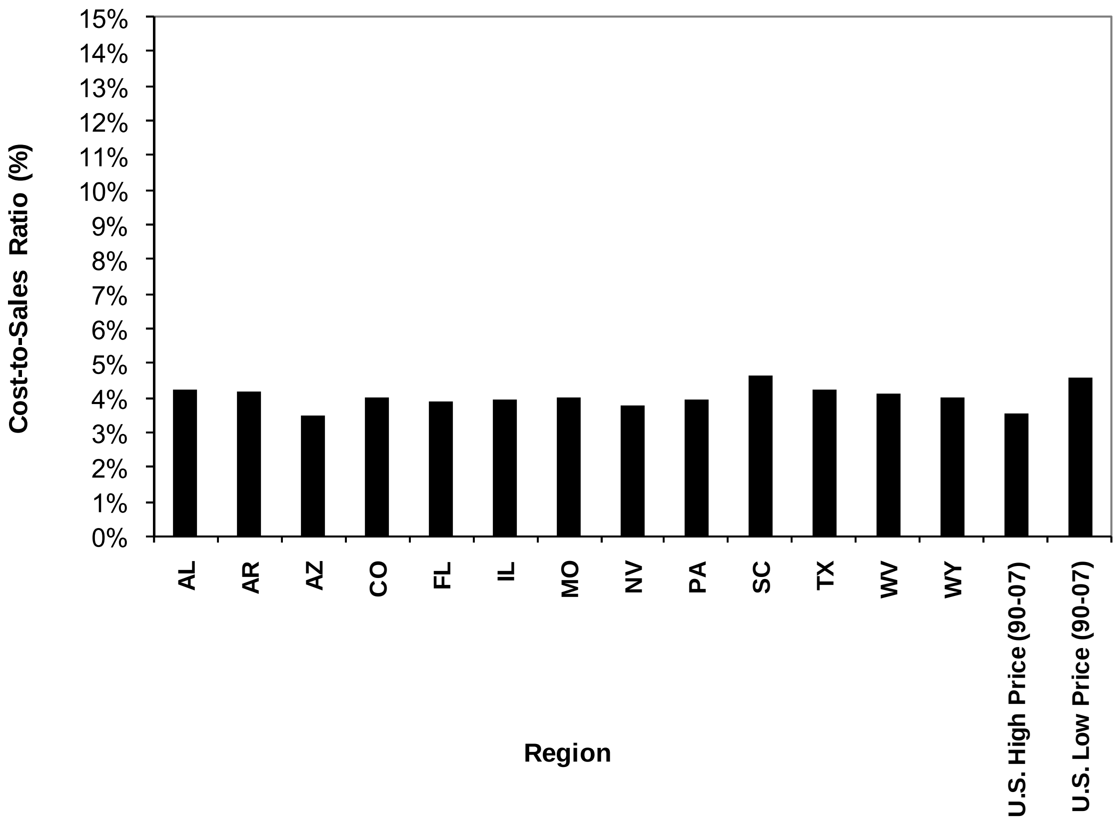

Figure 3-2. Hypothetical Cost-to-Sales Ratios for a Representative Kiln Coming On Line in 2013

[5] Using a cement/clinker ratio of 1.14, this is approximately \$3.50 per ton of cement.

From 2000 to 2006, the PCA reports that the average operating profit rates for the industry ranged from 17 to 21% (PCA, 2008c). If these profit data are representative of operating profit rates for new kilns, kilns could potentially significantly reduce their operating profit rates. As a result, companies may have the incentive to look for less expensive alternatives to meet the emission standards. If these alternatives are limited or not cost effective, the NESHAP may lead companies to consider delaying rates of construction of these new kilns until market conditions change (e.g., increases in demand that lead to rising cement prices) to cover these additional control costs.

3.4 Social Cost Estimates

The market adjustments in price and quantity were used to estimate the changes in aggregate economic welfare using applied welfare economics principles (see Appendix C). Table 3-10 presents the estimates of the social costs and their distribution. Higher cement prices and reduced consumption lead to consumer welfare losses ($402 million). Domestic producers (in aggregate) experience a net loss of $204 million. As noted in the previous section, individual domestic producers will gain or lose depending on the change in costs versus the change in the regional market prices. The total domestic surplus loss (consumer and producers) totals $606 million. Other countries selling cement to the United States will benefit from higher cement prices (a surplus gain of $89 million). The resulting net change in total surplus estimated by the partial-equilibrium analysis is $517 million.

The estimated social cost of the proposed NESHAP is $606 million. This estimate includes the results for existing kilns included in the partial-equilibrium analysis ($517 million) and the direct compliance costs for white cement kilns ($2 million) and 20 additional kilns projected to come on line in 2013 ($86 million). The social estimates are significantly higher than the engineering analysis estimate of annualized costs totaling $368 million. This is a direct consequence of EPA's assumptions about existing domestic plants' pricing behavior discussed extensively in previous cement industry rulemakings and in Section 2 and Appendix B of this RIA. Under baseline conditions without regulation, the existing domestic cement plants are assumed to choose a production level that is less than the level produced under perfect competition. As a result, a preexisting market distortion exists in the markets covered by the proposed rule (i.e., the observed baseline market price is higher than the [unobserved] market price that a model of perfect competition would predict). The imposition of additional regulatory costs tends to widen the gap between price and marginal cost in these markets and contributes to additional social costs. The above social costs for 2013 include annualized capital costs over the expected lifetime of the equipment and an opportunity cost of capital (7%) discount rate. To facilitate comparisons of benefits and costs when estimates vary of time across multiple years, EPA typically estimates a "consumption equivalent" present value measure of costs. This could be computed using a consumption rate of interest of 3% and 7%. However, this calculation was not necessary since the cost and benefit analyses only produce estimates for a single year (OAQPS, 1999a).

Table 3-10. Distribution of Social Costs ($\$10^6$): 2005

Partial-Equilibrium Model	
Change in consumer surplus	−$402
Change in domestic producer surplus	−$204
Change in domestic surplus	−$606
Change in foreign producer surplus	$89
Net change in total surplus	−$517
Direct Compliance Costs Method	
White cement (not modeled)	−$2
New kilns (not modeled)	−$86
Change in total surplus	−$605

3.5 Energy Impacts

Executive Order 13211 (66 FR 28355, May 22, 2001) provides that agencies will prepare and submit to the Administrator of the Office of Information and Regulatory Affairs, OMB, a Statement of Energy Effects for certain actions identified as "significant energy actions." Section 4(b) of Executive Order 13211 defines "significant energy actions" as any action by an agency (normally published in the *Federal Register*) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking: (1) (i) that is a significant regulatory action under Executive Order 12866 or any successor order, and (ii) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action.

This rule is not a significant energy action as designated by the Administrator of the Office of Information and Regulatory Affairs because it is not likely to have a significant adverse impact on the supply, distribution, or use of energy. EPA has prepared an analysis of energy impacts that explains this conclusion below.

To enhance understanding regarding the regulation's influence on energy consumption, EPA examined publicly available data describing the cement sector's energy consumption. The *AEO 2009* (DOE, 2008) provides energy consumption data. As shown in Table 3-11, this industry accounts for less than 0.4% of the U.S. total energy consumption. As a result, any energy consumption changes attributable to the regulatory program should not significantly influence the supply, distribution, or use of energy. EPA has also estimated the

Table 3-11. U.S. Cement Sector Energy Consumption (Trillion BTUs)[a]: 2013

	Quantity	Share of Total Energy Use
Residual fuel oil	1.05	0.0%
Distillate fuel oil	7.97	0.0%
Petroleum coke	53.70	0.1%
Other petroleum[b]	34.35	0.0%
Petroleum subtotal	97.07	0.1%
Natural gas	22.55	0.0%
Steam coal	227.33	0.2%
Metallurgical coal	7.70	0.0%
Coal subtotal	235.03	0.2%
Purchased electricity	44.79	0.0%
Total	399.44	0.4%
Delivered Energy Use	74,045	72.2%
Total Energy Use	102,581	100.0%

[a] Fuel consumption includes consumption for combined heat and power.

[b] Includes petroleum coke, lubricants, and miscellaneous petroleum products.

Source: U.S. Department of Energy, Energy Information Administration. 2008. Supplemental Tables to the Annual Energy Outlook 2009. Table 10 and Table 39. Available at <http://www.eia.doe.gov/oiaf/aeo/supplement/supref.html>.

amount of additional electricity consumption associated with add-on controls. The analysis shows electricity consumption may increase by 926 million kWh per year as a result of these controls. This is less than 0.1% of *AEO* 2013 electricity forecasts of total electricity use (4,091 billion kWh).

SECTION 4
SMALL BUSINESS IMPACT ANALYSIS

The Regulatory Flexibility Act (RFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a *significant* economic impact on a *substantial* number of small entities (SISNOSE). The first step in this assessment was to determine whether the rule will have SISNOSE. To make this determination, EPA used a screening and market analysis to indicate whether EPA can certify the rule as not having a SISNOSE. The elements of this analysis included

- identifying affected small entities,
- selecting and describing the measures and economic impact thresholds used in the analysis, and
- completing the assessment and determining the SISNOSE certification category.

4.1 Identify Affected Small Entities

For the purposes of assessing the impacts of the proposed rule on small entities, small entity is defined as (1) a small business as defined by the Small Business Administration's regulations at 13 CFR 121.201; according to these size standards, ultimate parent companies owning Portland cement manufacturing plants are categorized as small if the total number of employees at the firm is fewer than 750 (see Table 4-1 for list); (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise that is independently owned and operated and is not dominant in its field. As reported in Section 2, EPA has identified four small entities (see Table 4-1). One of the four entities is owned by a small Tribal government (Salt River Pima-Maricopa Indian Community). The remaining three entities are small businesses.

4.2 Sales and Revenue Test Screening Analysis

In the next step of the analysis, EPA assessed how the regulatory program may influence the profitability of ultimate parent companies by comparing pollution control costs to total sales (i.e., a "sales" test). To do this, we divided an ultimate parent company's total annualized compliance costs by its reported revenue:

Table 4-1. Small Entity Summary Data: 2005

Owner	Entity Type	Annual Sales ($$10^6$)	Employees	Plants	Kilns	Clinker Capacity (10^3 metric tons per year)	U.S. Capacity Share
Salt River Materials Group[a]	Tribal government	$184[b]	NA	1	4	1,477	1.6%
Monarch Cement Company	Business	$154	600	1	2	787	0.8%
Continental Cement Company, LLC	Business	$50[c]	<750	1	1	549	0.6%
Snyder Associate Companies	Business	$29	350	1	2	286	0.3%

[a] Enterprise is owned by Salt River Pima-Maricopa Indian Community.

[b] EPA estimate. Estimate uses revenue data for four of the six enterprises owned by Salt River Pima-Maricopa Indian Community.

[c] EPA estimate. Estimate uses cement production levels and average market prices.

$$CSR = \frac{\sum_{i}^{n} TACC}{TR_j} \tag{4.1}$$

where

CSR = cost-to-sales ratio,

TACC = total annualized compliance costs,

i = index of the number of affected plants owned by company j,

n = number of affected plants, and

TR_j = total sales from all operations of ultimate parent company j or annual government revenue.

This method assumes the affected entity cannot shift pollution control costs to consumers (in the form of higher market prices). Instead, the owning entity experiences a one-for-one reduction in profits. For small entities, the total reduction in profits under this method is approximately $7, and the average loss is $0.7 million per kiln.

The results of the screening analysis, presented in Figure 4-1 and Table 4-2, show that one small business has a CSR greater than 3%. One small business and one small government have an estimated CSR between 1 and 3%. The average (median) CSR for small entities is 2.0% (1.5%), and the average and median CSR for all large entities is 0.5% (0.3%).

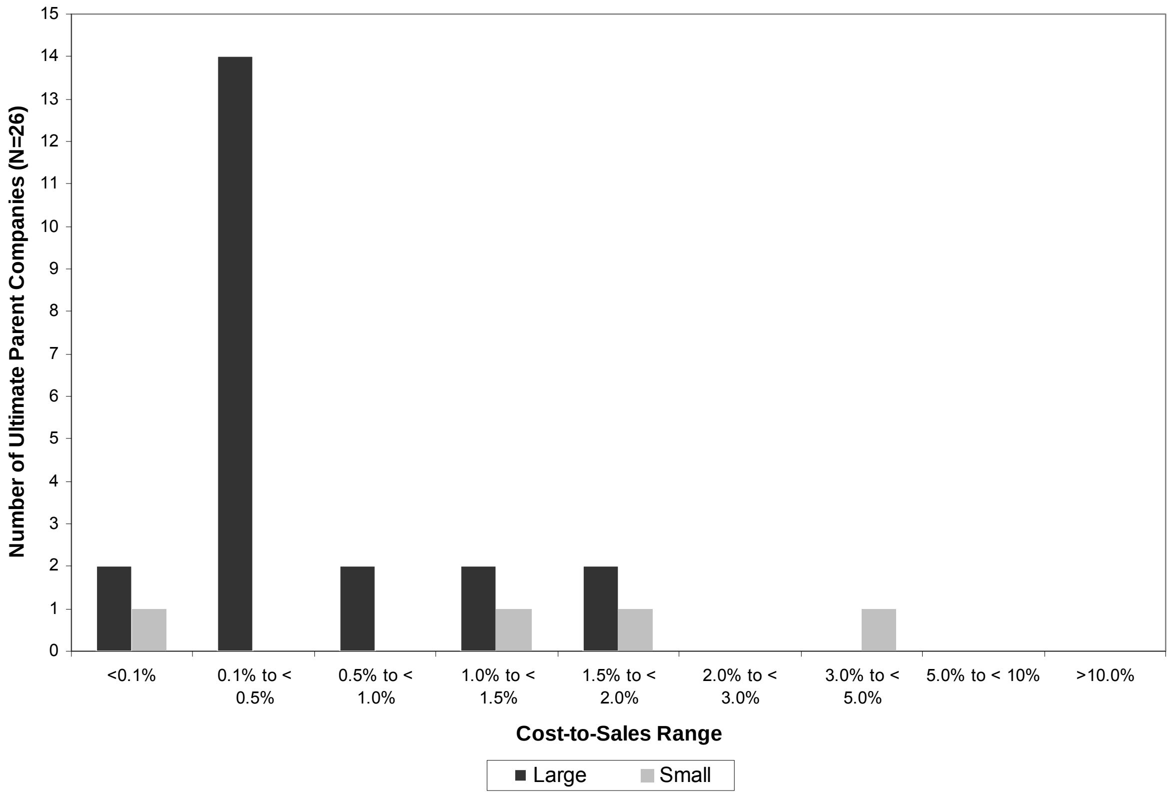

Figure 4-1. SBREFA Screening Analysis Results

4.3 Additional Market Analysis

In additional to the screening analysis, EPA also examined small entity effects after accounting for market adjustments. Under this assumption, the entities recover some of the regulatory program costs as the market price adjusts in response to higher cement production costs. Even after accounting for these adjustments, small entity operating profits fall by $4 million, or 9% (see Table 4-3). However, all nine cement kilns continue to operate under with-regulation conditions. As cement production falls, employment may decline by up to 23 employees, a 5% reduction.

Table 4-2. Summary Statistics for Small Business Regulatory Enforcement Fairness Act (SBREFA) Screening Analysis

	Small		Large	
	Number	**Share (%)**	**Number**	**Share (%)**
Companies	4	100%	22	100%
Compliance costs are <1% of sales	1	25%	18	82%
Compliance costs are ≥1% to 3% of sales	2	50%	4	18%
Compliance costs are ≥3% of sales	1	25%	0	0%
Annualized Compliance Cost Summary				
Total ($$10^6$)	$7		$273	
Average ($$10^6$ per kiln)	$0.7		$1.5	
Average ($ per metric ton)	$2.22		$3.23	
Cost-to-Sales Ratios (%)				
Average	2.0%		0.5%	
Median	1.5%		0.3%	
Maximum	4.8%		1.9%	
Minimum	0.0%		0.0%	

Table 4-3. Market Analysis—Small Entity Impacts: 2005

		Changes from Baseline	
	Baseline	**Absolute**	**Percent**
Revenues ($$10^6$)	$293	−$10	−3.6%
Costs ($$10^6$)	$0	−$6	−2,602.4%
Cement production	$247	−$12	−4.8%
Proposed NESHAP	$0	$6	NA
Operating profit ($$10^6$)[a]	$46	−$4	−8.7%
Employment	490	−23	−4.6%

[a] Estimates using median results of cement operations reported by PCA (2007, Table 44) ($18 per metric ton, or 15.7%).

SECTION 5
HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

5.1 Summary

EPA benefits estimates are the monetized human health co-benefits of reducing cases of morbidity and premature mortality among populations exposed to $PM_{2.5}$ from installing controls to limit hazardous air pollutants (HAPs), such as mercury, hydrochloric acid, and hydrocarbons. For the proposed Portland Cement NESHAP, EPA estimates the $PM_{2.5}$-related co-benefits of to be $4.4 billion to $11 billion (2005$) in the year of full implementation (2013).[1] These are our preferred estimates, which reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality. They reflect our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes.[2] The anchor points for these estimates are derived from two empirical (epidemiological) studies of the relationship between ambient $PM_{2.5}$ and premature mortality (the extended analyses of the Harvard Six Cities study by Laden et al (2006) and the American Cancer Society cohort by Pope et al (2002)). Since 2006, EPA had calculated benefits based on these two empirical studies, but derived the range of benefits, including the minimum and maximum results, from an expert elicitation of the relationship between exposure to $PM_{2.5}$ and premature mortality (Roman et al., 2008). Using alternate relationships between $PM_{2.5}$ and premature mortality supplied by experts, higher and lower benefits estimates are plausible (see Figure 5-1 below), but most of the expert-based estimates fall between the two epidemiology-based estimates (Roman et al., 2008). Methodological limitations prevented EPA from quantifying the monetized benefits of emissions reductions from HAPs.

[1] These benefits results use a 3% discount rate. Using a 7% discount rate, the benefits are about 9% to 10% less.
[2] Using the previous methodology (i.e., a threshold model at 10 $\mu g/m^3$ without two technical updates), EPA estimates the $PM_{2.5}$-related co-benefits of the proposed Portland Cement NESHAP to be $ 3.1 billion to $ 6.5 billion (2005$) in the year of full implementation (2013).

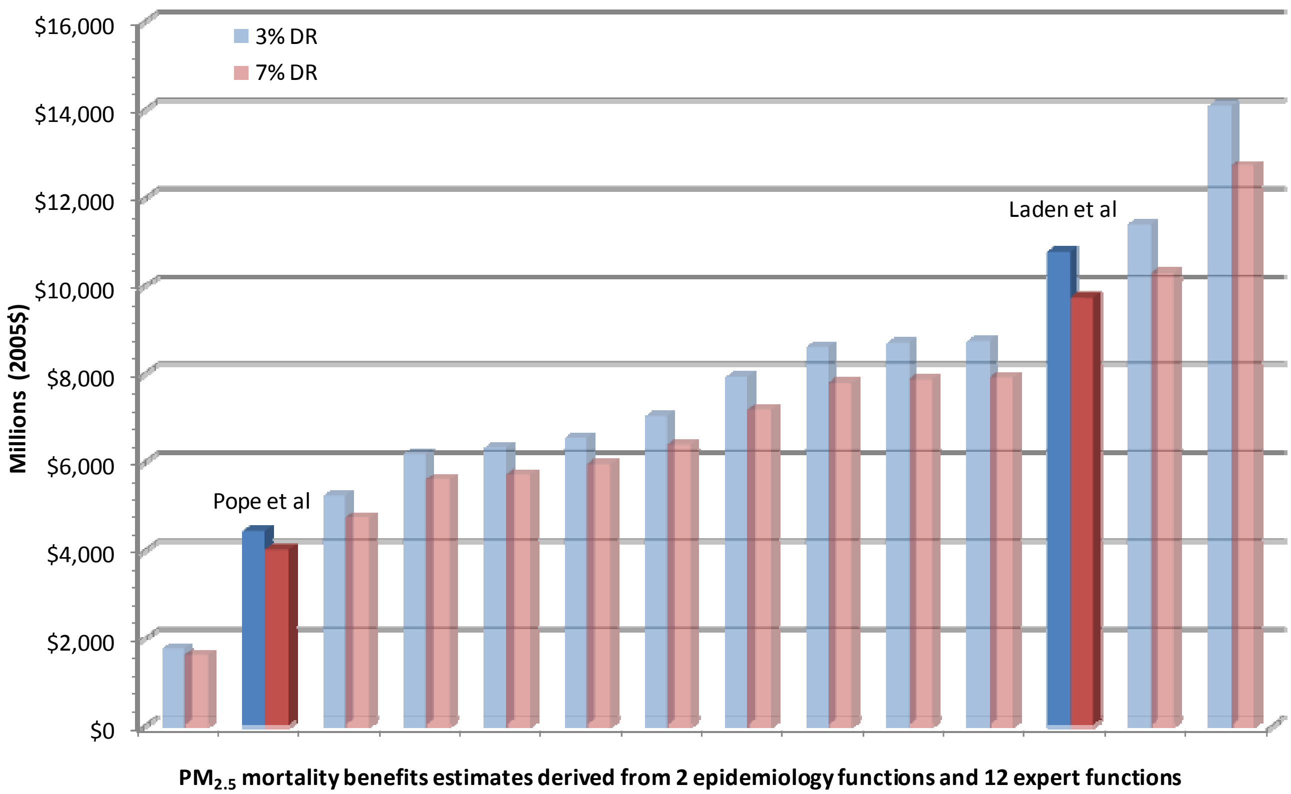

Figure 5-1. Monetized Human Health Co-Benefits of Proposed Portland Cement NESHAP in 2013[a]

[a] This graph shows the estimated benefits using the no-threshold at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

5.2 Calculation of Human Health Benefits

To estimate the $PM_{2.5}$-related human health benefits of reducing emissions from the proposed NESHAP for Portland Cement kilns, EPA used the benefits transfer approach it created for the regulatory impact analysis (RIA) accompanying the recent National Ambient Air Quality Standards (NAAQS) for Ozone.[1,2] This methodology incorporates the best available science, which is described in detail below. In that RIA, EPA developed and applied $PM_{2.5}$ benefit-per-ton coefficients to estimate the $PM_{2.5}$ co-benefits resulting from reductions in emissions of NO_X.

[1] U.S. EPA, 2008c. *Technical Support Document: Calculating Benefit Per-Ton estimates,* Ozone NAAQS Docket #EPA-HQ-OAR-2007-0225-0284. Available on the Internet at http://www.regulations.gov.

[2] U.S. EPA, 2008b. *Regulatory Impact Analysis, 2008 National Ambient Air Quality Standards for Ground-level Ozone*, Chapter 6. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/RIAs/6-ozoneriachapter6.pdf.

EPA has followed that same approach to estimate the health benefits for the projected emission reductions of $PM_{2.5}$ precursor pollutants associated with this proposal, but has made incremental updates to the benefit-per-ton estimates to reflect new science and data, as discussed below.

EPA did not perform an air quality modeling assessment of the emission reductions resulting from installing controls on these kilns because of the time and resource constraints and the limited value of such an analysis for the purposes of developing the regulatory approach for this proposal. This lack of air quality modeling limited EPA's ability to perform a comprehensive benefits analysis for this proposal because our benefits model BenMAP requires either air quality modeling or monitoring data. In the absence of formal air quality modeling, we applied $PM_{2.5}$ benefit-per-ton coefficients to estimate benefits. In addition to the 2008 Ozone NAAQS RIA, this benefit-per-ton approach has been used in RIAs prepared for a number of previous EPA rulemakings (e.g., the 2002 large industrial spark ignition engine and recreational vehicles rule, the 2004 Industrial Boilers and Process Heaters MACT, and the 2008 Petroleum Refineries NSPS).

The benefit per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and morbidity related benefits) of reducing one ton of $PM_{2.5}$ or $PM_{2.5}$ precursor emissions from a specified source. We include direct $PM_{2.5}$ and $PM_{2.5}$ precursor emissions (SO_X). These PM benefits are actually co-benefits, which result from the installing controls to limit hazardous air pollutants (HAPs). Methodological limitations prevented EPA from quantifying the monetized benefits of other emissions reductions from this proposed NESHAP, including 8 tons of mercury, 3,900 tons of hydrochloric acid, and 14,780 tons of total hydrocarbons annually. In addition, these monetized benefits do not incorporate additional emission reductions that would occur if cement facilities temporarily idle or reduce capacity utilization as a result of this regulation. Using the benefit-per-ton approach, we are unable to monetize the anticipated improvements in visibility due to reductions in $PM_{2.5}$ and $PM_{2.5}$ precursors.

The PM co-benefits estimates in this proposal analysis utilize the same concentration-response functions as described in the PM NAAQS RIA analysis.[1] Each data source is described below:

- One estimate is based on the concentration-response (C-R) function developed from the extended analysis of American Cancer Society (ACS) cohort, as reported in Pope

[1] U.S. EPA, 2006. *Regulatory Impact Analysis, 2006 National Ambient Air Quality Standards for Particulate Matter*, Chapter 5. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf.

et al. (2002), a study that EPA has previously used to generate its primary benefits estimate. When calculating the preferred estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 µg/m^3 as was done in recent (post 2006) RIAs.

- One estimate is based on the C-R function developed from the extended analysis of the Harvard Six Cities cohort, as reported by Laden et al (2006). This study, published after the completion of the Staff Paper for the 2006 PM NAAQS, has been used as an alternative estimate in the PM NAAQS RIA and PM co-benefits estimates in RIAs completed since the PM NAAQS. When calculating the preferred estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 µg/m^3 as was done in recent (post 2006) RIAs.

- Twelve estimates are based on the C-R functions from EPA's expert elicitation study[1,2] on the PM-mortality relationship and interpreted for benefits analysis in EPA's final RIA for the PM NAAQS. For that study, twelve experts (labeled A through L) provided independent estimates of the PM-mortality concentration-response function. EPA practice has been to develop independent estimates of PM-mortality estimates corresponding to the concentration-response function provided by each of the twelve experts, to better characterize the degree of variability in the expert responses.

The effect coefficients are drawn from epidemiology studies examining two large population cohorts: the American Cancer Society cohort (Pope et al., 2002) and the Harvard Six Cities cohort (Laden et al., 2006)[3]. These are logical choices for anchor points in our presentation because, while both studies are well designed and peer reviewed, there are strengths and weaknesses inherent in each, which we believe argues for using both studies to generate benefits estimates. Using estimates from both cohorts substantially narrows the range of benefits estimates when compared to the range of estimates from the expert elicitation.. Because the experts used these studies based on these cohorts to inform their concentration-response functions, benefits estimates using these functions generally fall between results using these epidemiology studies. As Figure 5-1 illustrates, the Pope et al. (2002) and Laden et al. (2006) estimates, based on the ACS and Six Cities cohorts, respectively, capture the mass of expert

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[1] Industrial Economics, Inc., 2006. *Expanded Expert Judgment Assessment of the Concentration-Response Relationship Between $PM_{2.5}$ Exposure and Mortality*. Prepared for the U.S. EPA, Office of Air Quality Planning and Standards, September. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/Uncertainty/pm_ee_report.pdf.

[2] Roman et al., 2008. Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S. Environ. Sci. Technol., 42, 7, 2268–2274.

[3] The American Cancer Society (ACS) cohort analyzed by Pope et al. includes a larger number of cities, and a greater population size, than the Harvard Six Cities cohort. However, the ACS cohort is also more affluent and less diverse, than the average population. Alternately, the Six Cities cohort offers a superior estimate of PM exposure.

opinion, while preserving the empirical basis of our estimates. This presentation style is flexible enough to incorporate future epidemiology studies based on these cohorts.

In recent RIAs, EPA presented benefits estimates using concentration response functions derived from the $PM_{2.5}$ Expert Elicitation as a range from the lowest expert value (Expert K) to the highest expert value (Expert E) (Roman et al., 2008; IEc, 2006). Although this approach characterized the bounds of the expert elicitation, it generated a range of benefits estimates extending nearly an order of magnitude. In addition, this approach did not indicate the agency's judgment on what the best estimate of PM benefits may be. According to EPA's Science Advisory Board, this presentation was misleading because:

1. "…[T]his is, in fact, a form of aggregation that assigns positive weight to the most extreme judgments and zero weight to all the others…,"[1] and
2. "…[T]he casual reader could easily infer substantial differences in scientific opinion when, in fact, there was a pronounced central cluster of views on PM2.5 mortality."[2]

The SAB advice captures the tension between providing readers with a coherent estimate of total benefits while also respecting the underlying uncertainty in the epidemiology-derived estimates of PM mortality. For this reason, above we present the cohort-based benefits estimates as well as the results of the Expert Elicitation jointly (see Figure 5-1).[3]

The effect coefficients are drawn from epidemiology studies examining two large population cohorts: the American Cancer Society cohort (Pope et al., 2002) and the Harvard Six Cities cohort (Laden et al., 2006).[4] These two studies are logical choices, given that EPA has previously applied effect coefficients from each analysis and these studies informed the judgment of the twelve experts as they developed their estimates.[5] While both studies are well designed and peer reviewed, there are strengths and weaknesses inherent in each, which we

[1] U.S. Environmental Protection Agency Science Advisory Board, 2008. *Characterizing Uncertainty in Particulate Matter Benefits Using Expert Elicitation*. EPA-COUNCIL-08-002. Pp 6.

[2] U.S. Environmental Protection Agency Science Advisory Board, 2008. *Characterizing Uncertainty in Particulate Matter Benefits Using Expert Elicitation*. EPA-COUNCIL-08-002. Pp ii.

[3] In the near term, we are using two alternate PM mortality estimates as a surrogate for a single central estimate, which will likely be interpreted as a range. We are still trying to determine how to present two alternate benefits estimates without implying a range, and we will continue to develop methods to improve the clarity of the benefits presentation.

[4] The American Cancer Society (ACS) cohort analyzed by Pope et al. includes a larger number of cities, and a greater population size, than the Harvard Six Cities cohort. However, the ACS cohort is also more affluent and less diverse, than the average population. Alternately, the Six Cities cohort offers a superior estimate of PM exposure.

[5] According to the expert elicitation report, "All of the experts cited the long-term cohort-based studies as major evidence in support of a positive relationship between ambient annual average $PM_{2.5}$ concentrations and mortality" (IEc, 2006, page 3-10).

believe argues for using both studies to generate the benefits estimates. Using both estimates from each cohort substantially narrows the range of benefits estimates. Because the experts used these studies based on these cohorts to inform their concentration-response functions, benefits estimates using these functions generally fall between results using these epidemiology studies. As Figure 5-1 illustrates, the Pope et al. (2002) and Laden et al. (2006) estimates, based on the ACS and Six Cities cohorts, respectively, capture the mass of expert opinion, while preserving the empirical basis of our estimates. This presentation style is flexible enough to incorporate future epidemiology studies based on these cohorts. Finally, this approach is generally consistent with advice from both the National Academy of Sciences (NRC, 2002) and the Science Advisory Board (U.S. EPA-SAB, 2004) directing EPA to rely upon prospective cohort studies as the basis for estimating PM mortality effects.

Within this benefits chapter, EPA presents independent estimates of PM-mortality estimates corresponding to the concentration-response function provided by each of the twelve experts to better characterize the degree of variability in the expert responses. Because in this RIA we estimate benefits using benefit-per-ton estimates, technical limitations prevent us from providing the associated credible intervals with the expert functions. EPA believes that the estimates derived from the expert elicitation are indicative of the uncertainty associated with a major component of the health impact functions; whereas, the benefits represented by estimates derived from Pope et al. and Laden et al. represent the preferred estimates of PM co-benefits. In general, the expert elicitation results support the conclusion that the benefits of $PM_{2.5}$ control are very likely to be substantial.

To develop the estimate of the co-benefits of reducing emissions from this proposal, we calculated the monetized benefits-per-ton of emissions reduction estimates for direct $PM_{2.5}$ and each $PM_{2.5}$ precursor pollutant. Readers interested in the complete methodology for creating the benefit-per-ton estimates used in this analysis may consult the Technical Support Document (TSD) accompanying the final Ozone NAAQS RIA (U.S. EPA, 2008c). In the TSD, we describe in detail how we generated the benefit-per-ton estimates. In summary, we used a model to convert emissions of direct $PM_{2.5}$ and $PM_{2.5}$ precursors (i.e., SO_2, NO_X, and VOCs) into changes in $PM_{2.5}$ air quality. Next, we used the benefits model (BenMAP) to estimate the changes in human health based on the change in $PM_{2.5}$ air quality. Finally, the monetized health benefits were divided by the emission reductions to create the benefit-per-ton estimates. Even though all fine particles are assumed to have equivalent health effects, the benefit-per-ton estimates vary between precursors because each ton of precursor reduced has a different propensity to form $PM_{2.5}$. For example, SO_X has a lower benefit-per-ton estimate than direct $PM_{2.5}$ because it may form $PM_{2.5}$ further from population centers than directly emitted $PM_{2.5}$ and thus and the monetized health benefits would be lower. After generating the benefit-per-ton estimate, we then multiply this estimate by the number of tons of each pollutant reduced to derive an overall monetary value of benefits.

It is important to note that the monetized benefit-per-ton estimates used here reflect specific geographic patterns of emissions reductions and specific air quality and benefits modeling assumptions. Use of these $/ton values to estimate benefits associated with different emission control programs (e.g., for reducing emissions from large stationary sources like EGUs) may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on national or broad regional emission reduction programs and therefore represent average benefits-per-ton over the entire United States. The benefits-per-ton for emission reductions in specific locations may be very different from the national average.

5.3 Assumptions regarding Thresholds in the Health Impact Function

The preferred benefit-per-ton coefficients in this analysis were derived using modified versions of the health impact functions used in the PM NAAQS Regulatory Impact Analysis. Specifically, EPA selected the same mortality and morbidity studies as were used in that RIA, but used models both with and without an assumed threshold for $PM_{2.5}$ related threshold adverse effects to test the sensitivity of this assumption. The Agency's peer review process conducted through the Science Advisory Board has provided advice regarding analytic treatment of thresholds for PM multiple times.

- In 1999, the SAB Advisory Council on Clean Air Compliance Analysis (ACCACA) concluded that there was currently no scientific basis for selecting any specific threshold (EPA-SAB, 1999).
- In 2004, the Health and Environmental Effect subcommittee of ACCACA concluded, "it is reasonable for EPA to assume a no threshold model down to, at least, the low end of the concentrations reported in the studies" (EPA-SAB, 2004).
- In 2005, CASAC indicated that "[t]he available epidemiological database on daily mortality and morbidity does not establish either the presence or absence of threshold concentrations for adverse health effects" (EPA-SAB, 2005).

In addition, in 2002, as a part of their review of EPA benefits methods, the National Research Council concluded that there is no evidence for any departure from linearity in the observed range of exposure to PM_{10} or $PM_{2.5}$, nor any indication of a threshold (NRC, 2002).

They cite the weight of evidence available from both short- and long-term exposure models and the similar effects found in cities with low and high ambient concentrations of PM.

These conclusions were based on a wide body of peer-reviewed literature on health effects of short and longer term PM exposures (Daniels et al., 2000; Pope, 2000; Pope et al., 2002; Rossi et al., 1999; Schwartz and Zanobetti, 2000; Schwartz et al., 2002; Smith et al., 2000; Krewski et al., 2000).

In the time since the CASAC advice was received, the EPA, with close OMB collaboration, conducted a $PM_{2.5}$ Expert Elicitation in which experts were asked to describe the true relationship between $PM_{2.5}$ exposure and premature mortality (Roman, 2008; I.Ec., 2006). Of the 12 experts included in the elicitation, only one expert (Expert K) elected to specify a threshold, as the rest cited a lack of empirical and/or theoretical basis for a population threshold. Expert K specified a 50% chance of no threshold, a 40% chance that there would be a threshold at a concentration of less than 5 $\mu g/m^3$, and only a 10% chance that there would be a threshold between 5 and 10 $\mu g/m^3$. No expert thought that there was any chance that there would be a threshold in excess of 10 $\mu g/m^3$. In addition, a recent extended follow-up of the Harvard Six Cities cohort concluded that the concentration response function is linear with no threshold (Schwartz, 2008).

In its December 2008 draft Integrated Science Assessment (ISA), EPA's Office of Research and Development concluded that the scientific literature consistently finds that a no-threshold log-linear model most adequately portrays the PM-mortality concentration-response relationship, while recognizing potential uncertainty about the exact shape of the concentration-response function. CASAC is currently considering EPA's assessment (in the $PM_{2.5}$ ISA) of the body of evidence on the shape of the C-R function relating $PM_{2.5}$ and mortality, including the evidence regarding the existence of a threshold. The CASAC is also currently considering EPA's draft scope and methods document for the PM risk and exposure assessment, which proposes to use the no-threshold model as the primary model for estimating mortality risk from $PM_{2.5}$ exposures. The ISA is being revised and will be reviewed again by the CASAC in October 2009, concurrent with the review of the first draft risk assessment. Although this document does not represent final agency policy that has undergone the full agency scientific review process, it provides a basis for reconsidering the application of thresholds in $PM_{2.5}$ concentration-response functions used in EPA's RIAs.

5.4 Updating the Benefits Data Underlying the Benefit-per-Ton Estimates

As described above, the estimates provided are derived through a benefits transfer technique that adapts monetized benefits from reductions in $PM_{2.5}$ precursor pollutants that were estimated for the Ozone RIA utilizing nationally distributed emissions reductions. Our preferred benefit-per-ton estimates for this analysis have been updated since the Ozone RIA was completed, and they reflect EPA's most current interpretation of the scientific literature on $PM_{2.5}$ and mortality. These estimates include a new population dataset, an expanded geographic scope of the benefit-per-ton calculation, and the functions directly from the epidemiology studies without a threshold adjustment. They reflect our updated benefits methodology (i.e., a no-threshold model that calculates incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels and incorporates two technical updates) compared to the estimates in previous RIAs that did not include these changes. Because the benefits are sensitive to the assumption of a threshold, we also provide a sensitivity analysis using the previous methodology (i.e., a threshold model at 10 $\mu g/m^3$ without the two technical updates) as a historical reference. Approximately 75% of the difference between the previous methodology and the updated methodology for this rule is due to removing thresholds with 25% due to the two technical updates. This percentage breakdown would vary for other rules depending on the combination of emission reductions from different sources and $PM_{2.5}$ precursor pollutants.

EPA is currently in the process of generating localized benefit-per-ton estimates to better account for the spatial heterogeneity of benefits for a small number of urban areas. EPA believes that these estimates may better represent the localized benefits of emission reductions at a specific location than benefits estimates that use national averages. However, because the kilns affected by this rule are widely distributed nationally, we believe that the national estimates are most appropriate for this analysis.

5.5 Results of Benefits Analysis

Using the preferred no-threshold model, in the year of full implementation (2013), EPA estimates the benefits of this proposal to be \$4.4 billion to \$11 billion and \$4.0 billion to \$9.7 billion, at 3% and 7% discount rates respectively.[1] Using the threshold model without technical updates, EPA estimates the benefits of this proposal to be \$3.1 billion to \$6.5 billion and \$2.8 billion to \$5.9 billion, at 3% and 7% discount rates respectively. Because the benefits are sensitive to the assumption of a threshold, we present the results using the threshold model below

[1] The benefits are discounted to account for the cessation lag in $PM_{2.5}$ benefits from premature mortality and acute myocardial infarctions (AMIs), rather than a discounted stream of future benefits; whereas discounting the costs reflects the lifetime costs of the equipment. For this reason, it is appropriate in this context to use two different discount rates for the benefits and costs.

to show the sensitivity of this assumption. Tables 5-1 and 5-2 provide general summaries of the results by precursor pollutant, including the emissions reductions and monetized benefits-per-ton using the no-threshold model and the threshold model (without technical updates), respectively.[1,2] Table 5-3 provides a summary of the reductions in health incidences associated with the benefit per ton estimates. Incidence estimates using the threshold-based benefit-per-ton methodology have not been calculated. Figure 5-3 provides a visual representation of the range of benefits estimates by precursor pollutant at a 3% discount rate using the no-threshold model. More details on the regulatory scenario, emissions, and emission reductions can be found in Section 4 of this RIA.

Table 5-1. Summary of $PM_{2.5}$ Health Co-Benefits of the Proposed Portland Cement NESHAP using the no-threshold model (preferred approach)[a]

		3% Discount Rate			7% Discount Rate		
Pollutant	**Emissions Reductions (tons)**	**Benefit per ton (Pope)**	**Benefit per ton (Laden)**	**Total Monetized Benefits (millions 2005$)**	**Benefit per ton (Pope)**	**Benefit per ton (Laden)**	**Total Monetized Benefits (millions 2005$)**
Direct $PM_{2.5}$	6,345	$180,000	$440,000	$1,200 to $2,800	$160,000	$400,000	$1,000 to $2,500
$PM_{2.5}$ Precursors							
SO_2	139,240	$23,000	$57,000	$3,300 to $8,000	$21,000	$52,000	$3,000 to $7,200
Grand Total				$4,400 to $11,000			$4,000 to $9,700

[a] All estimates are for the analysis year (2013), and are rounded to two significant figures so numbers may not sum across columns. All fine particles are assumed to have equivalent health effects, but the benefit per ton estimates vary between precursors because each ton of precursor reduced has a different propensity to form $PM_{2.5}$. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. This analysis assumes the $PM_{2.5}$ fraction is 45%.

[1] The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

[2] Because of the absence of data, we are unable to quantify the amount of reductions in condensable PM. PM emissions consist of both a filterable fraction and a condensable fraction, which exists as a gas in an exhaust stream and condenses to form particulate once the gas enters the ambient air. Most condensable PM is $PM_{2.5}$. In this analysis, all emission reductions and the corresponding benefits estimates reflect only the filterable fraction.

Table 5-2. Summary of Health Benefits of the Proposed Portland Cement NESHAP, using the threshold model (without technical updates) (sensitivity analysis)[a]

Pollutant	Emissions Reductions (tons)	3% Discount Rate: Benefit per ton (Pope)	3% Discount Rate: Benefit per ton (Laden)	3% Discount Rate: Total Monetized Benefits (millions 2005$)	7% Discount Rate: Benefit per ton (Pope)	7% Discount Rate: Benefit per ton (Laden)	7% Discount Rate: Total Monetized Benefits (millions 2005$)
Direct $PM_{2.5}$	6,345	$150,000	$320,000	$940 to $2,000	$140,000	$290,000	$860 to $1,800
$PM_{2.5}$ Precursors							
SO_2	139,240	$15,000	$32,000	$2,100 to $4,500	$14,000	$29,000	$1,900 to $4,100
Grand Total				$3,100 to $6,500			$2,800 to $5,900

[a] All estimates are for the analysis year (2013), and are rounded to two significant figures so numbers may not sum across columns. All fine particles are assumed to have equivalent health effects, but the benefit per ton estimates vary between precursors because each ton of precursor reduced has a different propensity to form PM2.5. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. This analysis assumes the $PM_{2.5}$ fraction is 45%.

Table 5-3. Summary of Reductions in Health Incidences of the Proposed Portland Cement NESHAP[a]

Avoided Premature Mortality	
Pope	620
Laden	1,600
Woodruff (Infant Mortality)	3
Avoided Morbidity	
Chronic Bronchitis	420
Acute Myocardial Infarction	1,000
Hospital Admissions, Respiratory	150
Hospital Admissions, Cardiovascular	320
Emergency Room Visits, Respiratory	590
Acute Bronchitis	1,000
Work Loss Days	82,000
Asthma Exacerbation	11,000
Acute Respiratory Symptoms	490,000
Lower Respiratory Symptoms	12,000
Upper Respiratory Symptoms	9,000

[a] All estimates are for the analysis year (2013) and are rounded to two significant figures. All fine particles are assumed to have equivalent health effects, but each PM2.5 precursor pollutant has a different propensity to form PM2.5.

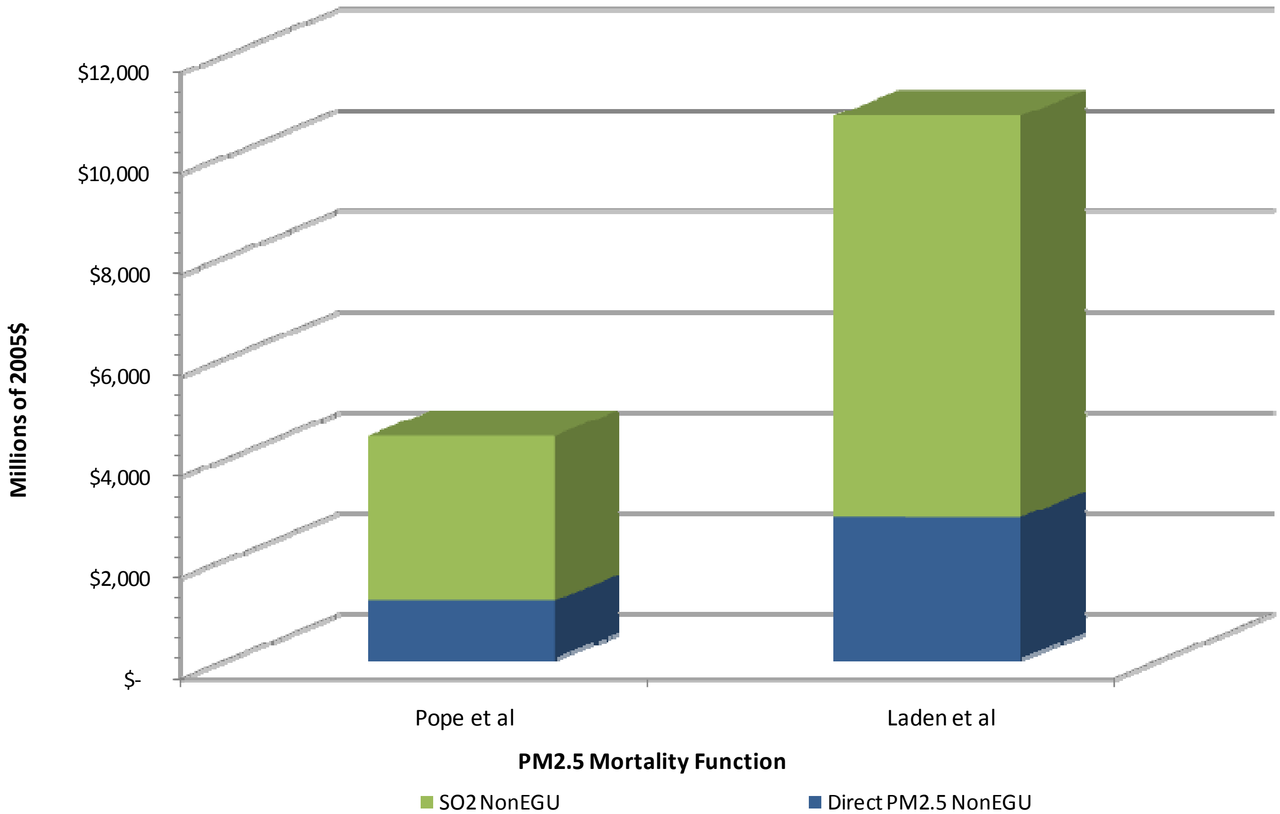

Figure 5-3. Monetized Health Benefits of the Proposed Portland Cement NESHAP by $PM_{2.5}$ Precursor in 2013 using the no-threshold model [a]

[a] This graph shows the estimated benefits by precursor pollutant using effect coefficients derived from the Pope et al. study and the Laden et al, study at a 3% discount rate. The breakdown by precursor pollutant would be similar at a 7% discount rate and using the threshold model. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary because each ton of precursor reduced has a different propensity to become $PM_{2.5}$

5.6 Characterization of Uncertainty in the Benefits Estimates

In any complex analysis, there are likely to be many sources of uncertainty. Many inputs are used to derive the final estimate of economic benefits, including emission inventories, air quality models (with their associated parameters and inputs), epidemiological estimates of concentration-response (C-R) functions, estimates of values, population estimates, income estimates, and estimates of the future state of the world (i.e., regulations, technology, and human behavior). There is uncertainty at each stage of the analytic process to generate benefits estimates. For some parameters or inputs, it may be possible to provide a statistical representation of the underlying uncertainty distribution. For other parameters or inputs, the necessary information is not available. Therefore, it is difficult to estimate the relative importance of each source of uncertainty, particularly when using benefit-per-ton estimates.

The annual benefit estimates presented in this analysis are also inherently variable due to the processes that govern pollutant emissions and ambient air quality in a given year. Factors such as hours of equipment use and weather are constantly variable, regardless of our ability to measure them accurately. As discussed in the $PM_{2.5}$ NAAQS RIA (Table 5-5), there is a variety of uncertainties associated with these PM benefits. Therefore, the estimates of annual benefits should be viewed as representative of the magnitude of benefits expected, rather than the actual benefits that would occur every year.

The benefits estimates are subject to a number of assumptions and uncertainties. For example, for key assumptions underlying the estimates for premature mortality, which typically account for at least 90% of the total PM benefits, we were able to identify the following uncertainties:

1. Inhalation of fine particles is causally associated with premature death at concentrations near those experienced by most Americans on a daily basis. Although biological mechanisms for this effect have not been established definitively yet, the weight of the available epidemiological evidence supports an assumption of causality.

2. All fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because PM produced via transported precursors emitted from EGUs may differ significantly from direct PM released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.

3. The impact function for fine particles is approximately linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of PM, including both regions that are in attainment with fine particle standard and those that do not meet the standard.

4. The forecasts for future emissions and associated air quality modeling are valid. Although recognizing the difficulties, assumptions, and inherent uncertainties in the overall enterprise, these analyses are based on peer-reviewed scientific literature and up-to-date assessment tools, and we believe the results are highly useful in assessing this proposal.

5. Benefits estimated here reflect the application of a national dollar benefit-per-ton estimate of the benefits of reducing directly emitted fine particulates from point sources. Because they are based on national-level analysis, the benefit-per-ton estimates used here do not reflect local variability in population density, meteorology,

exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.

This RIA does not include the type of detailed uncertainty assessment found in the PM NAAQS RIA because we lack the necessary air quality input and monitoring data to run the benefits model (BenMAP). Moreover, it was not possible to develop benefit-per-ton metrics and associated estimates of uncertainty using the benefits estimates from the PM RIA because of the significant differences between the sources affected in that rule and those regulated here. However, the results of the Monte Carlo analyses of the health and welfare benefits presented in Chapter 5 of the PM RIA can provide some evidence of the uncertainty surrounding the benefits results presented in this analysis. In this analysis, we provide additional benefits results that use the functions obtained in the expert elicitation as a reasonable characterization of the uncertainty in the relationship between $PM_{2.5}$ and mortality. Because this analysis uses benefit-per-ton estimates, we are only able to present the mean benefits results using the expert functions without the associated credible intervals. We recognize that this captures only a fraction of the overall uncertainty. We also recognize that the magnitude of the mortality C-R function is a critical parameter in the analysis, and the uncertainty in that parameter is likely to contribute a large fraction of the overall uncertainty in the benefits estimates. Tables 5-4 and 5-5 show all 14 benefits estimates for the no-threshold and threshold models, including those based on expert functions, at discount rates of 3% and 7%.[1] Figures 5-4 and 5-5 show the data from Tables 5-3 and 5-4 in a graphical form.

[1] Circular A-4 requires regulatory analyses to assess benefits using discount rates of 3% and 7%. Office of Management and Budget (OMB), 2003. *Circular A-4: Regulatory Analysis*. Washington, DC. Available on the internet at http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

Table 5-4. All Benefits Estimates for Proposed Portland Cement NESHAP in 2013 (in millions of 2005$) for no-threshold model (preferred approach)[a]

	3% Discount Rate	7% Discount Rate
Benefit-per-ton Coefficients Derived from Epidemiology Literature		
Pope et al.	$4,400	$4,000
Laden et al.	$11,000	$9,700
Benefit-per-ton Coefficients Derived from Expert Elicitation		
Expert A	$11,000	$10,000
Expert B	$8,700	$7,900
Expert C	$8,700	$7,900
Expert D	$6,200	$5,600
Expert E	$14,000	$13,000
Expert F	$7,900	$7,200
Expert G	$5,200	$4,700
Expert H	$6,600	$5,900
Expert I	$8,600	$7,800
Expert J	$7,000	$6,400
Expert K	$1,800	$1,600
Expert L	$6,300	$5,700

*All estimates are rounded to two significant figures. Estimates do not include confidence intervals because they were derived through the benefit-per-ton technique described above. The benefits estimates from the Expert Elicitation are provided as a reasonable characterization of the uncertainty in the mortality estimates associated with the concentration-response function.

Table 5-5. All Benefits Estimates for proposed Portland Cement NESHAP in 2013 (in millions of 2005$) for the threshold model (without technical updates) (sensitivity analysis) [a]

	3% Discount Rate	7% Discount Rate
Benefit-per-ton Coefficients Derived from Epidemiology Literature		
Pope et al.	$3,500	$3,200
Laden et al.	$7,500	$6,800
Benefit-per-ton Coefficients Derived from Expert Elicitation		
Expert A	$12,000	$11,000
Expert B	$9,100	$8,200
Expert C	$9,000	$8,100
Expert D	$6,400	$5,800
Expert E	$15,000	$13,000
Expert F	$8,200	$7,400
Expert G	$5,400	$4,900
Expert H	$6,800	$6,100
Expert I	$8,900	$8,100
Expert J	$7,300	$6,600
Expert K	$1,700	$1,600
Expert L	$6,500	$5,900

[a] All estimates are rounded to two significant figures. Estimates do not include confidence intervals because they were derived through the benefit-per-ton technique described above. The benefits estimates from the Expert Elicitation are provided as a reasonable characterization of the uncertainty in the mortality estimates associated with the concentration-response function. These monetized benefits do not incorporate additional emission reductions that would occur if cement facilities temporarily idle or reduce capacity utilization as a result of this regulation or the unquantifiable amount of reductions in condensable PM.

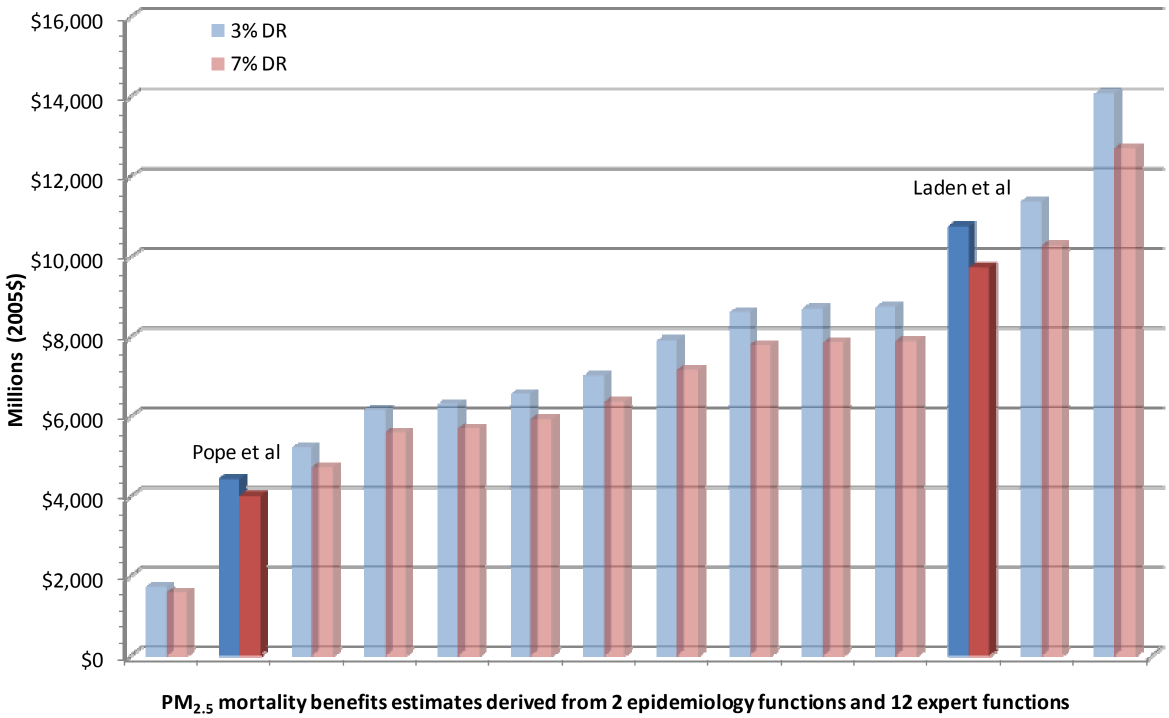

Figure 5-4. Monetized Human Health Benefits of Proposed Portland Cement NESHAP in 2013 based on the no-threshold model (preferred approach) [a]

[a] This graph shows the estimated at two discount rates using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. All fine particles are assumed to have equivalent health effects, but the benefit-per-ton estimates vary because each ton of precursor reduced has a different propensity to become $PM_{2.5}$. These monetized benefits do not incorporate additional emission reductions that would occur if cement facilities temporarily idle or reduce capacity utilization as a result of this regulation or the unquantifiable amount of reductions in condensable PM.

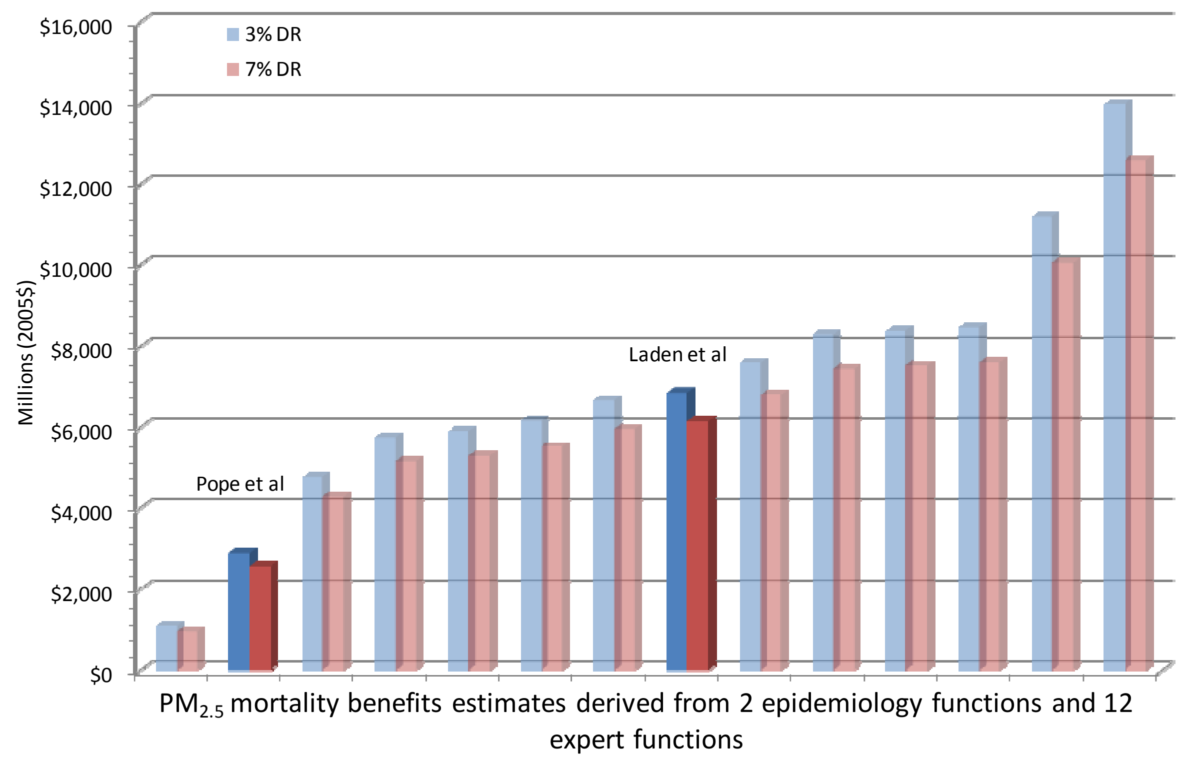

Figure 5-5. Monetized Health Benefits for Proposed Portland Cement NESHAP in 2013 based on the threshold model (without technical updates) (sensitivity analysis)[a]

[a] This graph shows the estimated benefits using the old methodology at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies.

5.7 Comparison of Benefits and Costs

Using the no-threshold model, in the year of full implementation (2013), EPA estimates the benefits of this proposal to be $4.4 billion to $11 billion and $4.0 billion to $9.7 billion, at 3% and 7% discount rates respectively.[1] Annualized domestic social costs are $694 million at a 7% discount rate as mentioned in Section 4 of this RIA.[2] Thus, the net benefits (i.e., benefits in 2013 minus annualized costs) are $3.7 billion to $11 billion and $3.3 billion to $9.0 billion, at 3% and 7% discount rates respectively. Using alternate relationships between $PM_{2.5}$ and premature mortality supplied by experts, higher and lower benefits estimates are plausible (see Figure 5-6), but most of the expert-based estimates fall between the two epidemiology-based

[1] The benefits are discounted to account for the cessation lag in $PM_{2.5}$ benefits from premature mortality and acute myocardial infarctions (AMIs), rather than a discounted stream of future benefits; whereas discounting the costs reflects the lifetime costs of the equipment. For this reason, it is appropriate in this context to use different discount rates for the benefits and costs.

[2] The domestic social cost does not include the estimated $89 million surplus gain for foreign producers.

estimates. EPA believes that the benefits are likely to exceed the costs by a substantial margin under this proposal even when taking into account uncertainties in the cost and benefit estimates.

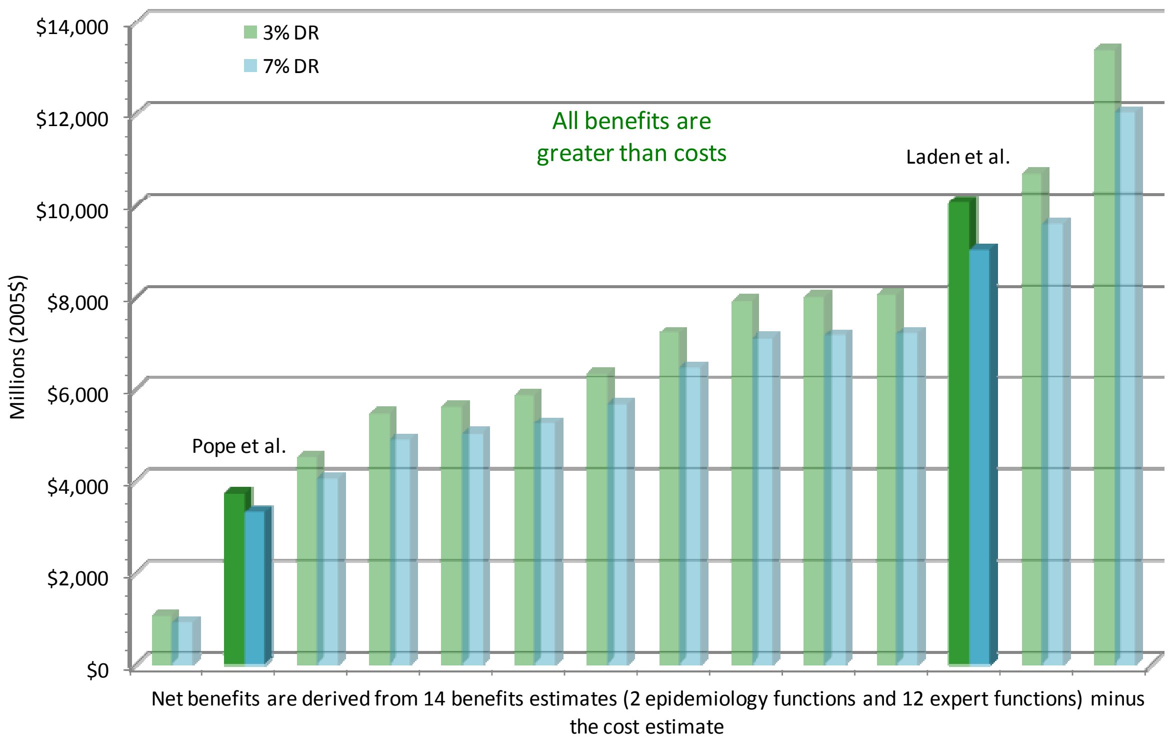

Figure 5-6. Net Benefits for Proposed Portland Cement NESHAP in 2013 at 2 Discount Rates using the no-threshold model[a]

[a] Net Benefits are quantified in terms of $PM_{2.5}$ benefits at a 3% discount rate and a 7% discount rate. This graph shows all of the benefits estimates combined with the cost estimate, specifically identifying the estimates based on Pope et al and Laden et al with green bars and the expert elicitation with translucent bars.

SECTION 6
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APPENDIX A

REGIONAL PORTLAND CEMENT MARKETS AND ECONOMIC MODEL

The Office of Air Quality Planning and Standards (OAQPS) has adopted the standard-industry level analysis described in the Office's resource manual (EPA, 1999a). This approach is consistent with previous EPA analyses of the Portland cement industry (EPA, 1998; EPA, 1999b) and uses a single-period static partial-equilibrium model to compare prepolicy cement market baselines with expected postpolicy outcomes in these markets. The benchmark time horizon for the analysis is the intermediate run where producers have some constraints on their flexibility to adjust factors of production. This time horizon allows us to capture important transitory impacts of the program on existing producers. Key measures in this analysis include

- market-level effects (market prices, changes in domestic production and consumption, and international trade),
- industry-level effects (changes in revenues, costs, profits, employment),
- facility-level effects (plant utilization changes), and
- social costs (changes in producer and consumer surplus).

The partial equilibrium analysis performed for this rule develops a cement market model that simulates how stakeholders (consumers and firms) may respond to the additional regulatory program costs. In this appendix, we provide details on the baseline data, behavioral assumptions, parameters, and model equations.

A.1 Baseline Market Data

Cement sales are often concentrated locally among a small number of firms for two reasons: high transportation costs and production economies of scale.[1] Transportation costs significantly influence where cement is ultimately sold; high transportation costs relative to unit value provide incentives to produce and sell cement locally in regional markets (USITC, 2006). To support this claim, the empirical literature has typically pointed to Census of Transportation data showing over 80% of cement shipments were made within a 200-mile radius (Jans and Rosenbaum, 1997) and reported evidence of high transportation costs per dollar of product value from case studies (Ryan, 2006). Based on this literature, the Agency assumed that the U.S. Portland cement industry is divided into a number of independent regional markets with each having a single market-clearing price.

To estimate cement demand for each of the 20 cement markets, RTI collected the Portland Cement Association's (2004) reported annual kiln clinker capacity data and state-level

[1] The 2002 Economic Census reports that the national Herfindahl-Hirschman Index (HHI) for cement NAICS 32731 is 568. However, this measure likely not representative of actual concentration that exists in regional markets.

utilization rates reported by the U.S. Geological Survey (USGS). Utilization rates are reported in Table A-1. For each kiln, we calculated clinker production as follows:

Kiln Clinker Production = State-Level Utilization Rate x Annual Clinker Capacity.

Next, we summed clinker production across kilns to obtain domestic clinker production in the United States. However, to match the 2005 national clinker production data (87,405 metric tons) from the USGS (U.S. Department of the Interior, 2006a, Table 1), we applied a scaling factor to these USGS utilization rates (value = 1.103). When making this calculation, we did constrain each kiln's clinker production capacity utilization rate to be 95% or less. With this adjustment, kiln clinker production is computed as follows:

Kiln Clinker Production =

Minimum[(State-Level Utilization Rate x 1.103 x Annual Clinker Capacity), (0.95 x Annual Clinker Capacity)].

Next, we summed clinker production across kilns in each market to obtain domestic clinker production in each cement market (m):

$$\text{Domestic Clinker Production}_m = \sum_i \left(\text{Kiln Clinker Production}_{im}\right).$$

We calculated Portland cement production by applying a ratio of Portland cement production to clinker production (value = 1.07) that leads us to match the reported 2005 national Portland cement production data (93,904 metric tons) from the USGS:

$$\text{Domestic Portland Cement Production}_m = \sum_i \left(\text{Kiln Clinker Production}_{im}\right) \times \text{Cement Factor}.$$

A portion of cement market demand is also met by international imports. We collected hydraulic cement import data by customs district from the USGS (2006a) and assigned these imports to markets using a district-to-market mapping shown in Table A-2. The USGS reports hydraulic cement imports were approximately 33.3 million metric tons in 2005.

Total grey Portland cement demand was 126.8 million metric tons in 2005 and ranged from 3.6 million metric tons in the Seattle market to 13.4 million metric tons in the Los Angeles market (see Table A-3). White cement demand was 2.1 million metric tons.

Table A-1. Capacity Utilization Rates by State: 2005

State	USGS Geographic Area	Utilization Rate (percent)
AL	Alabama	86.7
AR	Arkansas and Oklahoma	90.9
AZ	Arizona and New Mexico	87.0
CA	California, northern and southern	88.8
CO	Colorado and Wyoming	79.5
FL	Florida	85.9
GA	Georgia, Virginia, West Virginia	78.4
IA	Iowa, Nebraska, South Dakota	85.5
ID	Idaho, Montana, Nevada, Utah	95.5
IL	Illinois	91.4
IN	Indiana	86.8
KS	Kansas	89.1
KY	Kentucky, Mississippi, Tennessee	87.4
MD	Maryland	89.1
ME	Maine and New York	83.6
MI	Michigan	85.5
MO	Missouri	90.3
MS	Kentucky, Mississippi, Tennessee	87.4
MT	Idaho, Montana, Nevada, Utah	95.5
NE	Iowa, Nebraska, South Dakota	85.5
NM	Arizona and New Mexico	87.0
NV	Idaho, Montana, Nevada, Utah	95.5
NY	Maine and New York	83.6
OH	Ohio	84.7
OK	Arkansas and Oklahoma	90.9
OR	Oregon and Washington	83.3
PA	Pennsylvania, eastern and western	83.7
SC	South Carolina	64.5

Source: U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Table 5. Washington, DC: U.S. Department of the Interior.

For cement prices, we used the district-level average value per metric ton data reported by USGS (2006a, Table 11) and assigned a value to each state. Values represent mill net or ex-plant (free on board plant) valuations of total sales to final customers, including sales from plant. To calculate a price for the 20 cement markets in the model (see Table A-4), we computed a weighted average price using production and state price information for each kiln.

$$\text{Market price}_j = \sum_i \left(\text{USGS State Price}_{ij} \times \frac{\text{Kiln}_i \text{ Cement Production}}{\text{Total Market}_j \text{ Domestic Production}} \right)$$

Table A-2. Hydraulic Cement Imports by Market and Customs District (million metric tons): 2005

Market	Customs District	Quantity
Atlanta	Charleston, SC	1.1
	Norfolk, VA	0.7
	Savannah, GA	0.1
	Wilmington, NC	0.4
Baltimore/Philadelphia	Baltimore, MD	0.1
	Philadelphia, PA	0.5
Birmingham	Mobile, AL	0.5
	New Orleans, LA[a]	1.7
Chicago	Chicago, IL	0.0
	Milwaukee, WI, Canada	0.2
Dallas	New Orleans, LA[a]	2.4
Detroit	Detroit, MI	1.3
Florida	Miami, FL	2.3
	Tampa, FL	3.5
	U.S. Virgin Islands	0.1
Kansas City	St. Louis, MO	0.0
Los Angeles	Los Angeles, CA	3.1
	San Diego, CA	0.7
Minneapolis	Duluth, MN, Canada	0.2
	Minneapolis, MN, Canada	0.0
	Pembina, ND, Canada	0.2
New York/Boston	Boston, MA	0.1
	New York, NY	1.3
	Ogdensburg, NY	0.3
	Portland, ME	0.2
	Providence, RI	0.7
	St. Albans, VT, Canada	0.1
Pittsburgh	Buffalo, NY	0.8
	Cleveland, OH	0.8
Salt Lake City	Great Falls, MT	0.1
San Antonio	El Paso, TX, Mexico	0.7
	Houston-Galveston, TX	2.6
	Laredo, TX, Mexico	0.1
	Nogales, AZ, Mexico	1.1
San Francisco	Honolulu, HI	0.4
	San Francisco, CA	2.4
Seattle	Anchorage, AK	0.1
	Columbia-Snake, OR	0.9
	Seattle, WA	1.5
Total		33.3

Note: Excludes Puerto Rico.

[a] Imports for New Orleans were distributed between the Birmingham and Dallas markets using baseline domestic production levels in each market.

Source: U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Table 18. Washington, DC: U.S. Department of the Interior.

Table A-3. Portland Cement Demand by Market (10^6 metric tons): 2005

Market	U.S. Production	Imports [a] Canada	Imports [a] Rest of World	Total
Atlanta	6.1	—	2.3	8.4
Baltimore/Philadelphia	8.0	—	0.6	8.6
Birmingham	5.9	—	2.2	8.1
Chicago	4.3	0.2	0.0	4.5
Cincinnati	3.7	—	—	3.7
Dallas	8.2	—	2.4	10.6
Denver	3.4	—	—	3.4
Detroit	4.8	1.3	0.1	6.1
Florida	5.6	—	5.8	11.4
Kansas City	5.3	—	0.0	5.3
Los Angeles	9.6	—	3.8	13.4
Minneapolis	1.7	0.4	—	2.1
New York/Boston	3.2	0.6	2.1	6.0
Phoenix	4.1	—	—	4.1
Pittsburgh	1.5	1.6	0.0	3.1
St. Louis	5.4	—	—	5.4
Salt Lake City	2.4	0.1	—	2.4
San Antonio	5.7	—	4.6	10.3
San Francisco	3.4	—	2.8	6.2
Seattle	1.1	1.3	1.2	3.6
Total, Grey	93.6	5.4	27.9	126.8
Total, White	0.3	0.3	1.5	2.1
Total	93.9	5.7	29.4	129.0

[a] Hydraulic cement. The vast majority of these imports are Portland cement (approximately 29 million metric tons, or 86%). Excludes Puerto Rico.

To illustrate this calculation, we use the following simple example for the Seattle market. There are two domestic kilns in Washington; one kiln produces approximately 660,000 metric tons of cement, while the other produces approximately 420,000 metric tons of cement per year. The USGS reports the same average value per metric ton of cement in Oregon and Washington ($88 dollars). To derive the market price for the Seattle market, we perform the following calculation:

$$\$88 \times 660/(660 + 420) + \$88 \times 420/(660 + 420) = \$88.$$

A.2 Cost Function Updates for 2005

Previous EIAs (EPA, 1998; EPA, 1999) used a kiln-level average variable cost (AVC) function developed in a microeconomic study of kiln use and retirement (Das, 1992). Das

Table A-4. Portland Cement Prices by Market ($/metric tons): 2005

Market	Price ($/metric ton)
Atlanta	$81
Baltimore/Philadelphia	$86
Birmingham	$83
Chicago	$86
Cincinnati	$84
Dallas	$83
Denver	$89
Detroit	$93
Florida	$91
Kansas City	$86
Los Angeles	$97
Minneapolis	$92
New York/Boston	$89
Phoenix	$99
Pittsburgh	$88
St. Louis	$87
Salt Lake City	$91
San Antonio	$82
San Francisco	$97
Seattle	$88

describes five variable inputs in cement production: raw materials, repair and maintenance, labor, electricity, and fuel. Raw materials serve as the kiln feed, repair and maintenance are required for periodic upkeep of the kiln, labor is used in the quarry and for packing, electricity is consumed mainly by the auxiliary equipment, and fuel is largely consumed by the kilns.

The AVC function (expressed in dollars per metric ton of cement) can be written as

$$AVC = AVMI * P_m + AVRI * P_r + AVLI * w + AVFI * P_f f + AVEI * P_{e,}$$

where AVRI, AVLI, AVFI, AVEI, and AVMI are the average variable inputs of materials, repair and maintenance, labor, fuel, and electricity, and $P_{m,}$ P_r, w, P_f, and P_e are the prices of each variable input.

For the updated model, RTI collected data from the Portland Cement Association (PCA, 2005) and government statistical publications and updated selected cost function parameters. These updates are presented and discussed in this section.

A.2.1 Raw Materials

In Table A-5, we report the quantities of raw material inputs, cement production, and the raw material input ratio for the U.S. cement industry. In 2005, approximately 1.67 metric tons of raw materials were required to make a metric ton of cement.

Table A-5. Raw Material Input Ratios for the U.S. Cement Industry: 2005

	Metric Tons (10^3)
Raw material input[a]	159,700
Cement production[b]	95,488
Ratio (AVMI)	1.67

[a] U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Table 6. Washington, DC: U.S. Department of the Interior.

[b] U.S. Department of the Interior, U.S. Geological Survey. 2007a. *2005 Minerals Yearbook, Cement*. Table 3. Washington, DC: U.S. Department of the Interior.

State raw material prices for crushed stone range between $4 and $13 per metric ton (Table A-6). To calculate raw material costs, we multiplied state raw material prices by the raw material input ratio (1.67).

A.2.2 Repair and Maintenance

Rock Products (1994) magazine reports the 1993 values of annual repair and maintenance costs by kiln capacity (Table A-7). Since more recent repair and maintenance costs are not available, we adjusted these costs to 2005 dollars using the gross domestic product (GDP) deflator (U.S. BEA, 2007).

A.2.3 Labor

The Portland Cement Association reports labor productivity measures in terms of metric tons of cement per employee hour. We used these data to calculate the average variable labor inputs (AVLI): a measure of employee hours needed per ton of cement. AVLI estimates are computed by taking the inverse of each labor productivity measure. Table A-8 shows labor productivity continues to vary by process type and kiln size. Productivity is higher for dry process kilns compared with wet kilns; it is also higher for large-capacity kilns.

State average hourly earnings for the durable goods industry are presented in Table A-9. To calculate labor costs, we multiplied state average hourly earnings by labor hours per metric ton.

Table A-6. Raw Material Costs by Market and State: 2005

State(s)	Price of Raw Materials ($/metric ton)[a]	Cost of Raw Materials ($/metric ton of cement)
AL	$6.57	$10.99
AK	$6.60	$11.04
AZ	$5.75	$9.62
AR	$6.29	$10.52
CA	$8.37	$14.00
CO	$6.85	$11.46
CT	$9.19	$15.37
DE	$6.89	$11.52
FL	$8.67	$14.50
GA	$7.63	$12.76
HI	$13.34	$22.31
ID	$5.37	$8.98
IL	$7.16	$11.97
IN	$5.40	$9.03
IA	$7.27	$12.16
KS	$7.20	$12.04
KY	$7.24	$12.11
LA	$8.18	$13.68
ME	$6.85	$11.46
MD	$8.28	$13.85
MA	$9.19	$15.37
MI	$3.89	$6.51
MN	$8.30	$13.88
MS	$11.90	$19.90
MO	$7.37	$12.33
MT	$4.76	$7.96
NE	$7.10	$11.87
NV	$7.17	$11.99
NH	$8.02	$13.41
NJ	$7.04	$11.77
NM	$6.67	$11.16
NY	$8.44	$14.12
NC	$8.59	$14.37
ND	$4.45	$7.44
OH	$5.82	$9.73
OK	$5.67	$9.48
OR	$6.01	$10.05
PA	$6.67	$11.16
RI	$7.74	$12.94
SC	$7.61	$12.73
SD	$4.60	$7.69
TN	$7.55	$12.63
TX	$6.15	$10.29
UT	$5.58	$9.33
VT	$6.75	$11.29
VA	$9.03	$15.10
WA	$6.92	$11.57
WV	$6.86	$11.47
WI	$5.83	$9.75
WY	$5.68	$9.50

[a] U.S. Department of the Interior, U.S. Geological Survey. 2007b. *2005 Minerals Yearbook, Crushed Stone*. Table 4. Washington, DC: U.S. Department of the Interior.

Table A-7. Annual Repair and Maintenance Costs by Kiln Capacity: 2005

Kiln Capacity (short tons)	1993 ($/metric ton)	2005 ($/metric ton)[a]
<500,000 tons	$10.54	$15.46
500,000 to 750,000 tons	$8.30	$12.17
>750,000 tons	$5.85	$8.59

[a] Adjusted by chained (real) GDP obtained from the U.S. Department of Commerce, Bureau of Economic Analysis. 2007. *Current-Dollar and "Real" Gross Domestic Product.* Available at <http://www.bea.gov/national/xls/gdplev.xls>.

Table A-8. Labor Productivity Measures for the U.S. Cement Industry by Process Type and Kiln Size: 2005

Process Type	Metric Tons per Employee Hour[a, b]	AVLI (employee hours per metric ton)[a]
Wet Process	**2.16**	**0.4630**
≤500,000-ton capacity	1.87	0.5348
>500,000-ton capacity	2.31	0.4329
Dry Process	**3.14**	**0.3185**
≤500,000-ton capacity	1.93	0.5181
>500,000-ton capacity	3.19	0.3135
Precalciner	3.36	0.2976
Preheater	3.2	0.3125
All Plants	**2.96**	**0.3378**

[a] Following the PCA, the metric tons used to measure labor efficiency are an equivalent ton measure, composed of 85% clinker production and 15% finished cement production (PCA, 2005).

[b] Portland Cement Association (PCA). December 2005. *U.S. and Canadian Labor-Energy Input Survey 2005*. Skokie, IL: PCA's Economic Research Department.

A.2.4 Electricity

To reflect the differences in electricity consumption process type and kiln size, we collected energy consumption (kWh) and production data (Table A-10). We computed electricity consumption rates (AVEI) as follows:

$$AVEI = kWh/(0.92*Clinker\ Production + 0.08*Finished\ Cement\ Production).$$

This approach follows the Portland Cement Association's energy-efficiency measures using "equivalent tons" (PCA, 2005). This measure is composed of 92% clinker production and 8% finished cement production.

Table A-9. Average Hourly Earnings by Market and State: 2005

State	U.S. BLS Series Report ID	Average Hourly Earnings ($)
AL	SMU01000003100000006	$15.33
AK	SMU02000003000000006	$14.22
AZ	SMU04000003100000006	$14.72
AR	SMU05000003100000006	$13.98
CA	SMU06000003100000006	$16.47
CO	SMU08000003100000006	$16.17
CT	SMU09000003100000006	$19.57
DE	SMU10000003100000006	$23.20
FL	SMU12000003100000006	$13.94
GA	SMU13000003100000006	$15.96
HI	SMU15000003000000006	$14.34
ID	SMU16000003000000006	$14.96
IL	SMU17000003100000006	$16.35
IN	SMU18000003100000006	$18.90
IA	SMU19000003100000006	$15.95
KS	SMU20000003100000006	$17.82
KY	SMU21000003100000006	$17.50
LA	SMU22000003100000006	$16.62
ME	SMU23000003100000006	$16.77
MD	SMU24000003100000006	$18.67
MA	SMU25000003100000006	$18.48
MI	SMU26000003100000006	$23.07
MN	SMU27000003100000006	$16.99
MS	SMU28000003100000006	$14.26
MO	SMU29000003100000006	$19.12
MT	SMU30000003100000006	$14.87
NE	SMU31000003100000006	$15.30
NV	SMU32000003100000006	$15.29
NH	SMU33000003100000006	$15.95
NJ	SMU34000003100000006	$17.42
NM	SMU35000003000000006	$13.66
NY	SMU36000003100000006	$19.02
NC	SMU37000003100000006	$15.04
ND	SMU38000003100000006	$15.07
OH	SMU39000003100000006	$20.62
OK	SMU40000003100000006	$15.93
OR	SMU41000003100000006	$15.76
PA	SMU42000003100000006	$15.59
RI	SMU44000003100000006	$13.08
SC	SMU45000003100000006	$16.00
SD	SMU46000003000000006	$13.47
TN	SMU47000003100000006	$14.01
TX	SMU48000003100000006	$13.53
UT	SMU49000003100000006	$14.71
VT	SMU50000003100000006	$15.45
VA	SMU51000003100000006	$17.45
WA	SMU53000003000000006	$18.83
WV	SMU54000003100000006	$16.71
WI	SMU55000003100000006	$17.04
WY	SMU56000003000000006	$17.08

Source: U.S. Department of Labor, Bureau of Labor Statistics. 2007. “State and Area Employment, Hours and Earnings 2005.” Washington, DC: U.S. Department of Labor.

Table A-10. Electricity Consumption of U.S. Cement Producers by Process Type: 2005

Process Type	Clinker Production (metric tons)	Finished Cement Production (metric tons)	Electricity Consumption (1,000 kWh)	AVEI (kWh per metric ton)[a]
Wet Process	**11,054,608**	**12,150,780**	**1,660,208**	**149.0**
≤500,000-ton capacity	3,228,213	3,563,013	515,451	158.4
>500,000-ton capacity	7,826,395	8,587,767	1,144,757	145.1
Dry Process	**70,112,322**	**77,036,853**	**10,778,235**	**152.5**
≤500,000-ton capacity	1,563,774	1,690,568	276,358	175.6
>500,000-ton capacity	68,548,548	75,346,285	10,501,877	152.0
Precalciner	44,295,828	48,559,311	6,725,423	150.7
Preheater	60,357,246	66,278,745	9,224,958	151.6
All Plants	**81,166,930**	**89,187,633**	**12,438,443**	**152.0**

[a] Following the PCA, the metric tons used to measure energy efficiency are an equivalent ton measure composed of 92% clinker production and 8% finished cement production (PCA, 2005).

Source: Portland Cement Association (PCA). December 2005. *U.S. and Canadian Labor-Energy Input Survey 2005*. Skokie, IL: PCA's Economic Research Department.

Table A-11 presents state electricity prices. To calculate electricity costs, we multiplied these prices by AVEI.

A.2.5 Fuel

Das (1992) represents average variable fuel input rates using the following expression:

$$\text{AVFI} = (1 + \text{constant})^{\text{Age in 2005}} * \text{average variable fuel input of a new kiln.}$$

We used the calibration procedures described from EPA's 1998 cement study to compute a revised average variable primary fuel input of a new kiln. The constant used remains 0.0087, and Table A-12 reports the average variable fuel input of a new kiln by its process type and its capacity.

The AEO 2007 reports other industrial coal, natural gas, and residual fuel prices by census region (Table A-13) (Energy Information Administration, 2007). For petroleum coke price, we used the procedure outlined in the Energy Information Administration's *State Energy Consumption, Price, and Expenditure Estimates (SEDS): Technical Notes Prices and Expenditures Section 4* (DOE, 2006b). In the process described there, the average price was calculated by dividing the sum of the value of calcined and uncalcined petroleum coke exports by the sum of export quantities. We collected these data from the U.S. International Trade Commissions Database (USITC, 2007). To convert units to million

Table A-11. Electricity Price by Market and State: 2005

State	Cents per kWh
AL	4.52
AK	9.29
AZ	5.85
AR	4.74
CA	9.55
CO	5.74
CT	9.40
DE	6.21
FL	6.46
GA	5.28
HI	15.79
ID	3.91
IL	4.61
IN	4.42
IA	4.56
KS	4.85
KY	3.60
LA	6.71
ME	7.28
MD	7.01
MA	9.22
MI	5.32
MN	5.02
MS	5.37
MO	4.54
MT	4.83
NE	4.43
NV	7.71
NH	11.48
NJ	9.76
NM	5.61
NY	8.23
NC	5.04
ND	4.32
OH	5.10
OK	5.11
OR	4.83
PA	6.29
RI	10.01
SC	4.55
SD	4.95
TN	4.73
TX	7.14
UT	4.24
VT	7.77
VA	4.46
WA	4.27
WV	3.85
WI	5.39
WY	3.99

Source: U.S. U.S. Department of Energy, Energy Information Administration. 2006a. *Electric Power Annual 2005*. Figure 7-7. Washington, DC: U.S. Energy Information Administration.

Table A-12. Calibrated Average Variable Primary Fuel Input for New Kiln by Process Type: 2005

Process Type	Average Variable Fuel Input for a New Kiln (million BTU per metric ton)
Wet Process	
≤500,000-ton capacity	2.84
>500,000-ton capacity	3.34
Dry Process	
≤500,000-ton capacity	3.43
>500,000-ton capacity	2.61
Precalciner	2.97
Preheater	3.01

BTUs, we converted from metric tons to barrels by multiplying by 5.51, and we converted from barrels to million BTUs by multiplying by 6.024.

To calculate fuel costs, we used the primary fuel used by the kiln reported by the Portland Cement Association (2004) and multiplied fuel prices by the fuel input equation described above.

A.2.6 Results

RTI used the methods described above to revise the kiln-level AVC functions and to reflect the cost differences across kiln technologies and kiln size. The new AVC estimates for each kiln are reported in Table A-14. We report them in dollars per metric ton and dollars per short ton.

A.3 Partial Equilibrium Model

Once the markets were defined, we examined the evidence supporting the appropriate supplier pricing behavior assumptions in these markets. For example, the degree of concentration, entry barriers, and product differentiation can indicate a firm’s ability to influence market prices by varying the quantity of cement it sells. In markets with large numbers of sellers and identical products, firms are unlikely to be able to influence market prices via their production decisions (i.e., they are “price takers”). However, in markets with few firms, significant barriers to entry (e.g., licenses, legal restrictions, or high fixed costs), or products that are similar but can be differentiated, the firm may have some degree of market power (i.e., set or significantly influence market prices).

Table A-13. Fuel Prices by Census Region, State, and Fuel Type: 2005

Census Region	State	Fuel Price ($/million BTU) Other Industrial Coal[a]	Petroleum Coke[b]	Natural Gas[a]	Residual Oil[a]
East South Central	AL	$2.47	$1.80	$8.51	$7.81
Pacific	AK	$2.24	$1.80	$7.46	$7.98
Mountain	AZ	$1.73	$1.80	$7.71	$7.59
West South Central	AR	$1.79	$1.80	$7.80	$7.02
Pacific	CA	$2.24	$1.80	$7.46	$7.98
Mountain	CO	$1.73	$1.80	$7.71	$7.59
New England	CT	$3.71	$1.80	$10.47	$7.79
Middle Atlantic	DE	$2.13	$1.80	$9.65	$8.33
South Atlantic	FL	$2.83	$1.80	$9.11	$7.93
South Atlantic	GA	$2.83	$1.80	$9.11	$7.93
Pacific	HI	$2.24	$1.80	$7.46	$7.98
Mountain	ID	$1.73	$1.80	$7.71	$7.59
East North Central	IL	$2.24	$1.80	$8.52	$7.65
East North Central	IN	$2.24	$1.80	$8.52	$7.65
West North Central	IA	$1.21	$1.80	$7.86	$7.18
West North Central	KS	$1.21	$1.80	$7.86	$7.18
East South Central	KY	$2.47	$1.80	$8.51	$7.81
West South Central	LA	$1.79	$1.80	$7.80	$7.02
New England	ME	$3.71	$1.80	$10.47	$7.79
South Atlantic	MD	$2.83	$1.80	$9.11	$7.93
New England	MA	$3.71	$1.80	$10.47	$7.79
East North Central	MI	$2.24	$1.80	$8.52	$7.65
West North Central	MN	$1.21	$1.80	$7.86	$7.18
East South Central	MS	$2.47	$1.80	$8.51	$7.81
West North Central	MO	$1.21	$1.80	$7.86	$7.18
Mountain	MT	$1.73	$1.80	$7.71	$7.59
West North Central	NE	$1.21	$1.80	$7.86	$7.18
Mountain	NV	$1.73	$1.80	$7.71	$7.59
New England	NH	$3.71	$1.80	$10.47	$7.79
Middle Atlantic	NJ	$2.13	$1.80	$9.65	$8.33
Mountain	NM	$1.73	$1.80	$7.71	$7.59
East North Central	NY	$2.24	$1.80	$8.52	$7.65
South Atlantic	NC	$2.83	$1.80	$9.11	$7.93
West North Central	ND	$1.21	$1.80	$7.86	$7.18
East North Central	OH	$2.24	$1.80	$8.52	$7.65
West South Central	OK	$1.79	$1.80	$7.80	$7.02
Pacific	OR	$2.24	$1.80	$7.46	$7.98
Middle Atlantic	PA	$2.13	$1.80	$9.65	$8.33
New England	RI	$3.71	$1.80	$10.47	$7.79
South Atlantic	SC	$2.83	$1.80	$9.11	$7.93
West North Central	SD	$1.21	$1.80	$7.86	$7.18
East South Central	TN	$2.47	$1.80	$8.51	$7.81
East South Central	TX	$2.47	$1.80	$8.51	$7.81
Mountain	UT	$1.73	$1.80	$7.71	$7.59

(continued)

Table A-13. Fuel Prices by Census Region, State, and Fuel Type: 2005 (continued)

		Fuel Price ($/million BTU)			
Census Region	**State**	**Other Industrial Coal** [a]	**Petroleum Coke** [b]	**Natural Gas** [a]	**Residual Oil** [a]
New England	VT	$3.71	$1.80	$10.47	$7.79
South Atlantic	VA	$2.83	$1.80	$9.11	$7.93
Pacific	WA	$2.24	$1.80	$7.46	$7.98
South Atlantic	WV	$2.83	$1.80	$9.11	$7.93
East North Central	WI	$2.24	$1.80	$8.52	$7.65
Mountain	WY	$1.73	$1.80	$7.71	$7.59

[a] Other industrial coal, natural gas, and residual oil: U.S. Department of Energy, Energy Information Administration. 2007. *Annual Energy Outlook 2007*. Supplemental Tables 12, 15, and 16. Washington, DC: U.S. Energy Information Administration. For kilns using waste oil as a primary fuel, we used the residual fuel oil price as a proxy.

[b] Petroleum coke: Export trade data come from USITC Interactive Tariff and Trade DataWeb. 2007 <http://dataweb.usitc.gov/scripts/user_set.asp >. HTS codes: 271311 and 271312. The price calculation is described in *State Energy Consumption, Price, and Expenditure Estimates (SEDS): Technical Notes Prices and Expenditures Section 4* (U.S. Department of Energy, 2006b). <http://www.eia.doe.gov/emeu/states/sep_prices/notes/pr_petrol.pdf.>.

Although perfect competition on the supply side (and demand side) is widely accepted for modeling many industries (EPA, 2000), the cement industry has unique characteristics that lead us to use an alternative assumption about supplier pricing behavior. First, high transportation costs and other production economics limit the number of sellers, so each seller has a substantial market share. Potential entry is constrained by the high capital costs that involve purchases and construction of large rotary kilns that are not readily movable or transferable to other uses. In addition, large plants are typically more economical because they can produce cement at lower unit costs; this reduces entry incentives for small-sized cement plants. Second, cement producers offer very similar or identical products. American Society for Testing and Materials (ASTM) specifications tend to ensure uniform quality, and recent industry reviews (USITC, 2006) suggest that there is little or no brand loyalty that allows firms to differentiate their products. Given this evidence, EPA continued to use the oligopoly framework used in previous economic analyses (EPA, 1998, 1999b).

Table A-14. Average Variable Costs by Kiln: 2005

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
GA101	Atlanta	Lafarge North America	Atlanta Plant	Atlanta	GA	42	C	Dry	315	$60	$54
TN101	Atlanta	Buzzi Unicem USA, Inc.	Chattanooga Plant	Chattanooga	TN	5	K	Dry-C	771	$38	$35
GA201	Atlanta	Cemex	Clinchfield Plant	Clinchfield	GA	6	C	Dry-X	705	$48	$43
VA101	Atlanta	Titan America LLC	Roanoke Plant	Cloverdale	VA	9	C	Dry-C	1,120	$45	$41
SC101	Atlanta	Giant Cement Holding, Inc.	Harleyville Plant	Harleyville	SC	53	C	Wet	164	$57	$51
SC102	Atlanta	Giant Cement Holding, Inc.	Harleyville Plant	Harleyville	SC	49	C	Wet	156	$56	$51
SC103	Atlanta	Giant Cement Holding, Inc.	Harleyville Plant	Harleyville	SC	45	C	Wet	164	$56	$51
SC104	Atlanta	Giant Cement Holding, Inc.	Harleyville Plant	Harleyville	SC	33	C	Wet	164	$55	$50
SC201	Atlanta	Lafarge North America	Harleyville Plant	Harleyville	SC	17	C	Dry-C	972	$43	$39
SC401	Atlanta	Holcim (U.S.) Inc.	Holly Hill Plant	Holly Hill	SC	2	C	Dry-C	1,860	$41	$38
TN201	Atlanta	Cemex	Knoxville Plant	Knoxville	TN	27	C	Dry-C	667	$45	$41
PA601	Baltimore/ Philadelphia	Giant Cement Holding, Inc.	Bath Plant	Bath	PA	49	C	Wet	103	$54	$49
PA602	Baltimore/ Philadelphia	Giant Cement Holding, Inc.	Bath Plant	Bath	PA	49	C	Wet	506	$50	$45
PA801	Baltimore/ Philadelphia	Lehigh Cement Company	Allentown Plant	Blandon	PA	40	C	Dry	470	$56	$51
PA802	Baltimore/ Philadelphia	Lehigh Cement Company	Allentown Plant	Blandon	PA	40	C	Dry	470	$56	$51
MD101	Baltimore/ Philadelphia	Essroc Cement Corp.	Frederick Plant	Buckeystown	MD	47	C	Wet	155	$62	$57
MD102	Baltimore/ Philadelphia	Essroc Cement Corp.	Frederick Plant	Buckeystown	MD	47	C	Wet	155	$62	$57
MD301	Baltimore/ Philadelphia	St. Lawrence Cement Company	Hagerstown Plant	Hagerstown	MD	34	C	Dry	513	$52	$48

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
WV101	Baltimore/ Philadelphia	Essroc Cement Corp.	Martinsburg Plant	Martinsburg	WV	50	C	Wet	177	$54	$49
WV102	Baltimore/ Philadelphia	Essroc Cement Corp.	Martinsburg Plant	Martinsburg	WV	45	C	Wet	177	$54	$49
WV103	Baltimore/ Philadelphia	Essroc Cement Corp.	Martinsburg Plant	Martinsburg	WV	40	C	Wet	354	$53	$48
PA501	Baltimore/ Philadelphia	Essroc Cement Corp.	Nazareth Plant I	Nazareth	PA	27	C	Dry-X	1,116	$43	$39
PA502	Baltimore/ Philadelphia	Essroc Cement Corp.	Nazareth Plant III	Nazareth	PA	48	C	Dry	150	$57	$52
PA503	Baltimore/ Philadelphia	Essroc Cement Corp.	Nazareth Plant III	Nazareth	PA	48	C	Dry	155	$57	$52
PA504	Baltimore/ Philadelphia	Essroc Cement Corp.	Nazareth Plant III	Nazareth	PA	56	C	Dry	107	$58	$52
PA505	Baltimore/ Philadelphia	Essroc Cement Corp.	Nazareth Plant III	Nazareth	PA	56	C	Dry	107	$58	$52
PA201	Baltimore/ Philadelphia	Buzzi Unicem USA, Inc.	Stockertown Plant	Stockertown	PA	26	K	Dry-X	365	$49	$44
PA202	Baltimore/ Philadelphia	Buzzi Unicem USA, Inc.	Stockertown Plant	Stockertown	PA	12	K	Dry-X	543	$45	$40
MD201	Baltimore/ Philadelphia	Lehigh Cement Company	Union Bridge	Union Bridge	MD	4	C	Dry-C	1,715	$47	$43
PA701	Baltimore/ Philadelphia	Lafarge North America	Whitehall Plant	Whitehall	PA	40	C	Dry-X	419	$51	$46
PA702	Baltimore/ Philadelphia	Lafarge North America	Whitehall Plant	Whitehall	PA	30	C	Dry-X	283	$50	$46
MS101	Birmingham	Holcim (U.S.) Inc.	Artesia Plant	Artesia	MS	31	C	Wet	419	$61	$55
AL301	Birmingham	Lafarge North America	Roberta Plant	Calera	AL	3	C	Dry-C	1,498	$38	$35
AL101	Birmingham	Cemex	Demopolis Plant	Demopolis	AL	28	C	Dry-X	821	$41	$38
AL401	Birmingham	Lehigh Cement Company	Leeds Plant	Leeds	AL	29	C	Dry-X	716	$45	$41

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
AL501	Birmingham	National Cement Co. of Alabama	Ragland Plant	Ragland	AL	30	C	Dry-C	900	$40	$37
AL201	Birmingham	Holcim (U.S.) Inc.	Theodore Plant	Theodore	AL	24	C	Dry-C	1,440	$40	$36
IA201	Chicago	Lafarge North America	Buffalo Plant	Buffalo	IA	24	C	Dry-C	946	$37	$33
IL201	Chicago	Cemex	Dixon Plant	Dixon	IL	50	K	Dry-X	120	$49	$44
IL202	Chicago	Cemex	Dixon Plant	Dixon	IL	50	K	Dry-X	120	$49	$44
IL203	Chicago	Cemex	Dixon Plant	Dixon	IL	50	K	Dry-X	120	$49	$44
IL204	Chicago	Cemex	Dixon Plant	Dixon	IL	40	K	Dry	184	$53	$48
IN101	Chicago	Buzzi Unicem USA, Inc.	Greencastle Plant	Greencastle	IN	5	C	Dry-C	1,190	$37	$33
IL301	Chicago	Eagle Materials	La Salle Plant	La Salle	IL	31	K	Dry-X	602	$44	$40
IN201	Chicago	Essroc Cement Corp.	Logansport Plant	Logansport	IN	43	K	Wet	202	$49	$44
IN202	Chicago	Essroc Cement Corp.	Logansport Plant	Logansport	IN	43	K	Wet	202	$49	$44
IL101	Chicago	Buzzi Unicem USA, Inc.	Oglesby Plant	Oglesby	IL	33	C	Dry	569	$44	$40
KY101	Cincinnati	Cemex	Kosmosdale Plant	Louisville	KY	5	C	Dry-C	1,365	$39	$35
IN402	Cincinnati	Lehigh Cement Company	Mitchell Plant	Mitchell	IN	55	C	Dry-X	251	$49	$44
IN401	Cincinnati	Lehigh Cement Company	Mitchell Plant	Mitchell	IN	45	C	Dry-X	251	$48	$44
IN403	Cincinnati	Lehigh Cement Company	Mitchell Plant	Mitchell	IN	29	C	Dry-X	274	$47	$42
IN301	Cincinnati	Essroc Cement Corp.	Speed Plant	Speed	IN	33	C	Dry	279	$52	$47
IN302	Cincinnati	Essroc Cement Corp.	Speed Plant	Speed	IN	27	C	Dry-X	542	$43	$39
OH101	Cincinnati	Cemex	Fairborn Plant	Xenia	OH	31	K	Dry-X	661	$44	$40

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
OK201	Dallas	Holcim (U.S.) Inc.	Ada Plant	Ada	OK	47	C	Wet	278	$49	$45
OK202	Dallas	Holcim (U.S.) Inc.	Ada Plant	Ada	OK	47	C	Wet	278	$49	$45
AR101	Dallas	Ash Grove Cement Company	Foreman Plant	Foreman	AR	47	C	Wet	246	$49	$44
AR102	Dallas	Ash Grove Cement Company	Foreman Plant	Foreman	AR	43	C	Wet	246	$48	$44
AR103	Dallas	Ash Grove Cement Company	Foreman Plant	Foreman	AR	41	C	Wet	339	$48	$44
TX201	Dallas	Ash Grove Texas, L.P.	Midiothian Plant	Midiothian	TX	39	C	Wet	283	$54	$49
TX202	Dallas	Ash Grove Texas, L.P.	Midiothian Plant	Midiothian	TX	36	C	Wet	283	$54	$49
TX203	Dallas	Ash Grove Texas, L.P.	Midiothian Plant	Midiothian	TX	33	C	Wet	283	$54	$49
TX701	Dallas	Holcim (U.S.) Inc.	Holnam Texas L.P.	Midiothian	TX	18	C	Dry-C	1,036	$42	$38
TX702	Dallas	Holcim (U.S.) Inc.	Holnam Texas L.P.	Midiothian	TX	5	C	Dry-C	990	$41	$37
TX901	Dallas	Texas Industries Inc.	Midiothian Plant	Midiothian	TX	45	C	Wet	286	$55	$50
TX902	Dallas	Texas Industries Inc.	Midiothian Plant	Midiothian	TX	42	C	Wet	286	$54	$49
TX903	Dallas	Texas Industries Inc.	Midiothian Plant	Midiothian	TX	38	C	Wet	286	$54	$49
TX904	Dallas	Texas Industries Inc.	Midiothian Plant	Midiothian	TX	33	C	Wet	286	$54	$49
TX905	Dallas	Texas Industries Inc.	Midiothian Plant	Midiothian	TX	4	C	Dry-C	1,964	$41	$37
OK301	Dallas	Lafarge North America	Tulsa Plant	Tulsa	OK	44	C	Dry	347	$51	$46
OK302	Dallas	Lafarge North America	Tulsa Plant	Tulsa	OK	42	C	Dry	341	$51	$46

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
CO201	Denver	Holcim (U.S.) Inc.	Portland Plant	Florence	CO	4	C	Dry-C	1,631	$39	$35
WY101	Denver	Eagle Materials	Laramie Plant	Laramie	WY	9	C	Dry	181	$47	$43
WY102	Denver	Eagle Materials	Laramie Plant	Laramie	WY	6	C	Dry-X	416	$43	$39
CO101	Denver	Cemex	Lyons Plant	Lyons	CO	25	C	Dry-X	486	$48	$44
SD101	Denver	GCC of America, Inc.	Dacotah Cement	Rapid City	SD	50	C	Wet	147	$44	$39
SD102	Denver	GCC of America, Inc.	Dacotah Cement	Rapid City	SD	48	C	Wet	147	$43	$39
SD103	Denver	GCC of America, Inc.	Dacotah Cement	Rapid City	SD	10	C	Dry-X	557	$36	$33
MI301	Detroit	Lafarge North America	Alpena Plant	Alpena	MI	43	C	Dry	364	$54	$49
MI302	Detroit	Lafarge North America	Alpena Plant	Alpena	MI	40	C	Dry	364	$54	$49
MI303	Detroit	Lafarge North America	Alpena Plant	Alpena	MI	40	C	Dry	364	$54	$49
MI304	Detroit	Lafarge North America	Alpena Plant	Alpena	MI	40	C	Dry	536	$42	$38
MI305	Detroit	Lafarge North America	Alpena Plant	Alpena	MI	40	C	Dry	536	$42	$38
MI101	Detroit	Cemex	Charlevoix Plant	Charlevoix	MI	26	C	Dry-C	1,211	$38	$35
MI201	Detroit	Holcim (U.S.) Inc.	Dundee Plant	Dundee	MI	46	C	Wet	431	$52	$47
MI202	Detroit	Holcim (U.S.) Inc.	Dundee Plant	Dundee	MI	46	C	Wet	437	$52	$47
OH201	Detroit	Lafarge North America	Paulding Plant	Paulding	OH	49	A	Wet	226	$78	$70
OH202	Detroit	Lafarge North America	Paulding Plant	Paulding	OH	49	A	Wet	228	$78	$70
FL501	Florida	Suwannee American Cement		Branford	FL	2	C	Dry-C	682	$49	$45
FL101	Florida	Cemex	Brooksville Plant	Brooksville	FL	29	C	Dry-X	550	$53	$48
FL102	Florida	Cemex	Brooksville Plant	Brooksville	FL	20	C	Dry-X	506	$52	$47
FL301	Florida	Rinker Materials	Brooksville Plant	Brooksville	FL	18	C	Dry-X	605	$52	$47

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
FL601	Florida	Titan America LLC	Pennsuco Plant	Medley	FL	1	C	Dry-C	1,492	$45	$41
FL401	Florida	Rinker Materials	Miami Plant	Miami	FL	5	C	Dry-C	928	$46	$41
FL201	Florida	Florida Rock Industries	Thompson S. Baker Plant	Newberry	FL	6	C	Dry-C	726	$49	$45
KS101	Kansas City	Ash Grove Cement Company	Chanute Plant	Chanute	KS	4	C	Dry-C	1,308	$37	$34
KS301	Kansas City	Lafarge North America	Fredonia Plant	Fredonia	KS	69	A	Wet	169	$82	$74
KS302	Kansas City	Lafarge North America	Fredonia Plant	Fredonia	KS	49	A	Wet	243	$76	$69
KS401	Kansas City	Monarch Cement Company	Humbolt Plant	Humbolt	KS	32	C	Dry-X	284	$46	$42
KS402	Kansas City	Monarch Cement Company	Humbolt Plant	Humbolt	KS	30	C	Dry-C	503	$42	$38
KS201	Kansas City	Buzzi Unicem USA, Inc.	Independence Plant	Independence	KS	88	K	Dry	82	$58	$53
KS202	Kansas City	Buzzi Unicem USA, Inc.	Independence Plant	Independence	KS	88	K	Dry	82	$58	$53
KS203	Kansas City	Buzzi Unicem USA, Inc.	Independence Plant	Independence	KS	88	K	Dry	82	$58	$53
KS204	Kansas City	Buzzi Unicem USA, Inc.	Independence Plant	Independence	KS	88	K	Dry	82	$58	$53
NE101	Kansas City	Ash Grove Cement Company	Louisville Plant	Louisville	NE	29	C	Dry-X	338	$44	$40
NE102	Kansas City	Ash Grove Cement Company	Louisville Plant	Louisville	NE	23	C	Dry-C	507	$40	$36
OK101	Kansas City	Buzzi Unicem USA, Inc.	Pryor Plant	Pryor	OK	45	C	Dry	189	$51	$46
OK102	Kansas City	Buzzi Unicem USA, Inc.	Pryor Plant	Pryor	OK	43	C	Dry	186	$51	$46
OK103	Kansas City	Buzzi Unicem USA, Inc.	Pryor Plant	Pryor	OK	25	C	Dry	250	$50	$45

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
MO501	Kansas City	Lafarge North America	Sugar Creek Plant	Sugar Creek	MO	4	C	Dry-C	930	$37	$34
CA101	Los Angeles	California Portland Cement	Colton Plant	Colton	CA	43	C	Dry	340	$66	$60
CA102	Los Angeles	California Portland Cement	Colton Plant	Colton	CA	43	C	Dry	340	$66	$60
CA801	Los Angeles	National Cement Co. of California	Lebec Plant	Lebec	CA	6	K	Dry-C	1,033	$48	$43
CA701	Los Angeles	Mitsubishi Cement Corporation	Cushenbury Plant	Lucerne Valley	CA	23	C	Dry-C	1,543	$50	$45
CA201	Los Angeles	California Portland Cement	Mojave Plant	Mojave	CA	24	C	Dry-C	1,363	$50	$45
CA1101	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	57	C	Dry	155	$67	$61
CA1102	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	57	C	Dry	155	$67	$61
CA1103	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	57	C	Dry	155	$67	$61
CA1104	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	53	C	Dry	155	$67	$61
CA1105	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	53	C	Dry	155	$67	$61
CA1106	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	46	C	Dry	155	$66	$60
CA1107	Los Angeles	Texas Industries Inc.	Oro Grande Plant	Oro Grande	CA	46	C	Dry	155	$66	$60
CA601	Los Angeles	Lehigh Southwest Cement Company	Tehachapi Plant	Tehachapi	CA	14	C	Dry-C	958	$49	$45
CA301	Los Angeles	Cemex	Victorville Plant	Victorville	CA	22	C	Dry-X	1,046	$51	$47
CA302	Los Angeles	Cemex	Victorville Plant	Victorville	CA	4	C	Dry-X	1,681	$50	$46
IA101	Minneapolis	Holcim (U.S.) Inc.	Mason City Plant	Mason City	IA	39	C	Dry	600	$41	$37
IA102	Minneapolis	Holcim (U.S.) Inc.	Mason City Plant	Mason City	IA	39	C	Dry	371	$50	$45

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
IA301	Minneapolis	Lehigh Cement Company	Lehigh-Mason City	Mason City	IA	27	C	Dry-C	755	$37	$33
NY301	New York/ Boston	St. Lawrence Cement Company	Catskill Plant	Catskill	NY	41	C	Wet	580	$57	$52
NY101	New York/ Boston	Glens Fall Lehigh Cement Co.	Glens Falls Plant	Glens Falls	NY	32	C	Dry-X	586	$55	$50
NY201	New York/ Boston	Lafarge North America	Ravena Plant	Ravena	NY	43	C	Wet	852	$54	$49
NY202	New York/ Boston	Lafarge North America	Ravena Plant	Ravena	NY	43	C	Wet	868	$54	$49
ME101	New York/ Boston	Dragon Products Company	Thomaston Plant	Thomaston	ME	34	C	Wet	392	$62	$56
AZ201	Phoenix	Phoenix Cement Company	Clarkdale Plant	Clarkdale	AZ	46	C	Dry-C	187	$46	$42
AZ202	Phoenix	Phoenix Cement Company	Clarkdale Plant	Clarkdale	AZ	46	C	Dry-C	187	$46	$42
AZ203	Phoenix	Phoenix Cement Company	Clarkdale Plant	Clarkdale	AZ	44	C	Dry-C	191	$46	$42
AZ204	Phoenix	Phoenix Cement Company	Clarkdale Plant	Clarkdale	AZ	3	C	Dry-C	912	$37	$33
UT101	Phoenix	Ash Grove Cement Company	Leamington Plant	Nephi	UT	24	C	Dry-C	810	$35	$32
AZ101	Phoenix	California Portland Cement	Rillito Plant	Rillito	AZ	56	C	Dry	121	$53	$48
AZ102	Phoenix	California Portland Cement	Rillito Plant	Rillito	AZ	54	C	Dry	121	$52	$48
AZ103	Phoenix	California Portland Cement	Rillito Plant	Rillito	AZ	50	C	Dry	121	$52	$47
AZ104	Phoenix	California Portland Cement	Rillito Plant	Rillito	AZ	3	C	Dry-C	969	$37	$33
NM101	Phoenix	GCC of America, Inc.	Tijeras Plant	Tijeras	NM	46	C	Dry-X	216	$48	$43

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Average Variable Costs ($/short ton)
NM102	Phoenix	GCC of America, Inc.	Tijeras Plant	Tijeras	NM	45	C	Dry-X	216	$48	$43
PA401	Pittsburgh	Essroc Cement Corp.	Bessemer Plant	Bessemer	PA	44	C	Wet	225	$54	$49
PA402	Pittsburgh	Essroc Cement Corp.	Bessemer Plant	Bessemer	PA	41	C	Wet	339	$54	$49
PA101	Pittsburgh	Armstrong Cement & Sup. Corp.	Cabot Plant	Cabot	PA	79	C	Wet	143	$57	$52
PA102	Pittsburgh	Armstrong Cement & Sup. Corp.	Cabot Plant	Cabot	PA	79	C	Wet	143	$57	$52
PA301	Pittsburgh	Cemex	Wampum Plant	Wampum	PA	47	C	Dry	215	$57	$51
PA302	Pittsburgh	Cemex	Wampum Plant	Wampum	PA	47	C	Dry	205	$57	$51
PA303	Pittsburgh	Cemex	Wampum Plant	Wampum	PA	47	C	Dry	238	$57	$51
OR101	Salt Lake City	Ash Grove Cement Company	Durkee Plant	Durkee	OR	7	C	Dry-C	816	$38	$34
ID101	Salt Lake City	Ash Grove Cement Company	Inkom Plant	Inkom	ID	77	C	Wet	115	$48	$44
ID102	Salt Lake City	Ash Grove Cement Company	Inkom Plant	Inkom	ID	54	C	Wet	145	$46	$42
MT101	Salt Lake City	Ash Grove Cement Company	Montana City Plant	Montana City	MT	42	C	Wet	293	$46	$42
UT201	Salt Lake City	Holcim (U.S.) Inc.	Devil's Slide Plant	Morgan	UT	8	C	Dry-C	704	$38	$34
MT201	Salt Lake City	Holcim (U.S.) Inc.	Trident Plant	Three Forks	MT	32	C	Wet	280	$45	$41
TX1201	San Antonio	Texas-Lehigh Cement Company	Buda Plant	Buda	TX	27	C	Dry-C	1,125	$43	$39
TX501	San Antonio	Cemex	Balcones Plant	New Braunfels	TX	25	K	Dry-X	1,005	$41	$38
TX1001	San Antonio	Texas Industries Inc.	Hunter Cement Plant	New Braunfels	TX	26	C	Dry-C	780	$43	$39
TX601	San Antonio	Cemex	Odessa Plant	Odessa	TX	47	C	Dry	256	$58	$53
TX602	San Antonio	Cemex	Odessa Plant	Odessa	TX	26	C	Dry-X	285	$51	$46

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Variable Costs ($/short ton)
TX101	San Antonio	Alamo Cement Company	1604 Plant	San Antonio	TX	24	C	Dry-C	821	$43	$39
TX401	San Antonio	Capitol Aggregates, Ltd.	Capitol Cement Division	San Antonio	TX	40	C	Wet	269	$54	$49
TX402	San Antonio	Capitol Aggregates, Ltd.	Capitol Cement Division	San Antonio	TX	22	C	Dry-C	599	$46	$42
TX301	San Antonio	Buzzi Unicem USA, Inc.	Maryneal Plant	Sweetwater	TX	34	C	Dry-X	153	$52	$47
TX302	San Antonio	Buzzi Unicem USA, Inc.	Maryneal Plant	Sweetwater	TX	34	C	Dry-X	153	$52	$47
TX303	San Antonio	Buzzi Unicem USA, Inc.	Maryneal Plant	Sweetwater	TX	34	C	Dry-X	162	$52	$47
CA401	San Francisco	Hanson Permanente Cemente	Permanente Plant	Cupertino	CA	24	C	Dry-C	1,497	$50	$45
CA901	San Francisco	RMC Pacific Materials	Santa Cruz Plant	Davenport	CA	24	C	Dry-C	812	$50	$45
NV101	San Francisco	Eagle Materials	Nevada Cement	Femley	NV	41	C	Dry	226	$57	$52
NV102	San Francisco	Eagle Materials	Nevada Cement	Femley	NV	19	C	Dry-X	226	$51	$46
CA501	San Francisco	Lehigh Southwest Cement Company	Redding Plant	Redding	CA	24	C	Dry-C	592	$54	$49
WA101	Seattle	Ash Grove Cement Company	Seattle Plant	Seattle	WA	13	C	Dry-C	675	$43	$39
WA201	Seattle	Lafarge North America	Seattle Plant	Seattle	WA	38	K	Wet	425	$51	$46
MO101	St. Louis	Buzzi Unicem USA, Inc.	Cape Girardeau Plant	Cape Girardeau	MO	24	C	Dry-C	1,265	$38	$34
MO401	St. Louis	Holcim (U.S.) Inc.	Clarksville Plant	Clarksville	MO	38	C	Wet	1,241	$41	$38
MO201	St. Louis	Buzzi Unicem USA, Inc.	Festus Plant	Festus	MO	40	K	Dry	592	$44	$40

(continued)

Table A-14. Average Variable Costs by Kiln: 2005 (continued)

Kiln ID	Market Name	Company Name	Plant Name	City	State	Age in 2005	Primary Fuel ID[a]	Process[b]	Clinker Capacity (10^3 metric tons/year)	Average Variable Costs ($/metric ton)	Variable Costs ($/short ton)
MO202	St. Louis	Buzzi Unicem USA, Inc.	Festus Plant	Festus	MO	36	K	Dry	592	$44	$40
IL401	St. Louis	Lafarge North America	Joppa Plant	Grand Chain	IL	42	K	Dry	443	$53	$48
IL402	St. Louis	Lafarge North America	Joppa Plant	Grand Chain	IL	30	K	Dry	612	$42	$38
MO301	St. Louis	Continental Cement Co., Inc.	Hannibal Plant	Hannibal	MO	39	C	Wet	549	$45	$41
CA1001	White Cement	Texas Industries Inc.	Crestmore	Riverside	CA	47	O	Dry	51	$96	$87
CA1002	White Cement	Texas Industries Inc.	Crestmore	Riverside	CA	45	O	Dry	51	$95	$86
TX801	White Cement	Lehigh Cement Company	Waco Plant	Waco	TX	37	G	Wet	97	$78	$70
PA901	White Cement	Lehigh Cement Company	York Plant	York	PA	43	O	Wet	112	$79	$72

[a] Primary fuel ID codes are coal (C), coke (K), oil (O), and waste (A).

[b] Process codes are preheater (X) and precalciner (C).

One consequence of this assumption is that the seller individually chooses an output level that is less than the level produced under perfect competition. As a result, the baseline market price will be higher than a model of perfect competition, and there is a preexisting market distortion in the industry being regulated.[1] To provide some intuition about factors that influence the size of the existing distortion, we express a seller's "best" supply decision as a function of the market price, the seller's market share, the market demand elasticity, and the seller's marginal costs (see Varian [1992], pp. 289–290):

$$\text{Price} \times (1 + \text{Market Share}_i/\text{Demand Elasticity}) = \text{Marginal Cost}_i$$

This equation shows the relationship between the oligopoly model and perfect competition. The market distortion will typically be higher the smaller the number of sellers and in markets where the quantity demanded is less sensitive to price (i.e., the demand elasticity is inelastic).

A.4 Equations

To estimate the economic impacts of the regulation, EPA used four linear equations to calculate the following unknown variables:

- change in domestic plant production (dq_i),
- change in imports ($dq^{imports}$),
- change in cement market quantity (dQ), and
- change in cement price (dP).

Equation 1: Domestic Supply. For each plant, we describe its response to the regulatory program as follows. The total compliance cost per ton (c_i) is applied to each kiln, and the difference in the highest cost kiln with-regulation and the highest cost kiln in the baseline approximates the plant's change in the marginal cost of production (dMC_i). In with-regulation equilibrium, the change in marginal revenue (dMRi) must equal the change in the marginal cost (dMCi) for each plant.[2]

$$\text{dmarginal Revenue}_i = \text{dmarginal Cost}_i$$

or

[1] This ultimately influence partial equilibrium model's estimates of the social cost of the regulatory program since bigger existing market distortions tend tends to widen the gap between price and marginal cost in these markets and leads to the higher deadweight loss estimates than under the case of perfectly competitive markets. The Office of Management and Budget (OMB) explicitly mentions the need to consider market power–related welfare costs in evaluating regulations under Executive Order 12866.

[2] To highlight and make transparent the assumptions regarding seller behavior, this equation is formally derived in Appendix B.

$$\text{dprice}\times\left(1+\frac{\text{mkt share}_i}{\text{dem elasticity}}\right)+\frac{\text{dplant q}}{\text{market Q}}\times\frac{\text{price}}{\text{dem elasticity}}-\frac{\text{dmarket Q}}{(\text{market Q})^2}\times\text{plant q}\times\frac{\text{price}}{\text{dem elasticity}}=\text{dmarginal cost}$$

Equation 2: Supply of Imports. If applicable to the market, an equation describing the supply of cement from other countries was included:

dimports = import supply elasticity × (dprice/baseline price) × baseline imports.

For import supply, EPA used the latest empirical work on how other countries who export (i.e., supply imports) to the United States respond to price changes. Broda et al. (2008) report that the export supply elasticity for commodities imported by the United States was approximately two. This implies that a 1% increase in prices results in a 2% increase in the volume of exports for a typical good.

Equation 3: Market Supply. Market supply of Portland cement equals the change in domestic production and imports:

dmarket Q = dtotal domestic production + dimports.

This condition ensures that the market quantity is consistent with the individual supply decisions of domestic plants and imports in the new with-regulation equilibrium for each regional market.

Equation 4: Market Demand. The demand for Portland cement is derived from the demand for concrete products, which, in turn, is derived largely from the demand for construction. Based on a linear demand equation, the market demand condition for Portland cement must hold based on the projected change in market price, that is,

dMarketQ = demand elasticity (dprice/baseline price) × baseline consumption.

The use of published estimates from previous rulemakings is appropriate in cases when the cost of preparing original estimates is high (EPA, 2000). In previous analyses, EPA econometrically estimated the demand elasticity for cement and reported a point estimate of −0.88 (EPA, 1998). This value suggests that a 1% increase in the cement price would lead to a 0.88% reduction in cement consumption.

APPENDIX B

MODEL OF THE CEMENT PLANT'S PRODUCTION DECISION

This appendix provides additional detail about the cement plant production decision used in the economic model (see Equation 1 in Section 3 of the RIA). Table B-1 identifies and describes the key variables of the cement plant's profit function.

Table B-1. Variable Descriptions

P	Market price
$Q=\sum q_i$	Market output
q_i	Domestic plant i's output
FC_i	Plant fixed costs
VC_i	Plant variable costs

Step 1: First, we assume the plant's goal is to maximize profits:

$$\max_{q_i} \pi_i(Q) = P(Q)q_i - VC_i(q_i) - FC_i \ .$$

Step 2: The first-order conditions for a profit maximum are:

$$\frac{\partial \pi_i}{q_i} = P + \frac{\partial P(Q)}{\partial q_i} q_i - \frac{\partial VC_i(q_i)}{q_i} q_i = 0 \ .$$

Step 3: Apply two key assumptions in the Cournot price model:

- Plant's (i) recognizes its own production decisions influence the market price:

$$\frac{\partial P}{\partial q_i} \neq 0$$

- Plant (i) output decisions do not affect those of any other plant (j) (e.g., there is no strategic action among cement plants):

$$\frac{\partial q_j}{\partial q_i} = 0$$

Step 4: Next, multiply second term by

$$1 = \frac{Q}{P}\frac{P}{Q}$$

$$P + \frac{\partial P(Q)}{\partial q_i} q_i \left(\frac{Q}{P} \frac{P}{Q} \right) - \frac{\partial VC_i(q_i)}{q_i} q_i = 0 \ .$$

Step 5: Rearranging terms:

$$P + \left(\frac{\partial P(Q)}{P} \frac{Q}{\partial q_i} \right) \left(\frac{q_i}{Q} \right) P - \frac{\partial VC_i(q_i)}{q_i} q_i = 0 \ .$$

Step 6: Use and apply the following definitions:

$$\left(\frac{\partial P(Q)}{P} \frac{Q}{\partial q_i} \right) = \frac{1}{\eta} = \text{inverse demand elasticity}$$

$$\left(\frac{q_i}{Q} = q_i Q^{-1} \right) = \text{plant's market share} \ .$$

We derive the following expression:

$$P \left[1 + \left(\frac{\frac{q_i}{Q}}{\eta} \right) \right] = \frac{\partial VC_i(q_i)}{q_i} \ .$$

Step 7: The total differential of this equation is determined and gives us the optimal decision rule for the plant:

$$dP \left[1 + \left(\frac{\frac{q_i}{Q}}{\eta} \right) \right] + dq_i \left[\frac{P}{\eta} \frac{1}{Q} \right] - dQ \left[\frac{P}{\eta} \frac{q_i}{Q^2} \right] = \text{dMC} \ .$$

APPENDIX C

SOCIAL COST METHODOLOGY

The Office of Air Quality Planning and Standards (OAQPS) has adopted the standard industry-level analysis described in the Office's resource manual (EPA, 1999a). This approach is consistent with previous EPA analyses of the Portland cement industry (EPA, 1998; EPA, 1999b) and uses a single-period static partial-equilibrium model to compare prepolicy cement market baselines with expected postpolicy outcomes in these markets. The benchmark time horizon for the analysis is the intermediate run where producers have some constraints on their flexibility to adjust factors of production. This time horizon allows us to capture important transitory impacts of the program on existing producers. The model provides an estimate of the social costs (changes in producer and consumer surplus) associated with controls applying to existing kilns (see Section 4). Since the social cost methodology is identical to the approach used in previous cement analysis (EPA, 1998, Appendix C), we have included elements of the previous report's Appendix C in this RIA.

Figure C-1 illustrates the conceptual framework for evaluating the social cost and distributive impacts under the imperfectly competitive structure of U.S. cement markets. The baseline equilibrium is given by the price, P_0, and the quantity, Q_0. Without the regulation, the total benefits of consuming cement are given by the area under the demand curve up to the market output, Q_0. This equals the area filled by the letters ABCDEFGHIJ. The total variable cost to society of producing Q_0 equals the area under the MC function, given by the area IJ. Thus, the total surplus value to society from the production and consumption of output level Q_0 equals the total benefits minus the total costs, or the area filled by the letters ABCDEFGH.

This total surplus value to society can be further divided into producer surplus and consumer surplus. Producer surplus accrues to the suppliers of cement and reflects the value they receive in the market for producing Q_0 units of cement less their costs of production, i.e., their profits. As shown in Figure C-1, producer surplus is given by the area DEFGH, which is the difference between cement revenues (i.e., area DEFGHIJ) and production costs (area IJ). Consumer surplus accrues to the consumers of cement and reflects the value they place on consumption (total benefits of consumption) less what they must pay on the market, i.e., P_0. Consumer surplus is thereby given by the area ABC.

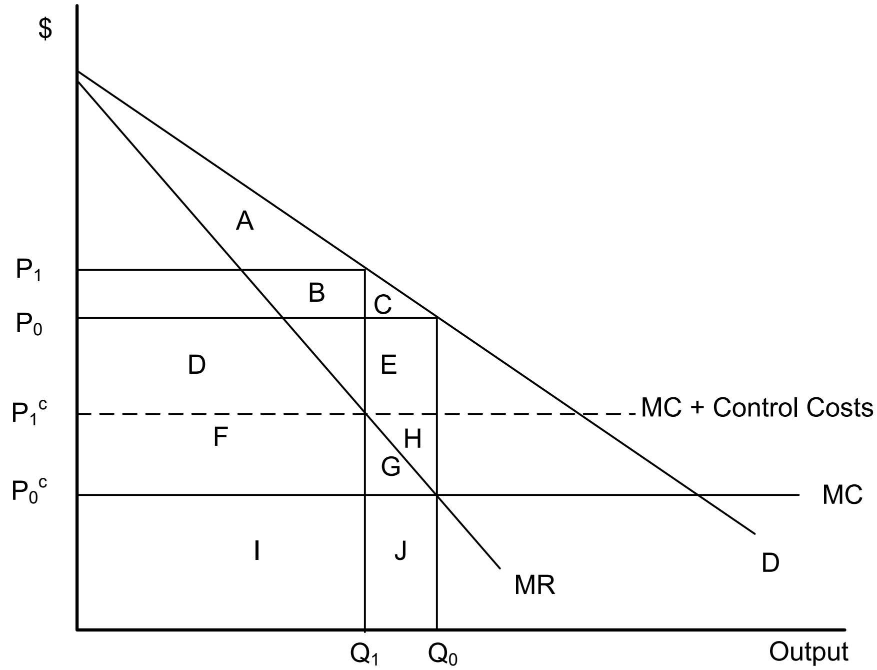

Figure C-1. Social Cost of Regulation Under Imperfect Competition

The proposed rule will increase the marginal cost of producing cement and thereby shift this curve upward by the amount of the incremental compliance costs. As shown in Figure C-1, this results in a new market equilibrium that occurs at a higher market price for cement, P_1, and a lower level of output, Q_1. In this scenario, the total benefits of consumption are equal to area ABDFI and the total variable costs of production are equal to area FI. This yields a with-regulation social surplus equal to area ABD with area BD representing the new producer surplus and area A being the new consumer surplus. The social cost of the regulation equals the total change in social surplus caused by the regulation. Therefore, the social cost of the regulation is represented by the area FGHEC in Figure C-1.

The distributive effects are estimated by separating the social cost into producer surplus and consumer surplus losses. First, the change in producer surplus is given by

$$\Delta PS = B - F - (G+H+E) \tag{C.1}$$

Producers gain B from the increase in price (a transfer from consumers to producers), but lose F from the increase in production costs due to the incremental compliance costs. Furthermore, the reduction of cement production leads to foregone baseline profits of G+H+E.

The change in consumer surplus is given by

$$\Delta CS = -(B + C) \tag{C.2}$$

This change results from the reduction in consumer surplus from the baseline value of ABC to the with-regulation value of A. In this case, consumers lose area B as a transfer to producers through the increase in the price they pay for the with-regulation level of cement consumption, while the reduction in cement consumption due to regulation leads to foregone baseline value of consumption equal to area C.

The social cost or total change in social surplus can then be derived simply by adding the changes in producer and consumer surplus, i.e.,

$$\text{Social Cost} = \Delta PS + \Delta CS = -(F + G + H + E + C) \tag{C.3}$$

This estimate can be compared to the engineering estimate of incremental compliance cost to demonstrate the difference between these two estimates of social cost. The incremental compliance cost estimate is given by the area FGH, which is simply the constant cost per unit times the baseline output level of cement. The social cost estimate from Equation (C.3) above, however, exceeds the engineering estimate by the area EC. In other words, the incremental compliance cost estimate understates the social costs of the regulation. The reason for this follows directly from the imperfectly competitive structure of the markets for cement. A comparison with the outcome under perfect competition will assist in illustrating this point.

Suppose that the MR curve in Figure C-1 was the demand function for a competitive market, rather than the marginal revenue function for an imperfectly competitive producer. Similarly, let the MC function be the aggregate supply function for all producers in the market. The market equilibrium is still determined at the intersection of MC and MR, but given the revised interpretation of MR as the competitive demand function, the baseline (competitive) market price, P_0^C, is now equal to MC and Q_0 is now interpreted as the competitive level of cement demand. In this case, all social surplus goes to the consumer. This is because producers receive a price that just covers their costs of production.

In the with-regulation perfectly competitive equilibrium, the market price would rise by the per unit control cost amount to P_1^c. The social cost of the regulation is given entirely by the loss in consumer surplus as given by area FG. As shown in Figure C-1, this estimate of social cost is less than the incremental compliance cost estimate (i.e., area FGH) so that the engineering estimate overstates the social cost of the regulation under perfect competition. The overstatement results from the fact that the incremental compliance costs are estimated based on the baseline market level of cement output. With regulation, output is projected to decline to Q_1, so that the actual incremental compliance costs incurred by the industry are given by area F. Area G represents the foregone value of cement consumption to consumers, also referred to as the deadweight loss (analogous to area C under the imperfect competition scenario).

In addition, the estimate of social cost under perfect competition is less than the estimate under imperfect competition by the area HEC, i.e.,

$$SC^{imp} - SC^{perf} = -[(F+G+H+E+C) - (F+G)] = -(H + E + C) \qquad (C.4)$$

The difference between these two measures results from the fact that the price paid by consumers (i.e., marginal value to society for cement) exceeds the cost of producing cement (i.e., the marginal cost to society of producing cement). As shown in Figure C-1, this difference in social cost is equal to the area between the demand curve (D) and the marginal revenue curve (MR) that exist under imperfectly competitive market structure. This area does not exist under perfect competition because the MR curve is interpreted as the demand curve so that the price paid by consumers equals the marginal cost of producing cement. The pre-existing social inefficiency of imperfect competition is exacerbated as the regulation moves society further away from the socially optimal level of cement production, which results in social costs greater than the incremental compliance cost imposed on the cement industry.