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Regulatory Impact Analysis:
Proposed National Emission
Standards for Hazardous Air
Pollutants (NESHAP) for Mercury
Emissions from Mercury Cell Chlor
Alkali Plants

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SECTION 1 INTRODUCTION AND EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is proposing amendments to the national emission standards for hazardous air pollutants (NESHAP) for mercury emissions from mercury cell chlor-alkali plants. On June 11, 2008, EPA proposed NESHAP amendments in response to a petition for reconsideration filed by the Natural Resources Defense Council (NRDC); this action supplements the June 11, 2008, proposal. The proposed rule would amend the NESHAP to prohibit emissions of mercury from the mercury cell process within 2 years from promulgation of the final rule and cease operation of mercury recovery units 3 years from promulgation of the final rule.

In 2003, when the maximum achievable control technology (MACT) was promulgated, there were 12 mercury cell plants. EPA believes that by 2010 there will only be four plants still using the mercury cell process. The four plants using the mercury cell process are currently owned by three ultimate parent companies:

- ASHTA Chemicals, Inc.: one plant (Ohio)
- Olin Corporation: two plants (Georgia and Tennessee)
- PPG Industries, Inc.: one plant (West Virginia)

ASHTA Chemicals is a small company with approximately 100 employees. Olin Corporation operates 10 North American chlor-alkali plants; its other line of business is Winchester Ammunition. Currently, Olin employs over 3,600 people within both business segments. PPG's commodity chemicals segment operates two chlor-alkali plants but operates over 100 coatings and glass manufacturing facilities and employees over 40,000 people company-wide.

As part of the regulatory process of preparing these amendments, EPA is required to develop a regulatory impact analysis (RIA). This report documents the RIA methods and results.

1.1 Executive Summary

The key results of the RIA are as follows:

Engineering Cost Analysis: For Option 1 (Non-mercury Technology Option), the engineering cost analysis estimates the total capital costs of conversion to be just under \$300 million, which results in annual costs of \$28 million per year annualized over 20 years. Individual plant-level annualized capital conversion cost estimates

range from \$3–15 million per year. All estimates are in 2007\$. The annual cost to store mercury is approximately \$250,000 per year. The individual plant-level annual energy savings due to conversion may range from \$1 million to \$14 million per year depending on the energy consumption reduction level assumed. The total annual cost of conversion for all four facilities, considering the associated savings, is around \$13 million per year. For Option 2 (Enhanced Work Practice Standards Option) the capital cost is \$120 thousand and the annual costs are \$25 thousand. Because of the small magnitude of Option 2 compared to Option 1, the market analysis only addresses Option 1.

- **Plant Closure:** EPA does not have sufficient data to predict whether individual companies would choose to convert or close directly affected plants. In some cases, if a plant were to close, the closure may affect other closely related manufacturing operations. For example, ASHTA uses potassium hydroxide made from the mercury cell process to make potassium carbonate. If the ASHTA plant were to choose not to convert and close the mercury cell process, it is unclear whether existing technology and economics would allow the company to consider an alternative source of potassium hydroxide to continue making potassium carbonate. The economics of making potassium carbonate could influence ASHTA's decision on how to respond to this rulemaking.
- **Local Job Effects:** Because EPA is unable to estimate plant closures, job losses associated with any closures are not estimated nor are any changes in employment associated with conversion.
- **Market Analysis:** Of the three major chlor-alkali products, the market for potassium hydroxide is the most highly concentrated. As of 2005, there were only four producers of potassium hydroxide (KOH) in the United States and approximately 50% is produced using mercury cells. As a result, closure of one or more mercury cell plants could raise concerns about competitiveness and subsequent pricing behavior in the potassium hydroxide market. In highly concentrated markets, non-mercury cell producers could have more scope to influence market prices above competitive levels by altering production decisions. EPA's review of publicly available sources also suggests that closures would have similar market concentration consequences for a downstream commodity: potassium carbonate. Competitive issues have also been raised in other regulatory contexts; the Federal Trade Commission set conditions on a proposed asset purchase that reduced the number of competitors in the potassium hydroxide and potassium carbonate markets.
- **Small Business Analysis:** EPA performed an impact analysis that compares annual conversion costs to sales. For Option 1 (Non-mercury Technology Option), EPA estimates that the one small entity's cost-to-sales ratio (CSR) would range from 1 to 2%, which suggests a significant economic impact. The other three plants are owned by large ultimate parent companies with significant company-wide sales. As a result, the CSRs for the large ultimate parent companies are below 1%. In contrast, when plant-only sales are considered, the

CSRs for plants owned by large ultimate parent companies range from 4 to 10%. EPA also considered industry profitability effects by comparing annual conversion costs to reported industry margins for a representative electrochemical unit (ECU). The analysis confirms the results of the sales tests; plant conversion costs will likely have an economically significant effect. In a typical year, conversion costs could reduce the margins by 10 to 20%. However, as explained in section 3, we do not consider this to be a significant impact on a substantial number of small businesses. For Option 2 (Enhanced Work Practice Standards Option) CSR for the only plant estimated to incur costs is less than 0.1 % and is not a significant economic impact.

- **Benefits Analysis:** In the year of full implementation (2013), EPA estimates the monetized energy co-benefits of Option 1 are \$22 million to \$43 million and \$21 million to \$40 million, at 3% and 7% discount rates, respectively. All estimates are in 2007\$ for the year 2013. Using alternate relationships between PM_{2.5} and premature mortality supplied by experts, higher and lower benefits estimates are plausible, but most of the expert-based estimates fall between these estimates. There are no emission reductions for Option 2.
- **Net Benefits:** The net benefits for Option 1 are \$9 million to \$30 million and \$8 million to \$27 million, at 3% and 7% discount rates, respectively (Table 1-1). The net benefits for Option 2 are \$-25,000. All estimates are in 2007\$ for the year 2013.

Table 1-1. Summary of the Monetized Co-Benefits, Social Costs, and Net benefits for the Proposed Mercury Chlor Alkali NESHAP in 2013 (thousands of 2007\$)^a

	3% Discount Rate		7% Discount Rate	
Option 1: Non-mercury Technology Option				
Total Monetized Benefits ^b	\$22,000	to	\$43,000	\$21,000 to \$40,000
Total Social Costs ^c			\$13,000	\$13,000
Net Benefits	\$9,000	to	\$30,000	\$8,000 to \$27,000
Non-monetized Benefits	656 pounds of mercury (including energy co-benefits)			
	Health effects from NO ₂ and SO ₂ exposure			
	Ecosystem effects			
	Visibility impairment			
Option 2: Enhanced Work Practice Standards				
Total Monetized Benefits ^b	\$0		\$0	
Total Social Costs ^c	\$25		\$25	
Net Benefits	-\$25		-\$25	

^a All estimates are for the implementation year (2013), and are rounded to two significant figures.

^b The total monetized co-benefits reflect the human health co-benefits associated with reducing exposure to PM_{2.5}. It is important to note that the monetized co-benefits include many but not all health effects associated with PM_{2.5} exposure. It is important to note that the monetized benefits include many but not all health effects associated with PM_{2.5} exposure. Benefits are shown as a range from Pope et al. (2002) to Laden et al. (2006). These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because there is no clear scientific evidence that would support the development of differential effects estimates by particle type. CO₂-related benefits were calculated using the social cost of carbon (SCC), which is discussed in Section 5. The net present value of reduced CO₂ emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SCC at 5, 3, 2.5 percent) is used to calculate net present value of SCC for internal consistency. This table shows monetized CO₂ co-benefits at discount rates of 3 and 7 percent that were calculated using the global average SCC estimate at a 3% discount rate because the interagency workgroup on this topic deemed this marginal value to be the central value. In Section 5, we also provide the monetized CO₂ co-benefits using discount rates of 5 percent (average), 2.5 percent (average), and 3 percent (95th percentile).

^c The annual compliance costs serve as a proxy for the annual social costs of this rule. The compliance cost of a regulation is generally a slight overestimate of social cost for competitive markets. The size of the overestimate is roughly one half the price change times the quantity change. The markets for chlorine and sodium hydroxide are expected to be competitive with the market share provided by the affected facilities quite small. However, the market share for potassium hydroxide is large and the market may not be competitive. In this case, social cost might be larger than compliance cost. Because insufficient data was available to estimate price and quantity changes the compliance cost was used as a rough estimate of the social cost.

1.2 Organization of this Report

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

- Section 2 presents a profile of the affected industry and focuses on plants affected by the proposed rule. Although extensive individual plant information would help

assess the economic impacts of the rule, in most cases, detailed information is not publicly available. As a result, we frequently rely on parent company information provided in company annual reports (e.g., form 10-K), local press and industry trade publications, and company Web sites.

- Section 3 describes the engineering cost analysis.
- Section 4 describes the economic impact analysis and small business impact analysis.
- Section 5 presents the benefits estimates.

SECTION 2

INDUSTRY PROFILE

There are four mercury cell chlor-alkali plants currently operating in the United States in 2010 that have the combined capacities to produce approximately 500,000 tons of chlorine per year. These plants are Olin Corporation in Augusta, Georgia (Olin GA); Olin Corporation in Charleston, Tennessee (Olin TN); PPG Industries in New Martinsville, West Virginia (PPG); and ASHTA Chemicals in Ashtabula, Ohio (ASHTA).

EPA has developed an industry profile to provide the reader a general understanding of the technical and economic aspects of the industry. We outline processes and costs of getting chlorine products to market; identify key uses, consumers, and market characteristics; and provide economic data for the plants and owning companies affected by the proposed rule. Although we prefer to have extensive individual plant information, in most cases this information is not publicly available. As a result, we frequently rely on parent company information provided in company annual reports (e.g., form 10-K), local press and industry trade publications, and company websites.

2.1 Supply Side

2.1.1 Chlorine Production Process

Although chlorine can be generated as a by-product in a variety of chemical reactions, brine electrolysis accounts for 95% of total world chlorine production (World Chlorine Council, 2002). Through a chemical reaction catalyzed by an electric current in a series of electrolytic cells, a salt-based solution containing either sodium or potassium chloride yields elemental chlorine gas, a caustic solution, and hydrogen gas in fixed proportions (“Special Focus on Chlorine,” 2007). The electrolysis occurs when electric current flows between the negatively charged cathodes and the anodes, which are the positive electrodes from which the chlorine is collected (World Chlorine Council, 2002).

Three types of electrolytic cells can host this reaction: the diaphragm cell, the membrane cell, or the mercury cell. Although the three cell types share the basic chemical production formula, they are differentiated by the way in which the chlorine is kept separate from the co-products generated in the cathode in the chemical process (“Special Focus on Chlorine,” 2007). The predominant manufacturing process in North America involves diaphragm cell technology, which is characterized by the asbestos-based diaphragm structure that keeps the cathodes separate from the anodes. The membrane cell is structurally similar, though it uses an ion-

exchange membrane to separate the anodes and chlorine gas from the caustic product. Mercury cell technology uses two distinct cells and functions through a sodium-mercury stream that forms an amalgam and serves as the cathode (“Special Focus on Chlorine,” 2007).

Of the three electrolytic processes, the diaphragm and membrane processes are the most similar (Table 2-1). Both share the advantage of lower electricity consumption, but the unique ion-exchange structure enables membrane cells to produce a purer caustic product than the asbestos-based diaphragm. Another disadvantage of the diaphragm cell is the caustic limitations; although mercury and membrane cells can use sodium or potassium chloride for brine solution, diaphragm cells require sodium chloride. Mercury cells produce a high-quality caustic solution and chlorine gas, but emit harmful mercury pollutants into the environment. New plant construction has favored membrane cell construction because of low capital investment and operating costs relative to diaphragm and mercury processes (“Special Focus on Chlorine,” 2007).

Table 2-1. Comparison of the Processes

	Cell Type		
	Diaphragm	Mercury	Membrane
Separation Technique	Asbestos-based diaphragm	Sodium-mercury amalgam	Ion-exchange membrane
Caustic Capabilities	Sodium hydroxide	Sodium hydroxide, potassium hydroxide	Sodium hydroxide, potassium hydroxide
Advantages	<ul style="list-style-type: none"> • Use of well brine (no solid salt needed) • Low electricity requirements • Simplest brine system 	<ul style="list-style-type: none"> • High purity caustic, chlorine, hydrogen • Simple purification of brine 	<ul style="list-style-type: none"> • Low energy consumption • Low capital investment • Easily operable cells • High purity caustic • Immune from variations in cell load and shutdown
Disadvantages	<ul style="list-style-type: none"> • Asbestos use • High steam requirements for caustic concentration 	<ul style="list-style-type: none"> • Mercury emissions and related environmental and regulatory costs • Solid salt requirement • Expensive cell operations • Large physical floor space requirement 	<ul style="list-style-type: none"> • Solid salt requirement • High purity brine requirements • Expensive membrane • High oxygen contamination in chlorine product

Source: “Special Focus on Chlorine.” October 2007. *Chemical Business*. pp. 27-40. Accessed July 29, 2009, from Business Source Corporate database.

2.1.2 Product Types

2.1.2.1 Chlorine

Chlorine takes form in a greenish-yellow poisonous gas at STP. It has a pungent odor and is 2.48 times denser than air. When liquefied, it becomes a yellow mobile fluid with low electrical conductivity. As a solid, chlorine retains the yellow color in the form of rhombic crystals. Chlorine is soluble in cold water and in salt solutions, although the solubility decreases with salt strength and temperature. Chlorine is stored and transported as a liquefied gas (“Special Focus on Chlorine,” 2007).

2.1.2.2 Caustic Products: Sodium Hydroxide and Potassium Hydroxide

Sodium hydroxide, commonly referred to as caustic soda, is produced as a co-product with chlorine and usually sold in the form of a 50% solution. All three cell types can use sodium chloride brine in the electrolysis process to derive sodium hydroxide, but the variations between the cell structures require different degrees of evaporation and purification to reach the 50% concentration. Only mercury cells generate the 50% liquid caustic solution directly; diaphragm cells yield a solution of 12% that is processed through filters and evaporators to reach the acceptable grade, while membrane cells produce a 30% liquid that is evaporated to the 50% level (Occidental Chemical Corporation, 2008b).

While most chlor-alkali production involves sodium chloride brine, potassium hydroxide or caustic potash is the caustic solution produced when potassium chloride is used as a feedstock in the brine electrolysis process (Sim, 2005). Membrane and mercury cell electrolysis can produce a caustic potash solution that is evaporated to 45% or 50% concentration for sale. The solution can also be concentrated to dry form and sold as flakes or crystals (Occidental Chemical Corporation, 2008a).

2.1.3 Materials and Costs of Production

Energy, salt brine, and raw materials represent the majority of the production costs in the chlor-alkali industry. The recent U.S. Census Bureau’s 2007 Economic Census provides industry-level expenditures on production inputs for North American Industry Classification System (NAICS) code 325181 (Alkalis and Chlorine Manufacturers). The cost of materials (including electricity and purchased fuels) was 62.7% of the total production costs and nearly half of the industry’s total value of shipments. Electricity and fuels made up over 31% of total production costs. Labor expenses account for around 12.5% of the total reported costs in the industry.

Although the census data provide insight into the chlor-alkali industry cost structure on the aggregate level, there is variation between companies in the industry because of size, structure, and technology. Olin Corporation, (2008) operates a number of chlor-alkali facilities across the country and cites electricity and salt as the largest share of raw material expenditures, which represent 55% of total production costs for the company. Other principle materials include potassium chloride, sulfur dioxide, and hydrogen (Olin Corporation, 2008).

Although energy costs are important for all producers, each cell type requires a different combination of energy inputs. For example, membrane cell technology uses 25% less electricity than mercury cells but requires steam to concentrate the caustic product that mercury cells do not (“Special Focus on Chlorine,” 2007). Table 2-2 illustrates the approximate energy requirements of the different cell types as well as the average electricity prices for the states in which the relevant plants are located.

Table 2-2. Approximate Energy Requirements of Different Cell Types

	Cell Type		
	Diaphragm	Mercury	Membrane
Electricity (kWh)	2,800–3,000	3,200–3,600	2,600–2,800
Steam equivalent (kWh)	800–1,000	0	100–200
Total kWh	3,600–4,000	3,200–3,600	2,700–3,000
Relative energy	100	92	75
Average Electricity Price for Industrial Sector (2007 cents/kWh)			
Georgia (Olin GA)	5.53		
Ohio (ASHTA)	5.76		
Tennessee (Olin TN)	5.19		
West Virginia (PPG)	3.95		

Sources: “Special Focus on Chlorine.” October 2007. *Chemical Business*. pp. 27-40. Accessed July 29, 2009, from Business Source Corporate database.
 Energy Information Administration. 2009. “Electric Power Annual 2007: State Data Tables.” http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html. Accessed July 31, 2009.

Individual facility capital costs are also contingent on the specific requirements of the electrolytic cells used in the production process. For example, the complex mercury cell has a higher current density than the diaphragm or membrane and demands a relatively higher capital investment. The variations in purification requirements impose the highest brine costs for membrane cell plants, whereas the relatively simple brine system accounts for only 3 to 4% of a diaphragm cell facility’s capital costs (“Special Focus on Chlorine,” 2007). A mid-sized mercury

cell plant not only bears the additional costs of the mercury itself, but also spends 10 to 15% of the total capital investment on equipment to prevent the hazardous emissions and to remove the mercury from the finished products (“Special Focus on Chlorine,” 2007).

2.1.4 Chlor-alkali Transportation

A critical element in any production industry is the successful transfer of final products from the facility to the client. However, the hazardous nature of chemical products requires chlor-alkali companies to devote extra resources to developing a geographic network of facilities and shipping points that integrates both cost considerations and safety concerns. Industry experts are acutely aware of the risks associated with chemical production and strive to maintain security of their products, the safety of their employees and consumers, and the well-being of local communities.

In addition to complying with carefully developed industry standards and stewardship practices, chlor-alkali facilities are also subject to federal regulations regarding the proper handling of dangerous chemicals. The U.S. Department of Transportation’s Pipeline and Hazardous Materials Safety Administration (PHMSA) regulates the transportation of chlorine and its derivatives under the Hazardous Material Regulations (49 CFR 171-180) (U.S. Department of Transportation, 2009a and 2009b). The PHMSA and other federal regulatory agencies control the movement of hazardous materials by all applicable modes of transportation. Chlorine and its derivatives are shipped via rail, highway, water vessel, and pipeline. According to the American Chemistry Council, rail hosts the majority of bulk chlorine shipments in the United States (30,000 tank car/yr) and is the safest mode of chlorine transportation (American Chemistry Council, 2009). Although accidents are rare, a 2005 Norfolk Southern freight train collision in South Carolina that killed or injured over 200 people illustrates real risks that chlorine transportation poses to civilians and communities (Environmental News Service, 2005). Even though industry experts work in conjunction with transportation authorities to ensure that procedures and policies are carefully executed, the risk of an accident can never be completely eliminated.

One way to mitigate the risk of an accident is to minimize the distance from the producer to the end-user, which effectively curtails the potential for unexpected events or hazardous leaks during transit. Cutting down on travel distance and time is not only cost-effective for producers, but it also prevents unnecessary exposure of civilian communities to the dangers associated with a collision. Familiarity with travel routes and transportation contractors may also aid chlorine producers in reducing the potential for unforeseen circumstances that could threaten the security of the cargo.

In light of these issues, companies in the chlor-alkali industry have selected existing facility locations based on the financial, logistic, and safety concerns involved with shipping their products. Plants, warehouses, and distribution centers are deliberately constructed in specific locations to serve customers safely and efficiently. ASHTA's production facility is located adjacent to the titanium dioxide plant to which it sells 100% of its chlorine (U.S. House of Representatives Committee on Commerce and Energy, 2009). The company also has warehouses, liquid distribution points, and sales headquarters placed strategically across the United States to cater to nationwide potassium hydroxide demand (ASHTA, 2009a). PPG pioneered 1,100-ton capacity barges as a safe mode of chlorine transport from the Natrium plant, which is ideally situated on the Ohio River easily accessible by the CSX rail line (PPG, 2009a). Olin Corporation's Charleston plant produces potassium hydroxide and uses rail, barge and trucks to ship the product to customers and the terminal facility located in nearby Chattanooga (Olin Corporation, 2009c).

2.2 The Demand Side

A variety of applications use chlor-alkali products to make other goods. As a result, the demand for chlor-alkali products indirectly depends on conditions in downstream end-use markets. The organic chemicals industry uses chlorine to make polyvinyl chloride (PVC), and the construction industry subsequently uses PVC materials. The pulp and paper industry uses caustic soda during manufacturing processes that create paper and other products. Electronic products (e.g., televisions and computer monitors) requiring glass cathode ray tubes use potassium carbonate made from caustic potash. As a result of these links, growth or downturns in end-use markets ultimately influence the demand for chlor-alkali products.

2.2.1 Who Uses Chlorine, Caustic Soda, and Caustic Potash?

Plant-specific information regarding end-users and other within/between plant relationships is not generally available or is limited. According to company annual reports (Olin Corporation, 2009a), industry-wide data show that the organic chemical industry uses over 60% of chlorine (Figure 2-1). Vinyl chemical producers are industrial consumers (37%), and other organic chemical producers use an additional 28%. For caustic soda (Figure 2-2), organic chemicals, pulp and paper, and inorganic chemicals are significant end users; each industry accounts for more than 20% of caustic soda demand. For caustic potash (Figure 2-3), potassium carbonate (28%), other potassium chemicals (15%), and potassium phosphates (10%) are the most significant end uses (The Innovation Group [TIG], 2009). The remaining applications are diverse and all account for less than 10% of the market.

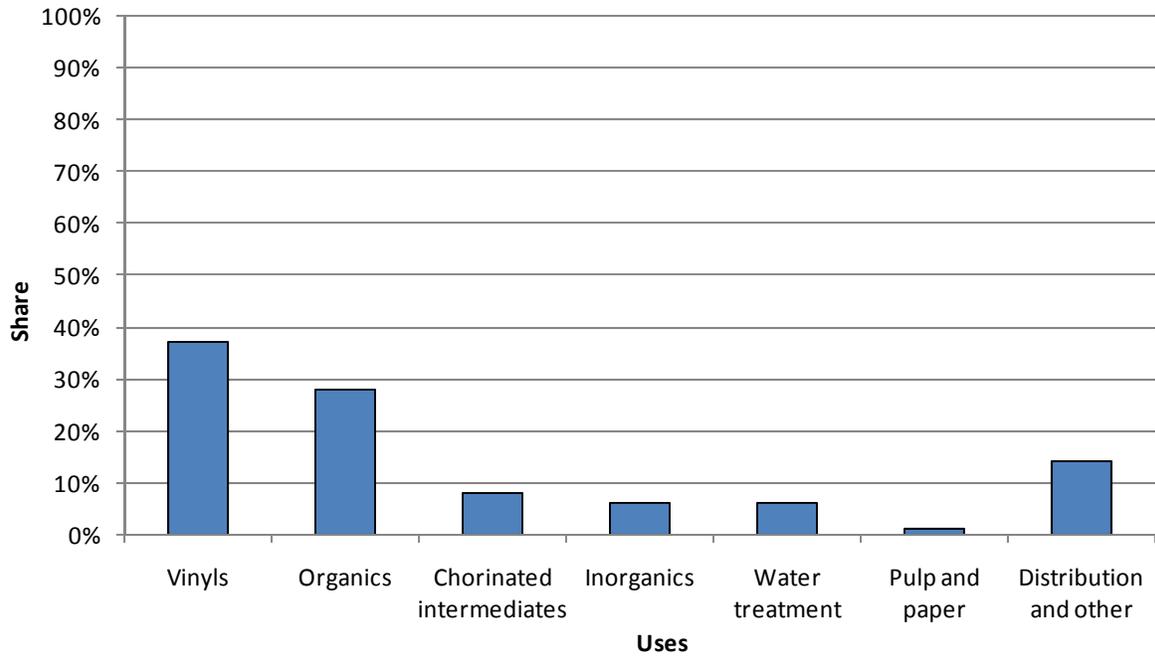


Figure 2-1. Industry-wide Uses of Chlorine by Industry

Source: Olin Corporation, 2009a.

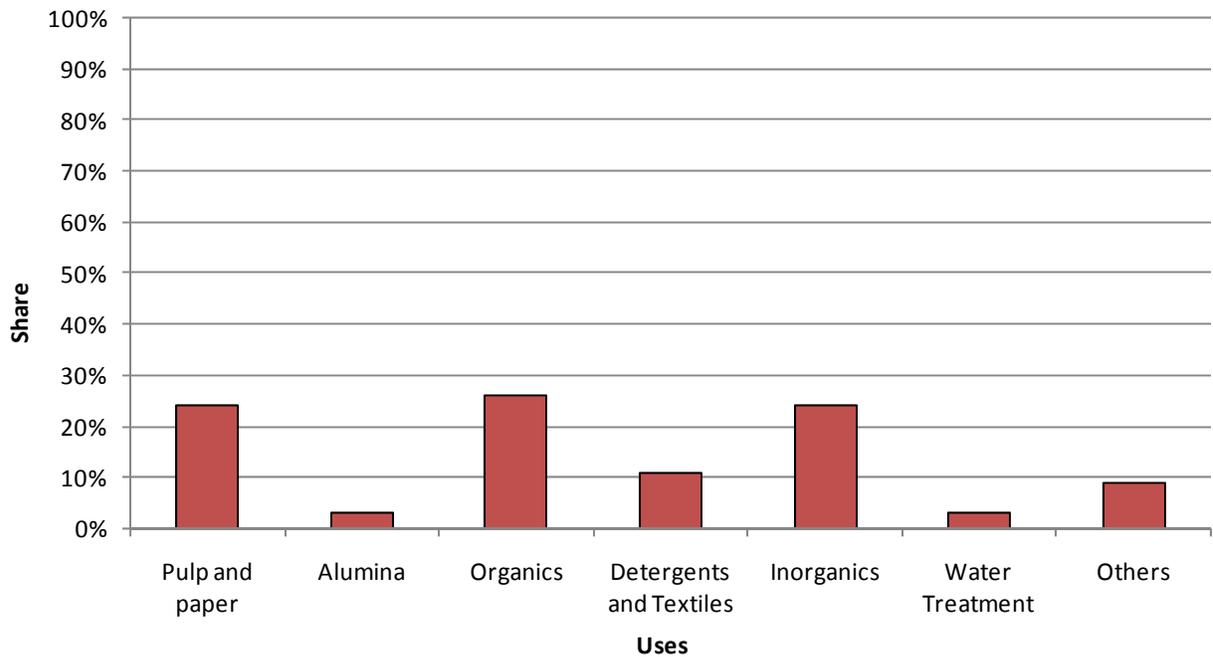


Figure 2-2. Use of Caustic Soda by Industry

Source: Olin Corporation, 2009a.

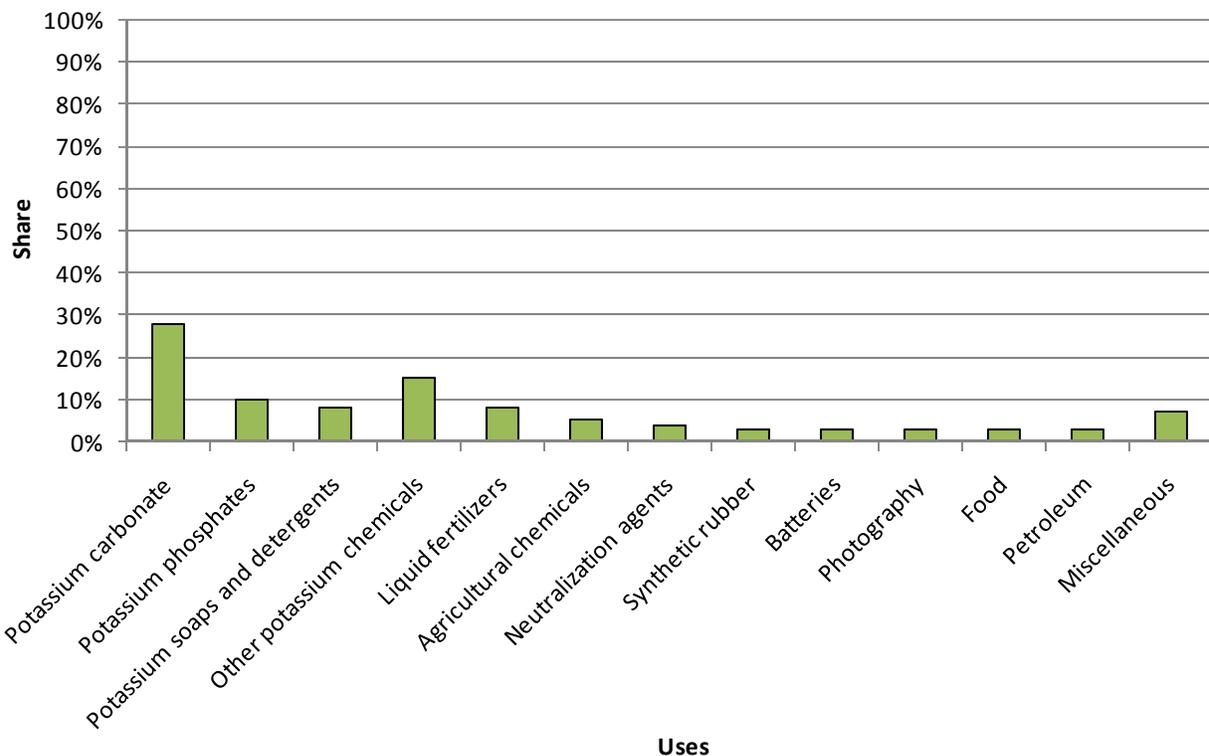


Figure 2-3. Use of Caustic Potash by Industry

Source: The Innovation Group (TIG). 2009. “Caustic Potash Chemical Profile.” <http://www.the-innovation-group.com/welcome.htm>. Accessed July 2009.

Olin Corporation (2008) also reports details regarding company-specific end uses and customers for their chlor-alkali products in the company’s annual reports (Table 2-3). This information applies to all 10 North American chlor-alkali plants and may not necessarily be representative of the end-users associated with the mercury cell plant. However, it is the best publicly available information EPA was able to identify. Olin sells a majority of its chlor-alkali products to third parties; in 2008, no single customer bought more than 8% of total sales (Olin Corporation, 2008). Chlorine is also sold to a relatively small number of industrial customers; In contrast, caustic soda is sold to a large number of users or distributors (Olin Corporation, 2008).

Trade publications report that ASHTA supplies chlorine to a nearby titanium dioxide facility originally owned by Lyondell Chemicals (Sim, 1995); the plant is now owned by Cristal’s Millennium Inorganic Chemicals business and continues to produce titanium dioxide (Millennium Inorganic Chemicals, 2009). ASHTA reports that all of its chlorine is sold to “a company located adjacent to ASHTA’s facility” (U.S. House of Representatives Committee on Commerce and Energy, 2009). Some of ASHTA’s other alkali products are used within the

Table 2-3. Olin Corporation Products and Services and Major End Uses: 2008

Products and Services	Major End Uses	Location
Chlorine/sodium hydroxide (caustic soda)	Pulp and paper processing, chemical manufacturing, water purification, manufacture of vinyl chloride, bleach, swimming pool chemicals, and urethane chemicals	Augusta, GA ^a Becancour, Quebec Charleston, TN ^a Henderson, NV McIntosh, AL Niagara Falls, NY St. Gabriel, LA
Potassium hydroxide (caustic potash)	Fertilizer manufacturing, soaps, detergents and cleaners, battery manufacturing, food processing chemicals, and deicers	Charleston, TN ^a

^a Denotes plant using mercury technology.

company to produce other chemicals. For example, liquid potassium hydroxide is used to make potassium carbonate. ASHTA (2009a) also reports that it is a manufacturer and marketer in the following chemical markets:

- 45% and 50% liquid potassium hydroxide
- anhydrous potassium carbonate K_2CO_3
- anhydrous potassium carbonate flake
- chlorine
- 47% liquid potassium carbonate
- anhydrous potassium hydroxide walnut (briquette)
- potassium hydroxide
- chloropicrin

2.2.2 What Factors Influence Demand?

The chlor-alkali industry is considered a procyclical industry where demand for product depends on trends in overall economic activity. For example, Olin Corporation (2008) notes:

The business of most of our customers, particularly our vinyl, urethanes, and pulp and paper customers are, to varying degrees, cyclical and have historically experienced periodic downturns. These economic and industry downturns have been characterized by diminished product demand, excess manufacturing capacity and, in some cases, lower average selling prices. Therefore, any significant downturn in our customers' businesses or in global economic conditions could

result in a reduction in demand for our products and could adversely affect our results of operations or financial condition. (p. 8)

Recent research has also suggested that environmental regulations affecting chlorine end-use markets have reduced the demand for chlorine and help explain the exit of selected chlorine plants (Snyder, Miller, and Stavins, 2003). Chlorine plants that were co-located with pulp and paper mills and plants affected by the Montreal Protocol were more likely to shutdown (11 to 15% higher than the average chlorine plant) (Snyder, Miller, and Stavins, 2003).

In addition to overall demand conditions, selected chlor-alkali product markets are very sensitive to price changes of close substitute products. For example, when the price of caustic soda rises, soda ash can be substituted for caustic soda in certain uses (e.g., pulp and paper, water treatment, and certain chemical sectors) (U.S. Geological Survey [USGS], 2009).

2.3 Market Characteristics

A review and description of market characteristics (i.e., geography, product differentiation, entry barriers, and degree of concentration) can enhance our understanding of how chlor-alkali markets operate. These characteristics provide indicators of a firm's ability to influence market prices by varying the quantity of product 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, a firm may have some degree of market power (i.e., set or significantly influence market prices).

2.3.1 Geography

Most chlorine is not sold on the market and is consumed internally by the manufacturer. However, marketed chlorine and potassium hydroxide compete in a North American market; imports are limited by transportation costs and customer requirements for service and product availability (Olin Corporation, 2008; U.S. Federal Trade Commission [FTC], 2005). In contrast, caustic soda producers sell their product in a worldwide market (Olin Corporation, 2008).

2.3.2 Product Differentiation

Product differentiation can occur both from differences in product attributes and quality and from brand name recognition of products. For a given end use, industrial consumers are likely to view chlor-alkali products produced by different firms as very good substitutes. As a result, the products are likely to be sold primarily on a price basis (Olin Corporation, 2008). In

addition, a close substitute for caustic soda exists (soda ash) and limits the ability of caustic soda producers to significantly influence caustic soda prices by varying the quantities produced (USGS, 2009).

2.3.3 Entry

Short-term entry into the chlor-alkali market is difficult because new plants require significant capital expenditures and take time to build. For example, the FTC concluded that new entry in the potassium hydroxide market would not be “timely, likely, or sufficient” in response to significant price increases (FTC, 2005, p. 5). Historically, imports have only played a major competitive role in the caustic soda markets only.

2.3.4 Concentration

Of the three chlor-alkali products, the market for potassium hydroxide is the most highly concentrated. As of 2005, there were only four producers of potassium hydroxide in the United States (FTC, 2005b). Approximately 50% is produced using mercury cells; ASHTA Chemicals reports a market share of approximately 15% (U.S. House of Representatives Committee on Commerce and Energy, 2009). The FTC (2005a, b) has also assessed competitive effects of proposed company acquisitions in this sector in some detail. Given these characteristics and conclusions of the FTC study, significant changes in production levels at a single company using mercury cells are likely to influence market prices, particularly over short periods.

2.4 Overview of Businesses Affected by the Rule

The proposed rule affects four mercury cell plants operating in the United States. We provide basic economic statistics for each plant and the ultimate parent companies that own each plant. These data are subsequently used for the economic impact analysis described in Section 3.

2.4.1 Mercury Cell Plants

The four mercury cell plants are located in four different states: Georgia, Ohio, Tennessee, and West Virginia. Annual plant sales ranges were estimated using economic data from the 2002 Economic Census (Table 2-4) and employment data. Given the uncertainties with sales data, we report a low and high range estimate for each plant. Lower-bound sales were obtained by multiplying the average value of shipments per employee by the number of employees. The upper-bound sales represent the average establishment value of shipments for the appropriate establishment size. In cases where census data were not disclosed, we used the industry average. As shown, annual plant sales estimates range from \$30 to \$130 million (Table 2-5).

Table 2-4. 2002 Economic Census Sales and Employment by Establishment Size

Plant	Establishments	Employees	Value of Shipments (\$Million)	\$ per Employee	\$ per Establishment (\$ Million)
All establishments	40	6,022	\$2,702	\$448,679	\$68
1 to 4 employees	7	19	\$8	\$411,842	\$1
5 to 9 employees	2				
10 to 19 employees	4	52	\$19	\$358,231	\$5
20 to 49 employees	7	246	\$105	\$428,415	\$15
50 to 99 employees	1				
100 to 249 employees	12	1,901	\$980	\$515,679	\$82
250 to 499 employees	5	1,571	\$662	\$421,701	\$132

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing; Industry Series: Industry Statistics by Employment Size: 2002." <<http://factfinder.census.gov>>; accessed July, 2009.

Table 2-5. Estimated Plant-Level Sales and Employment: 2008

Plant	State	Owned by Small Entity	Sales Range (\$ million)	Employment	Employment Source
ASHTA	OH	Yes	\$40-\$70	~100	U.S. House of Representatives Committee on Commerce and Energy, 2009
Olin	GA	No	\$40-\$70	85	Pavey, 2008
Olin	TN	No	\$120-\$130	280	Cleveland/Bradley Chamber of Commerce, Economic Development Council, 2009
PPG	WV	No	\$30-\$70	540 ^a	West Virginia Development Office, 2009

^a Ward (2007) suggests that 60 employees are associated with mercury cell operations.

2.4.2 Ultimate Parent Companies

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 2-6 provides sales and employment data for three ultimate parent companies operating mercury plants. EPA classified each parent company as a small or large entity 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 chlor-alkali companies are covered by NAICS code 325181 and are categorized as small if the total number of employees at the ultimate parent company is fewer than 500; otherwise, the ultimate parent company is classified as large. As shown in Table 2-6 ASHTA Inc. is considered a small business.

Table 2-6. Ultimate Parent Company Sales and Employment: 2008

Plant	State	Parent Company	Owned by Small Entity	Sales	Employment
ASHTA	OH	ASHTA Chemicals Inc.	Yes	<\$75 million	<100
Olin	GA, TN	Olin Corporation	No	\$1.8 billion	3,600
PPG	WV	PPG Industries Inc.	No	\$15.8 billion	44,900

Sources: Olin Corporation. December 31, 2008. Form 10-K. Filed February 25, 2009. http://b2i.api.edgar-online.com/EFX_dll/EdgarPro.dll?FetchFilingConvPDF1?SessionID=DOVFWfuqOuZBE-9&ID=6436012. Accessed July 2009.

PPG Industries, Inc. December 31, 2008. Form 10-K. Filed February 19, 2009. <http://corporateportal.ppg.com/NR/rdonlyres/EAC49DFC-DB9C-4320-B9A3-421E40162220/0/10KYREND2008.pdf>. Accessed July 2009.

2.4.2.1 Company Profitability Measures

Company profitability trends significantly influence the ability and desire to take on large-scale capital projects. Although data on profits for individual companies are limited, historical government statistics about industry groups and publicly traded companies provide accounting measures of profit in annual reports. In Figure 2-4, we present information from the U.S. Census Quarterly Manufacturing Reports about the Basic Chemicals, Resins, and Synthetics (NAICS 3251 and 3252) (U.S. Census Bureau, 2000–2006). This is the finest level of detail reported by the Census and includes other chemical industries in addition to the chlor-alkali industry. As shown, there is substantial variation in the profitability rates for the industry; before-tax profits as a percentage of net sales range from 1 to 10% during this period, with an average of 5% and a standard deviation of 3%.

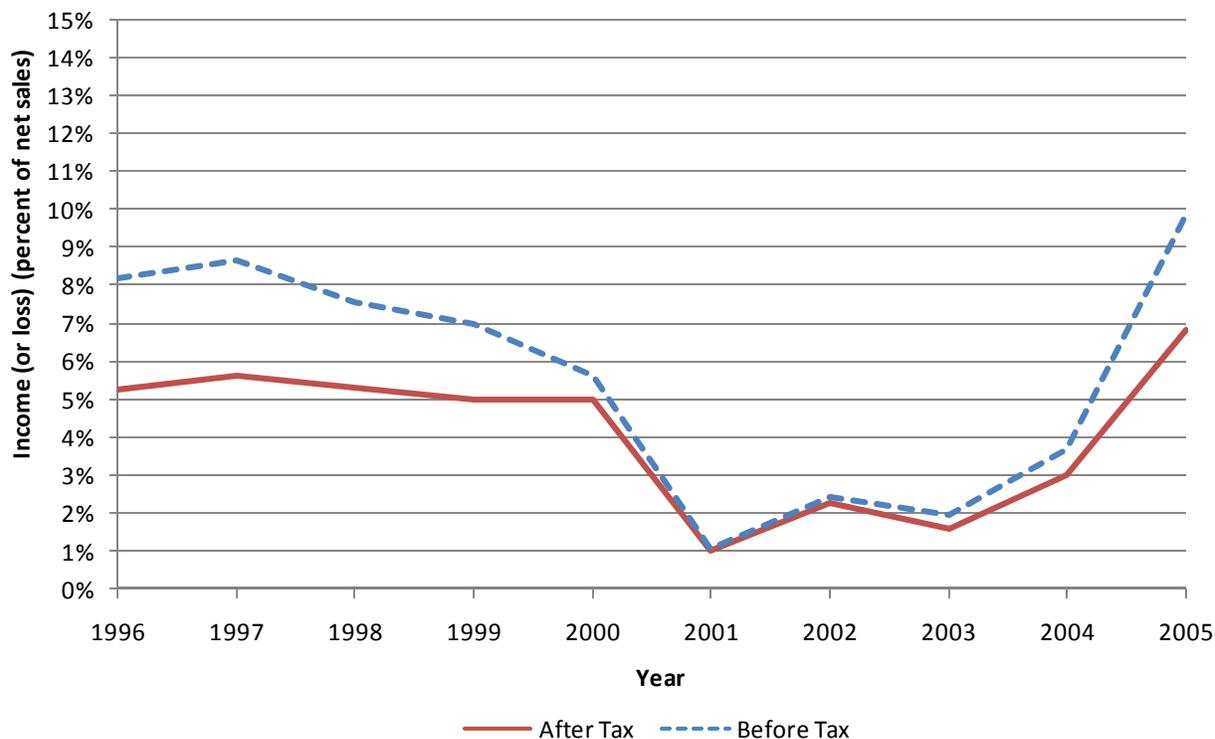


Figure 2-4. Income (or Loss) as Net a Percentage of Sales, Basic Chemicals, Resins, and Synthetics (NAICS 3251 and 3252): 2000–2005

Source: U.S. Census Bureau. 2001–2006. Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations, 1st Quarter reports. <http://www.census.gov/prod/www/abs/qfr-mm.html>. Accessed July 2009.

Census data also show that smaller companies (defined by Census as companies with less than the \$25 million in assets) have profit rates that are smaller than industry averages. For example, in a representative year during this period (2000), before-tax profits as a percentage of net sales for small companies were less than 1% compared to approximately 6% for the industry as a whole.

To assess how representative the census data were for individual companies, EPA examined annual reports for Olin Corporation and PPG Industries and found before-tax profit rates were comparable with quarterly financial report (QFR) 2000 industry averages. Olin reported a rate of approximately 8% and PPG reported a rate of 11% (Olin Corporation, 2001; PPG, 2001). These values are based on income statements and include all operations in addition to the chlor-alkali segment. Olin reported similar profit rates for its chlor-alkali segment (~7%), but PPG did not report separate profitability information for their chemical commodity segment.

SECTION 3 ENGINEERING COST ANALYSIS

Most of this section addresses the cost analysis for For Option 1 (Non-mercury Technology Option). The other option In order to estimate the capital and annual costs associated with a conversion from mercury cell chlor-alkali technology to membrane cell technology, information was used from the following resources:

- EPA's Mercury Report to Congress¹
- Recent news reports regarding plants converting or considering converting^{2,3,4,5,6,7,8}
- EPA waste minimization study⁹
- Fact sheet from the conversion of a Canadian facility¹⁰
- General chlor-alkali reference¹¹

¹ U.S. EPA. Mercury Study Report to Congress Volume VIII: An Evaluation of Mercury Control Technologies and Costs. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. December 1997.

² Bradbury, D. *Portrait of a Polluter*. Portland Press Herald. 1997.

³ Markets—News Release. Houston Chronicle. January 30, 2007.

⁴ McCoy, M. *PPG to Convert Chlorine Cells*. Chemical and Engineering News. August 8, 2005.

⁵ Wise, A. *Port Edwards sells School Forest Land to ERCO Worldwide; Nekoosa Considers Similar Deal*. Wisconsin Rapids Tribune. January 13, 2009. Available on the Internet at: www.wisconsinrapidstribune.com.

⁶ Westlake Chemical Corporation (2003, December 31). Form 10-K, United States Securities and Exchange Commission. Available on the Internet at <http://www.sec.gov/Archives/edgar/data/1262823/000095012904001565/h13929e10vk.htm>

⁷ Chlorine/Chlorate Newsletter. "Tessengerlo Upgrades Chlorine; Expands VCM, PVC." March 2002. p. 10-11. Available on the Internet at: <http://www.eltechsystems.com/newsletter/ELTECH%20Newsletter%20March%202002.pdf>. Accessed 3/2/2007.

⁸ Hydrocarbon Processing (2007, November 19). "Uhde Opens New Electrolysis Plant."

⁹ Drabkin, M. and Rissmann, E. *Project Summary Waste Minimization Audit Report: Case Studies of Minimization of Mercury Bearing Wastes at a Mercury Cell Chlor-alkali Plant*. EPA/600/S2-88/011. U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH. March 1988.

¹⁰ Fact Sheet No. 12. *PPG Canada*. St Lawrence Vision 2000, Beauharnois, Quebec, Canada. 1996.

¹¹ *Modern Chlor-Alkali Technology, Volume 2*. Jackson, C., Editor. Society of Chemical Industry, London, England. 1983.

- European Best Available Techniques Document¹²
- Oceana¹³ and the Chlorine industry

In addition to reviewing the Oceana correspondence, all directly relevant references cited by Oceana in their comments were obtained, reviewed, and considered. These references are compiled and available in the docket as one docket entry.¹⁴

3.1 Capital Costs

Initially, to determine capital costs of conversion to non-mercury technology, EPA collected capital cost data for mercury cell conversion projects that occurred between 1992 and 2008 from the search of the resources listed above. In their September 15, 2009 memorandum, Oceana pointed out that several of the capital cost data points were not appropriate because either the costs were from unsubstantiated estimates or they were developed from conversions that were done so long ago that they did not apply to membrane cell technologies currently being used.

Initially, Oceana identified seven capital cost data points for conversion to non-mercury technology that were derived from estimates rather than actual conversions. These were:

- One 1997 estimate published by a HoltraChem facility where the conversion did not in actuality occur;
- One 1988 estimate for a facility in the U.S. that could not be identified;
- One 1992 estimate for a “model plant” representing a mid-range facility size, with no documentation included; and
- Four European estimates for conversions to non-mercury technology, which did not include information on plant production capacities.

In addition, Oceana stated that conversion project costs prior to 1995 are not applicable to current-day conversion costs. According to Oceana, newer membrane-cell technology uses

¹² *Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing Industry*. European Integrated Pollution Prevention and Control (IPPC) Bureau, Seville, Spain. December 2001. Available on the Internet at <http://eippcb.jrc.es/reference/cak.html>.

¹³ Oceana is a large international organization focused on ocean conservation (www.oceana.org). They have provided comments on EPA’s analyses of the costs and other impacts of converting mercury cell chlor-alkali plants to membrane cells on multiple occasions, along with providing substantial data and analyses to support their comments.

¹⁴ Memorandum from Brown, H.P., EC/R Incorporated, Chapel Hill, NC, to Docket EPA-HQ-OAR-2002-0017. *Capital and Annual Costs References Cited By Oceana in Their Comments on EPA’s Cost Analysis of the Conversion of Mercury Cells to Membrane Cells*. (Docket No. EPA-HQ-OAR-2002-0017). March 15, 2010.

bipolar electrolyzers, which were not commercially available until around 1997. The conversions prior to 1995 would have used the older monopolar electrolyzers. Therefore, we agree with Oceana's position that for this analysis it is not appropriate to include the data points derived from conversions that took place prior to 1995; thus these data points were not used in our current analysis.

We developed capital cost factors for conversion to membrane cell technology in units of dollars per ton (\$/ton) of chlorine (Cl_2) production using data from conversions anywhere in the world that took place after 1995, excluding the cost data described above. These costs and cost factors are shown in Table 3-1. The cost factors ranged from \$267 to \$941/ton Cl_2 produced and averaged \$535/ton Cl_2 . In addition, Table 3-1 shows the average of the cost factors from only the most recent US conversions (since 2000), which is \$596/ton Cl_2 .

Since membrane cells are smaller than mercury cells, in some conversions the companies have elected to use the extra available space to install additional membrane cells, thus increasing the chlorine and caustic production capacity of the facility. Therefore, for some conversion projects included in Table 3-1, an increase in production capacity was also included. Oceana indicated in their comments that a conversion cost analysis should either exclude the costs attributed to expanding capacity or include the cost saving benefits derived from expanding capacity. We do not believe that it is appropriate to make an assumption about savings because any benefits derived from additional sales due to increased capacity assumes that product demand would simultaneously increase. We do not disagree that the additional incremental costs of the expanded capacity should be excluded. However, the available information does not provide a breakdown of the costs associated with conversion versus the costs associated with the increased capacity. Therefore, the capital costs for some conversions may include expansion costs. This could result in the capital costs based on these data being biased high.

When providing comments on the June 2009 memorandum, ASHTA stated that differences in size, the new or expanded infrastructure required, and the end products desired (e.g., vapor or liquid chlorine, dilute or merchant concentration of caustic) all impact the actual cost of conversion. ASHTA suggested that, minimally, conversion cost estimates should take into account economies of scale. However, Oceana expressed concern with the use of an equation that relates increasing size to lower conversion costs to estimate the cost of conversion for the four remaining facilities, since extrapolation of the costs to very small or very large capacities produces illogical conclusions. But we do believe that there could be some economies of scale. An equation we developed using the limited data set of the recent U.S. conversions

Table 3-1. Cost Factors for Conversion of Mercury Cell Chlor-Alkali Facilities to Membrane Cell Technology (\$/ton Cl₂ produced)

Year of Estimate	Location of Conversion	Capital Cost (as provided)	Capacity (ton Cl ₂ /yr)	Capital Cost Factor (\$/ton Cl ₂ produced/yr)		Reference
				Base Year	2007 ^a	
1997	Europe	\$104,946,640	173,063	\$606	\$824	12
1997	Europe	\$32,856,014	110,231	\$298	\$405	12
1998	Europe	\$16,334,213	66,139	\$247	\$333	12
1998	Europe	\$13,094,369	66,139	\$198	\$267	12
1998	Europe	\$29,923,557	44,092	\$679	\$915	12
1998	US (OxyTech) ^a	\$57,327,236	135,033	\$425	\$573	12
1998	Asia	\$39,775,832	182,983	\$217	\$293	12
1999	Europe	\$131,159,254	330,693	\$397	\$533	12
1999	Europe	\$31,026,058	82,673	\$375	\$505	12
2002	US (Westlake, KY)	\$86,100,000	205,000	\$420	\$497	6
2004	Belgium	\$171,032,583	363,762	\$470	\$556	7
2005^c	US (PPG, LA)	\$90,000,000	275,000	\$327	\$367	4
2007^c	US (Pioneer, LA)	\$117,000,000^c	197,000	\$594	\$594	3
2007^c	Germany	\$109,678,733	250,000	\$439	\$439	8
2008^c	US (ERCO, WI)	\$107,112,676^b	118,000	\$908	\$908	5
Average					\$535	
Average of Recent US Conversions^b					\$596	

N/A = Not Available

^a The conversion to 2007 dollars was estimated using the Chemical Engineering Plant Cost Index Economic Indicators. Base year costs were adjusted to 2007 dollars using the ratio of the 2007 economic indicator and the base year economic indicator. See Reference.¹⁵

^b Refers to conversions that occurred in the United States after 2000.

^c Used in this analysis to develop an average factor for near future U.S. conversions.

¹⁵ *Chemical Engineering Plant Cost Index*. Chemical Engineering. February 2009. Available on the Internet at www.che.com.

showed a good correlation (correlation coefficient (R^2),¹⁶ = 0.9981) of costs to facility size/capacity.¹⁷ However, when the entire data set (in Table 3-1) was plotted, a similar correlation was not observed.

Figure 3-1 presents these cost factors versus plant chlorine capacity for all the facilities. As shown in Figure 3-1, there is little correlation between cost factor and plant chlorine capacity ($R^2 = 0.0102$) for all global conversions with documented data. Therefore, we agree with Oceana that it is most appropriate to use a single cost factor to estimate the capital costs of conversion.

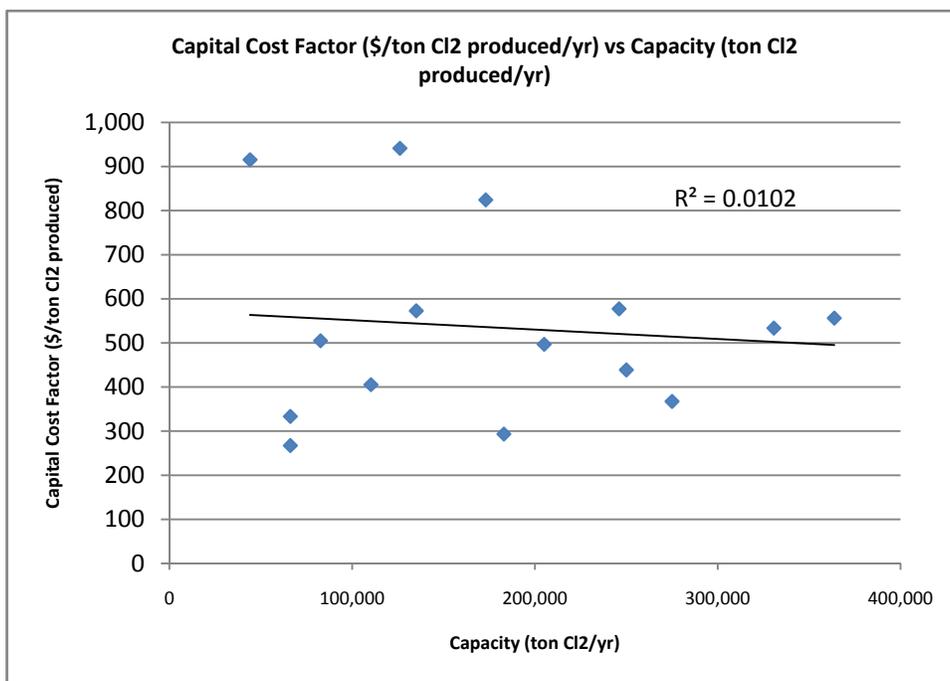


Figure 3-1. Capital Cost Factor (\$/ton Cl2 produced) vs. Capacity

¹⁶ The correlation coefficient is a measure of how accurately a regression predicts a value. The regression is most accurate when R^2 is equal to one (1).

¹⁷ Memorandum from Jones, D.L., PhD, EPA, Research Triangle Park, NC, Brown, H.P. and Norwood, P., EC/R Incorporated; Chapel Hill, NC; to Project File—Mercury Chlor-Alkali NESHAP. *Revised Conversion Costs and Baseline Emissions—Conversion From Mercury Cell Chlor-Alkali to Membrane Cell Technology*. (Docket Item No. EPA-HQ-OAR-2002-0017-0105). September 15, 2009.

In order to develop capital cost factors for the current four mercury cell facilities, the chlorine production capacities from the 1997 Directories of Chemical Producers¹⁸ were obtained and are shown in Table 3-2. The capital costs of converting to membrane cell technology for the four facilities in current operation were then estimated using these capacities. As shown in Table 3-2, capital costs were estimated using both the average capital cost factor for the entire data set (\$535/ton Cl₂) in Table 3-1, and then also using the average of only the four most recent U.S. conversions (\$596/ton Cl₂) since 2000.

Table 3-2. Estimated Capital Costs for Existing Mercury Cell Chlor-Alkali Facilities

Facility	Cl ₂ Production Capacity (ton/yr) ^a	Capital Costs (\$)	
		Based on Entire Data Set ^b	Based on Recent U.S. Conversions ^{c,d}
ASHTA	47,421	25,375,938	28,246,460
Olin GA	119,031	63,695,899	70,901,169
Olin TN	262,451	140,442,954	156,329,838
PPG	72,848	38,982,173	43,391,830
Totals		268,496,964	298,869,297

^a From Reference 18.

^b Calculated using average capital cost factor of \$535/ton Cl₂ for entire data set.

^c Calculated using average capital cost factor of \$596/ton Cl₂ for recent (i.e., after 2000) U.S. Conversions.

^d Used in this analysis to develop costs for near future U.S. conversions.

Because of several known factors, including environmental regulations and process safety management, we do not believe the broad range of data represented by all the facilities shown in Table 3-1 to be as accurate as the recent conversions that have occurred since 2000 in the U.S. to use to estimate the potential capital costs of conversion for the four remaining U.S. facilities. We believe that the average cost factor from the four recent U.S. conversions results in the best estimate of the capital costs that would occur for all four mercury cell chlor-alkali plants to convert to membrane cells. The total estimated capital cost of conversion for all four facilities, therefore, is approximately \$300 million, which is also shown in Table 3-2.

3.2 Annual Costs

The annual costs associated with the conversion of mercury cells to membrane cells include costs related to capital recovery, unused mercury storage costs, and energy costs due to the need for increased steam required to further concentrate caustic. However, some of these

¹⁸ 1997 Directory of Chemical Producers—United States of America. Stanford Research Institute International. Menlo Park, CA. 1997.

additional annual costs will be offset by savings realized due to the elimination of mercury, e.g., mercury-related environmental compliance costs and the reduced energy needs for the membrane cell process. Each of these costs and savings are described below.

3.2.1 Capital Recovery Cost

Annualization of the capital costs involves establishing an annual “payment” sufficient to finance the investment over the expected lifetime of the equipment or loan period. This payment is typically referred to as the “capital recovery cost.” The three key inputs into the capital recovery costs are the capital costs, the interest rate, and the finance period. The estimates for capital costs were discussed above; the remainder of this discussion is focused on the interest rate and the finance period.

As pointed out by Olin in their February 2, 2010, correspondence “access to capital and available interest rates are a function of many things, including the overall financial environment, the financial condition of the prospective borrower (including its debt load), and the amount and length of the loan.” In their June 25, 2009 correspondence, Olin also stated that “a 7 percent interest rate is simply not available to industry in this economy.” They suggested replacing the 7 percent rate with a 10 percent, or even a 14 percent rate. In their February 2010 correspondence, Olin provided an example to support the use of an interest rate higher than 7 percent. Olin reported that they sold \$150 million in Senior Notes, and that these notes had an interest rate of 8.875 percent and a maturity date of August 2019. According to Olin, the effective interest rate was over 9 percent considering the costs and discount.

The interest rate can result in significant differences in total annualized costs. For example, for a finance period of 15 years, the difference in capital recovery costs is approximately 20 percent higher for a 10 percent interest rate than for a 7 percent interest rate. This difference is even more profound for longer finance periods.

EPA’s Office of Air Quality Planning and Standards always provides an interest rate of 7 percent for cost analysis. While we do not disagree with Olin’s information, we feel that it is important to maintain uniformity to allow decision-makers to consider consistent information across various regulatory decisions. Therefore, in this present analysis, an interest rate of 7 percent was used in the development of the capital recovery cost. It should be noted that for a particular firm at a particular time, this interest rate of 7% might not be available because of either the firm’s financial health or temporary economic condition. In previous versions of this analysis, a finance period of 15 years was used. Oceana commented that this underestimates the useful life of the equipment and overestimates the annualized costs. Oceana suggested that a 30-

year finance period was more appropriate, and cited a previous analysis for the mercury cell industry where EPA used a 30-year period to estimate the capital recovery costs.¹⁹ However, it is important to note that the use of a 30-year finance period in the analysis cited by Oceana was for a stationary building and not an operating industrial process. Therefore, we do not agree that this example establishes a precedent that is pertinent to our analysis.

To illustrate the importance of the choice of finance period, consider the fact that the capital recovery costs for a 30-year finance period at 7-percent interest rate would be approximately 30 percent lower than those for a 15 year finance period. Table 3-3 shows the annual capital recovery costs for both a 15-year and 30-year period, using the capital cost estimates based on the cost factor from the average of recent U.S. conversions shown in Table 3-2 of the previous section. While we recognize that a 15-year finance period may understate the lifetime of the membrane cell process equipment, we believe that the use of a 30-year period will bias the annualized costs unreasonably low. Therefore, we chose to base our capital recovery cost estimates on a 20-year finance period which is higher than our previous estimate of 15 percent. This results in total annualized costs for the four U.S. facilities of approximately \$30 million/yr, which we believe represent the best estimate of the capital recovery costs, as shown in Table 3-3.

Table 3-3. Estimated Capital Recovery Costs for Varying Finance Periods (Using 7 percent interest rate)

Plant	Best Estimate of Capital Cost (\$) ^a	Capital Recovery Costs (\$/yr)		
		15 years (CRF ^b = 0.1098)	30 years (CRF ^b = 0.0806)	20 years ^c (CRF ^b = 0.0944)
ASHTA	\$28,246,460	\$3,101,309	\$2,276,281	\$2,666,266
Olin GA	\$70,901,169	\$7,784,567	\$5,713,670	\$6,692,569
Olin TN	\$156,329,838	\$17,164,176	\$12,598,059	\$14,756,431
PPG	\$43,391,830	\$4,764,190	\$3,496,792	\$4,095,882
Totals		\$32,814,242	\$24,084,802	\$28,211,147

^a Using the average cost factor from recent U.S. Conversions (See Table 3-2).

^b CRF = Capital Recovery Factor.

^c Used in this analysis to develop costs for near future U.S. conversions.

¹⁹ Memorandum from Brown, H.P., EC/R Incorporated, Chapel Hill, NC, to D.L. Jones, U.S. Environmental Protection Agency, Research Triangle Park, NC. *Documentation of Building Replacement Cost Estimates*. June 5, 2008.

3.2.2 Annual Costs Associated with Storage of Unused Mercury

According to the Chlorine Institute, there were 1,376 tons of mercury available at the five mercury cell plants operating in 2008.²⁰ These plants operated a total of 264 mercury cells, which equates to 5.2 tons of mercury per cell (ton Hg/cell) on the average. To estimate the amount of mercury available at each of the four currently operating facilities, that would need to be stored if they converted to membrane cells, this average factor was multiplied by the number of cells in each of the facilities. As shown in Table 3-4, this results in an estimated total of 1,272 tons of mercury to be stored, ranging from 125 tons at ASHTA to over 550 tons at Olin TN.

Table 3-4. Estimate of Annual Mercury Storage Costs

Facility	Number Cells ^a	Available Mercury (ton) ^b	Mercury Storage Costs (\$/yr)		
			Using EPA Factor (\$0.134/yr/lb)	Using DOD Factor (\$0.0561/yr/lb)	Midpoint of EPA and DOD Factors ^c
ASHTA	24	125	\$33,399	\$14,035	\$23,717
Olin GA	60	313	\$83,498	\$35,088	\$59,293
Olin TN	106	552	\$147,513	\$61,989	\$104,751
PPG	54	281	\$75,148	\$31,579	\$53,364
Totals	244	1,271	\$339,558	\$142,691	\$241,125

^a Reference 18.

^b Total amount of available mercury (5.28 tons/cell) distributed by number of mercury cells (see Reference 20).

^c Used in this analysis to develop costs for near future U.S. conversions.

There were two sources of information identified that provided estimates of mercury storage costs. EPA's Office of Pollution Prevention and Toxics and the EPA Office of Solid Waste and Emergency Response²¹ has estimated future mercury storage costs at a private facility would be between \$0.081 and \$0.186 per year per pound of mercury stored, with an average of \$0.134 per year per pound. The Defense National Stockpile Center also has presented information indicating that the cost associated with the federal mercury storage is \$0.0561/yr/lb Hg.²²

²⁰ The Chlorine Institute, Inc. "Chlor-Alkali Industry 2008. Mercury Use and Emissions in the United States (Twelfth Annual Report)." August 2009.

²¹ Mercury Storage Cost Estimates—Final Report. U.S. Environmental Protection Agency. Office of Pollution Prevention and Toxics and Office of Solid Waste and Emergency Response, Washington, DC. November 6, 2007. Page 28, Exhibit 15. Available on the Internet: http://www.epa.gov/mercury/stocks/Storage_Cost_Draft_Updated_11-6-final.pdf

²² Lynch, Dennis, Environmental Protection Specialist. Presentation made at the *Asia Mercury Storage Project Inception Workshop* on March 4, 2009 at the Defense National Stockpile Center, Fort Belvoir, VA.

Table 3-4 shows the estimated storage costs using both the average factor from EPA (\$0.134/yr/lb) and the factor from the Department of Defense (\$0.0561/yr/lb). While there is a considerable difference in these estimates, the sources of the information are reliable. Use of either factor could bias the annual cost estimates high or low. Therefore, we assumed that these two points represent the upper and lower bounds of the storage costs, and that the midpoint of the range of storage costs represents the best estimate of the mercury storage costs that would be incurred. These midpoint costs, which are also shown in Table 3-4, total just over \$240,000 per year for all four plants.

The Mercury Export Ban Act (MEBA), which became public law on October 14, 2008 (Public Law No. 110-414), is intended to reduce the availability of elemental mercury in domestic and international markets. MEBA prohibits the export of elemental mercury as of January 1, 2013, and requires the Department of Energy (DOE) to designate and operate a facility (or facilities) for the purpose of long-term management and storage of elemental mercury generated in the United States. MEBA also prohibits the transfer of elemental mercury held by federal agencies as of the date of enactment in order to further control the flow of elemental mercury in the domestic market. MEBA covers elemental mercury but not mercury compounds.

MEBA requires DOE to publish guidance establishing procedures and standards for the receipt, management and long-term storage of elemental mercury by October 1, 2009. DOE issued an Interim Guidance document to fulfill this requirement, which is available at [http://mercurystorageeis.com/Elementalmercurystorage%20Interim%20Guidance%20\(dated%202009-11-13\).pdf](http://mercurystorageeis.com/Elementalmercurystorage%20Interim%20Guidance%20(dated%202009-11-13).pdf) (See also Notice of Availability, November 16, 2009, 74 FR 58952). DOE must designate a facility or facilities for long-term management and storage of elemental mercury by January 1, 2010 according to MEBA. DOE has issued a Draft Long-Term Management and Storage of Elemental Mercury Environmental Impact Statement (EIS) which analyzes a number of candidate facilities. The draft Mercury Storage EIS is available at <http://www.mercurystorageeis.com/> (See also Notice of Availability, January 29, 2010, 75 FR 4801). DOE is due to release a draft environmental impact statement (dEIS) for evaluating potential storage sites by December 2010.

MEBA requires that DOE to assess and collect fees for providing management and storage of elemental mercury. The amount of the fees will be made publicly available by October 1, 2012. MEBA also requires a designated facility or facilities to be operational by January 1, 2013; the facility will be subject to RCRA Subtitle C requirements, except for the storage prohibition contained in § 3004(j) of the Solid Waste Disposal Act. MEBA requires the storage facility to accept custody, for the purpose of management and storage, of elemental mercury

generated within the United States and delivered to the facility, and that persons who deliver elemental mercury to the storage facility are indemnified against any liability related to the release or threatened release of mercury after delivery to the facility. MEBA also requires EPA or an authorized state to issue a final decision on a RCRA permit application for a DOE facility by January 1, 2015.

In addition, MEBA authorizes DOE to establish terms and conditions for the long-term management and storage of elemental mercury. DOE has indicated that elemental mercury to be stored at the DOE facility or facilities must be of a purity of 99.5 percent or greater by volume (see DOE Interim Guidance document and Draft Mercury Storage EIS). Therefore, elemental mercury of lower purity would need to be further refined before it could be stored at the DOE facility (or facilities), but export or federal agency transfer of such mercury is still prohibited. MEBA does not affect RCRA or RCRA regulations except that elemental mercury stored at the DOE facility, or elemental mercury that is destined for the DOE facility and accumulated for 90 days or less is not subject to the RCRA storage prohibition, 3004(j) of the Solid Waste Disposal Act (42 U.S.C. 6924(j)). (See MEBA Sec. 5(g)(2)).

The elemental mercury that chlor-alkali facilities store on-site remains a commercial chemical product and its storage is not barred by federal environmental statutes as long as it is not discarded. This is the case whether the facility continues to operate a mercury cell process, converts to a non-mercury process or shuts down the plant. State or local restrictions may apply, however. After the establishment and operation of the DOE facility, mercury being stored at chlor-alkali plants can continue to be stored as a product. However, if storage continues over a long period of time, or if the supply of commodity grade mercury exceeds domestic demand, EPA may assess on a case-by-case basis the legitimacy of a claim that elemental mercury storage does not constitute discard. For a full discussion, see

<http://www.epa.gov/boston/topics/cleanup/compendium/2002-Mercury-from-the-HoltraChem-Manufacturing-Co.pdf>

The EPA encourages responsible stewardship of the elemental mercury designated to go to a DOE facility, which could involve arranging secure temporary storage, such as a RCRA-permitted facility with the capacity to store mercury on a short term basis, until the company can send it to DOE for long-term storage.

3.2.3 Costs Savings Associated with the Elimination of Mercury-Related Environmental Compliance Costs

There are some expected costs savings related to the conversion from a mercury-containing process to the membrane cell process due to the elimination of compliance costs associated with the use of mercury. These savings can be categorized into three environmental

elements: air, waste, and water. Air-related environmental compliance cost savings are realized when the facility no longer has to comply with mercury-related air regulations, as well as labor due to the elimination of mercury-related air monitoring, reporting, abatement measures, and occupational exposure monitoring. Waste-related environmental compliance cost savings are realized when a facility no longer incurs costs due to recycling, retorting, transporting, storing and/or disposing of mercury wastes. Water-related environmental compliance cost savings are realized when the facility no longer is required to operate mercury wastewater treatment programs.

We used information from the literature²³ (with costs converted from Euros to U.S. dollars using the average 2004 exchange rate²⁴ of 1.2439) and cost information presented to the State of Ohio by ASHTA as a part of their consent order²⁵ to estimate the cost savings. Information related to annual compliance costs associated with reducing mercury air emissions from the hydrogen and end box vent streams, presented to the Ohio EPA by ASHTA under the consent order, indicated that ASHTA would spend approximately \$228,000 annually on air compliance. This value was converted to a \$/ton Cl₂ value based on ASHTA's capacity of 47,421 ton Cl₂/yr,¹⁸ resulting in a cost factor of \$4.81/ton Cl₂ capacity. Since these costs would no longer be incurred after conversion, this factor represents a savings. In contrast, European information indicates that a savings of approximately \$2.20/ton Cl₂ in expenditures related to air compliance could be realized from the elimination of mercury.²³

In addition to the air-related compliance costs described above, ASHTA presented to the Ohio EPA that they would be spending approximately \$256,500 annually on fugitive mercury emission-related activities (including the implementation of leak detection and repair standards). Upon conversion to membrane cells, this would represent a savings. These costs and savings are not relevant for the other three facilities because ASHTA is the only facility that did not install a cell room instrumental monitoring program and, therefore, is required to perform a leak program.

ASHTA also presented information to the Ohio EPA related to costs for their water treatment system. According to ASHTA, they spend approximately \$98,000 annually on their storm water recovery system. This converts to a cost/savings factor of \$2.07/ton Cl₂ capacity for

²³ Maxon, Peter, Director. Concorde East/West Sprl. *Status Report: Mercury Cell Chlor-Alkali Plants in Europe*. Prepared for European Environmental Bureau, Brussels, Belgium. October 2006.

²⁴ Historic Exchange Rates. Prepared by GOCurrency.com. Available on the Internet at www.gocurrency.com. Accessed April 1, 2009 and April 30, 2009.

²⁵ ASHTA Chemicals. Early MACT Compliance. Consent Agreement. Exhibits B and C. (Docket No. EPA-HQ-OAR-2002-0017). August 2004.

elimination of water-related compliance costs due to mercury use. The European information indicates that a cost savings of approximately \$1.92/ton Cl₂ could be realized by the eliminations of a mercury wastewater treatment system.²³

Waste-related environmental compliance cost savings are realized by facilities no longer being required to recycle, retort, transport, store and/or dispose of mercury-containing wastes. The only information available was the European data that indicated that facilities could expect a cost savings of \$6,470/ton waste, at an average mercury waste production rate of 4.2x10⁻⁵ ton waste per ton Cl₂.²³ This results in a waste-related cost savings of \$0.27/ton Cl₂ capacity for elimination of waste-related compliance costs due to mercury use.

Table 3-5 presents the cost savings factors for each environmental compliance element discussed above from both the information from ASHTA as well as the European literature. A total environmental compliance cost savings factor was obtained from the sum of all the individual elements in each data set. Since ASHTA did not provide data related to annual cost of handling mercury-related wastes, the value from the literature was used to obtain a total from all media. With this approach, a value of \$7.15/ton Cl₂ shown in Table 3-5, was developed from data mostly from ASHTA, and a value of \$4.63/ton Cl₂ was developed from the European literature.

Table 3-5. Environmental Compliance Cost Savings Factors from Elimination of the Mercury Process

Environmental Element	Cost Saving Factors from Elimination of Mercury (\$/ton Cl ₂)	
	ASHTA Factor ^a	Literature Factor ^b
Air	4.81	2.20
Water	2.07	2.16
Waste	0.27 ^c	0.27
Totals	7.15^{c,d}	4.63

^a See Reference 25.

^b See Reference 23.

^c Since ASHTA did not provide data related to annual cost of compliance for mercury-related wastes, the value from the literature was used for this element.

^d Used in this analysis to develop costs for near future U.S. conversions.

Table 3-6 presents the estimated annual cost savings from the elimination of mercury-related compliance costs for each of the four U.S. facilities using both total environmental compliance saving cost factors from Table 3-5. Since the cost data found in the literature were based on facilities in Europe and not from actual U.S. facilities, we believe that the annual cost savings from the elimination of mercury that is based mostly on the ASHTA cost factors represent the best estimate of the cost savings for the remaining U.S. facilities.

Table 3-6. Annual Cost Savings from Elimination of the Mercury Processes, by Facility

Facility	Chlorine Capacity (tpy)	Savings from Hg Elimination (\$/yr)	
		ASHTA Factor ^a	Literature Factor ^b
ASHTA ^c	47,421	595,386	595,386
Olin GA	119,031	850,634	550,600
Olin TN	262,451	1,875,561	1,214,017
PPG	72,848	520,592	336,970
Totals		3,842,173^d	2,696,973

^a Using the ASHTA factor of 7.15 \$/ton Cl₂ presented in Table 3-5.

^b Using the literature factor of 4.63 \$/ton Cl₂ presented in Table 3-5.

^c As discussed above, the ASHTA compliance costs savings include \$256,500/yr related to their fugitive emissions compliance costs (that includes a leak detection and repair element, as well as the installation of a temporary canopy for the cell room); whereas, the other facilities do not include these costs because ASHTA was the only facility that did not install an instrumental monitoring program to comply with the NESHAP.

^d Used in this analysis to develop costs for near future U.S. conversions.

3.2.4 Energy Savings and Costs

The membrane cell process requires less electricity than the mercury cell process. Therefore, there are reduced energy requirements with membrane cells as compared to mercury cells. Energy cost savings due to reduced electricity usage were estimated using information from literature and average State electricity prices.¹² Although there could be variations in local electricity costs, according to the information in the literature, the electricity used by the membrane cell technology is approximately 2,500 kilowatt hours per ton chlorine produced (kWh/ton Cl₂), which is about 700 kWh/ton Cl₂ less than that used by the mercury cell process (3,230 kWh/ton Cl₂).¹² This equates to an approximately 22 percent reduction in electricity usage. The total chlorine production capacity of the four mercury cell plants is 500,000 tons per year. Using the 700 kWh/ton decrease in electricity usage, the total estimated electricity reduction after conversion of the four plants would be around 350 million kWh/year, or 350,000 Megawatt hours/year.

Oceana provided information that indicated that a 37.5 percent reduction was Applying a 37.5 percent reduction to the mercury cell process electricity usage estimate of 3,230 kWhr/ton Cl₂ would yield a reduction in energy usage of approximately 1,211 kWhr/ton Cl₂.

These energy cost savings from reduced electricity usage are slightly offset by an increase in energy required to concentrate the caustic co-product generated in the membrane cell process. Mercury cells produce caustic at the market concentration of 50 percent, and membrane cells produce caustic at a 33 percent concentration. Therefore, there is an increase in energy use (in the form of steam) due to the need to further concentrate the caustic produced with the membrane cell technology.

The energy requirement (in the form of steam) to concentrate the caustic to 50 percent was estimated to be 601 kWh/ton Cl₂ (\$13.6/ton Cl₂), as obtained from the average of estimates provided for three U.S. facilities. This cost was deducted from the energy savings described above to develop an estimate of overall energy cost savings with membrane cell technology due to reduced energy needs. The energy cost savings are shown in Table 3-7.

Further evaluation of Oceana's claim of a 37.5 percent energy cost reduction²⁶ shows that although the estimate is for an actual facility, it is not clear whether steam costs are included. In addition, Oceana also indicated in their September 16, 2009, letter that a 25 percent reduction was commonplace. Therefore, we believe that the total energy cost savings based on the 22 percent electricity usage reduction represents the best cost estimate.

In their September 29, 2009, letter, Oceana stated that the steam cost was an overestimate of the required energy needs to concentrate the caustic. Oceana argued that even though additional energy is required to generate steam, the steam could be obtained without additional expense. According to Oceana, facilities could use byproduct hydrogen as fuel to generate the necessary steam. While it may be possible to assume that byproduct hydrogen could be used to generate the steam required to concentrate caustic from a membrane cell, we agree with industry's claim that increases in the demand for and the value of high purity chemical hydrogen make this use of byproduct hydrogen economically impractical. Therefore, we have not made adjustments to the energy usage costs (in the form of steam) based on the use of byproduct hydrogen as fuel.

²⁶ Government of India Bureau of Energy Efficiency. 2006. "The Travancore-Cochin Chemicals Limited." December 14. http://www.bee-india.nic.in/sidelinks/EC%20Award/eca06/Award2006_CD/06ChlorAlkali/TheTravancore-CochinChemicalsLimited.pdf.

Table 3-7. Energy Savings Associated with Conversion from the Mercury Cell to the Membrane Cell Process

Facility	Chlorine Capacity (tpy)	Average Industrial Retail Electricity Cost (cents/kWh) ^a	Steam Cost (\$/yr) ^b	Annual Energy Savings (\$/yr)		Total Energy Cost Savings (\$/yr) ^f	
				22% Energy Reduction ^{c,d}	37.5% Energy Reduction ^e	22% Energy Reduction ^{c,d}	37.5% Energy Reduction ^e
ASHTA	47,421	5.77	644,788	1,911,268	3,313,692	1,266,480	2,668,904
Olin GA	119,031	5.48	1,618,476	4,556,346	7,899,639	2,937,870	6,281,163
Olin TN	262,451	5.40	3,568,575	9,901,023	17,166,059	6,332,448	13,597,484
PPG	72,848	3.90	990,515	1,986,964	3,444,931	996,449	2,454,416
Totals						11,533,247	25,001,967

^a Average retail price of electricity to ultimate customers by end-use sector, by state (Reference ²⁷).

^b Steam cost associated with concentrating caustic produced by membrane cells from 33 percent to 50 percent at an average cost of \$13.60/ton Cl₂ (Reference 12).

^c Calculated using a 22 percent energy savings associated with the conversion, at 699 kWh/ton Cl₂. (Reference 12).

^d Used in this analysis to develop costs for near future U.S. conversions.

^e Calculated using a 37.5 percent energy savings associated with the conversion, at 1,211 kWh/ton Cl₂.

^f Energy Cost Savings = Energy Savings (\$/yr) – Steam Cost (\$/yr).

3.2.5 Overall Annual Costs

For each of the costs and savings elements discussed in the previous sections, there is credible information that would result in different estimated levels of costs/savings. For each element, this resulted in a high- and low-end estimate. These values are shown in Table 3-8.

For each element, we chose the method of estimation that we believe is the best estimate of the cost or savings, as follows:

- For capital recovery costs and mercury storage costs, we concluded that neither the high-end nor the low-end of the ranges represented the best estimate of the costs that would be incurred. Instead, we concluded that using a 20-year finance period provided the best estimate. (See Table 3-3 above.)
- For the mercury storage costs, we determined that the midpoint of the range of data from two sources (list) was the best estimate. (See Table 3-4 above.)

²⁷ U.S. Department of Energy. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State for 2006*. Available on the Internet at http://www.eia.doe.gov/cneal/electricity/epm/table5_6_b.html. Accessed February 24, 2009.

Table 3-8. Ranges of Individual Annual Cost/Savings Elements for the Conversion of Mercury Cells to Membrane Cells

Facility	Capital Recovery Costs (\$/yr) ^a		Mercury Storage Costs (\$/yr) ^b		Environmental Compliance Savings (\$/yr)		Energy Savings (\$/yr)	
	7% and 30 years	7% and 15 years	EPA Factor	DOD Factor	ASHTA Factors ^c	Literature Factors	22% Energy Reduction ^c	37.5% Energy Reduction
ASHTA	\$2,276,281	\$3,101,309	\$33,399	\$14,035	(\$595,386)	(\$595,386)	(\$1,266,480)	(\$2,668,904)
Olin GA	\$5,713,670	\$7,784,567	\$83,498	\$35,088	(\$850,634)	(\$550,600)	(\$2,937,870)	(\$6,281,163)
Olin TN	\$12,598,059	\$17,164,176	\$147,513	\$61,989	(\$1,875,561)	(\$1,214,017)	(\$6,332,448)	(\$13,597,484)
PPG	\$3,496,792	\$4,764,190	\$75,148	\$31,579	(\$520,592)	(\$336,970)	(\$996,449)	(\$2,454,416)
Totals	\$24,084,802	\$32,814,242	\$ 0	\$339,558	(\$3,842,173)	(\$2,696,973)	(\$11,533,247)	(\$25,001,967)

^a A recovery period of 20 years and 7% was use in the final analysis.

^b The midpoint of the EPA and DOD factor range was used in the final analysis.

^c These data were used in the final analysis.

- For the environmental compliance savings element, we chose the higher estimated savings, using the cost factors developed mostly from ASHTA data to provide the best estimate for these U.S. facilities. (See Table 3-6 above.)
- For the energy savings, we believe that the lower savings level based on a 22 percent electricity usage reduction provides the best estimate. (See Table 3-7 above.)

Table 3-9 shows the estimates for each facility for each individual cost element that incorporate the choices described above, and also shows the total annual costs calculated using these estimates for each facility for conversion to non-mercury technology. The values in Table 3-9 represent our best estimate of the annual costs that would be incurred due to the conversion of the four currently operating mercury cell facilities to membrane cells. These annual costs range from less than \$1 million per year for ASHTA to almost \$7 million per year for Olin TN, and a total estimate of \$13 million for all four facilities.

3.3 Uncertainty Analysis

While we selected the values that we believe provide the best estimates of the costs that would be incurred and savings that would be realized in the conversion from mercury cells to membrane cells at these four facilities, there is some uncertainty associated with the estimates. While most of the information obtained and provided by commenters appears to be credible and representative of actual conversions that have occurred, there is a high amount of variability. This is most likely due to the fact that the conditions associated with the potential conversion of

each mercury cell plant are different, resulting in potentially significant differences in the costs and savings.

Table 3-9. EPA Estimates of the Annual Costs of Conversion of Mercury Cells to Membrane Cells

Facility	Capital Recovery Costs (\$/yr) ^a	Annual Costs			Total Annual Costs (\$/yr)
		Mercury Storage Costs (\$/yr) ^b	Environmental Compliance Savings (\$/yr) ^c	Energy Savings (\$/yr) ^d	
ASHTA	\$2,666,266	\$23,717	(\$595,386)	(\$1,266,480)	\$828,117
Olin GA	\$6,692,569	\$59,293	(\$850,634)	(\$2,937,870)	\$2,963,358
Olin TN	\$14,756,431	\$104,751	(\$1,875,561)	(\$6,332,448)	\$6,653,173
PPG	\$4,095,882	\$53,364	(\$520,592)	(\$996,449)	\$2,632,205
Totals	\$28,211,147	\$241,125	(\$3,842,173)	(\$11,533,247)	\$13,076,853

^a Using 20 year finance period with a resulting CRF of 0.0944

^b Using midpoint of EPA and DOD factors.

^c Using ASHTA factors for air and water compliance costs and a literature value for waste compliance costs not provided in ASHTA data.

^d Using an estimate of 22 percent energy reduction with membrane process.

In order to consider the uncertainties, we conducted a simple Monte Carlo simulation.²⁸ For this simulation, we assumed a normal distribution for each variable. We set the peak of the distribution at our best estimate. For the elements where we believe one end of the range provides the best estimate (i.e., the environmental compliance savings and the energy savings), we truncated the distribution so that the peak of the distribution curve was at the best estimate. We ran the simulation with 100,000 calculations to create distributions of the individual plant annual costs over all annual costs. The results are shown in Table 3-10. As can be seen, the results of this analysis are very close to our best estimated costs. This shows that collectively, considering the ranges of each parameter/input to the annual costs, a mean value is obtained from the simulation that is only slightly lower (4 percent) than our estimate.

²⁸ Monte Carlo simulation is a computerized mathematical technique that is used to account for uncertainty in quantitative analyses and is often used in decision making and risk analysis. The simulation technique builds models of possible results by substituting a range of values—often a probability distribution—for any factor that has inherent uncertainty, and then recalculates the results numerous times, each time using a different set of random values from the probability functions. The results of Monte Carlo analyses are distributions of possible outcome values.

Table 3-10. Results of the Monte Carlo Simulation Compared to the EPA Estimates

Facility	EPA Estimate Total Annual Costs (\$/yr)	Monte Carlo Simulation Mean Total Annual Costs (\$/yr)
ASHTA	\$828,117	\$736,743
Olin GA	\$2,963,358	\$2,821,114
Olin TN	\$6,653,173	\$6,349,942
PPG	\$2,632,205	\$2,608,708
Totals	\$13,076,853	\$12,516,508

3.4 Summary of Results

For Option 1 (Non-mercury Technology Option), this section provided estimated costs for the conversion of the four currently operating mercury cell chlor-alkali facilities to membrane cells. The EPA estimate of the total capital cost for this conversion is slightly under \$300 million, with the EPA estimate of total annual costs at approximately \$13 million. Per facility estimated costs range from a low of \$828,117 (ASHTA) to \$6,653,173 (Olin TN).

For Option 2 (Enhanced Work Practice Standards Option), only the ASHTA facility incurs costs. These costs are estimated to be \$120 thousand in capital costs and \$25 thousand in total annualized costs.

SECTION 4

ECONOMIC IMPACT ANALYSIS (EIA)

EPA prepares an EIA to provide information about a new environmental policy's unfavorable effects (i.e., social costs) and how these costs are distributed among stakeholders (EPA, 2000). Although several tools are available to estimate the economic costs of direct performance standards, the proposed regulation is unique in that it bans emissions of mercury from the mercury cell process within 2 years from final promulgation and bans operation of mercury recovery units 3 years from final promulgation. EPA's *Guidelines* note that this type of regulation can be more difficult to assess when compared with traditional direct performance standards because it is hard to predict how stakeholders will respond (EPA, 2000). Bans may lead to shutdowns that will involve adjustment costs for people working at the affected plants. Affected plants may also have strong links with other firms or downstream markets; as a result, secondary consequences of the regulation become more important to consider.

4.1 Conversion Versus Plant Closure

The facilities currently in operation that do not already have plans to convert or close would have to convert to one of the non-mercury technologies, such as membrane cells. As a result, the owners of a plant have to make an investment decision that compares the costs of conversion with future benefits of the conversion. Although there is historical evidence that owners have converted from mercury technologies in Europe and United States, other mercury plant owners have, to date, concluded the investment decision was currently not in their company's interest given their assessment of future economic conditions (U.S. House of Representatives Committee on Commerce and Energy, 2009; PPG, 2009). The extremely concentrated markets (few suppliers) for some chlor-alkali products may provide manufacturers with an ability to pass on cost increases. ASHTA is one of only three producers of liquid potcarb and domestic entry is very difficult.

Although EPA does not have quantitative data to evaluate investment decisions (e.g., using capital budgeting techniques), the economics literature has emphasized three characteristics that influence the owner's best investment decision (Dixit and Pindyck, 2004):

- *Uncertainty*: the future rewards of an investment are unknown
- *Irreversibility*: the resources used to make the investment typically cannot be undone

- *Timing:* owners who delay investment get more information that they value; as a result, there is an “opportunity cost” associated with making an investment decision now versus later

Supply and demand conditions in the chlor-alkali product markets are highly variable; chlor-alkali product prices regularly spike and fall during short periods (see Figure 4-1). Olin Corporation reports that the average product price for chlorine-caustic soda co product (electrochemical unit or ECU) dropped from approximately \$1,300 per short ton to just under \$600 per short ton in the first 6 months of 2009 (Olin Corporation, 2009). Figure 4.1 (below) shows that the long term price trend for chlor alkali products shows that prices have more than doubled since 2004, even when considering the recent price decreases.

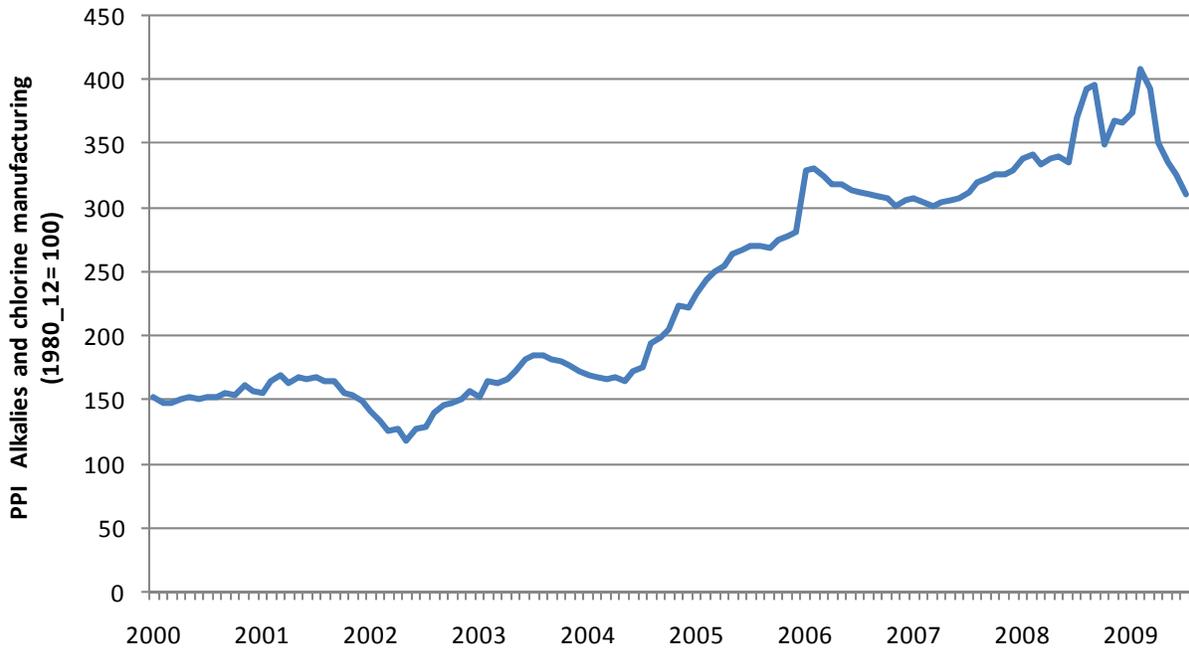


Figure 4-1. Price Trends: Alkalies and Chlorine Manufacturing: 2000 to 2009

Source: U.S. Bureau of Labor Statistics. 2009a. Producer Price Index Industry Data, Series ID = PCU PCU325181325181. <http://data.bls.gov/PDQ/outside.jsp?survey=pc>. Accessed August 18, 2009.

The sharp price changes highlight the risks associated with chlor-alkali capital investments. For example, OxyChem completed an announced \$60 million investment at its membrane chlor-alkali plant in Taft, Louisiana, to produce KOH instead of caustic potash (Access Intelligence, LLC, 2008). Almost a year later, an announcement suggests the plant has idled because of unstable market conditions (Access Intelligence, LLC, 2009).

Given the current market conditions, the benefits of delaying investment and waiting for new information are likely large if plants can delay conversion decisions. However, if plants delay, they risk other manufacturers entering the market before them and losing profits and market share. If for example, there are industrial consumers of chlorine nearby, it is unlikely that chlorine manufacturers will not meet that demand. And it appears to be cost-effective to produce chlor alkali products close to large industrial consumers. Firms would like to require rates of return that exceed the cost of capital to make new capital investments now. As reported above, prices for large industrial consumers of these facilities' products could be sufficient to justify the investment in conversion

To our knowledge, the only existing economics literature that examines regulation-induced plant closures in the chlor-alkali industry is a study by Snyder and colleagues (2003). Environmental regulations *affecting chlorine end-use markets* have reduced the demand for chlorine and help explain the exit of selected chlorine plants (Snyder, Miller, and Stavins, 2003). For example, chlorine plants that were co-located with pulp and paper mills and plants affected by the Montreal Protocol were more likely to shutdown (11 to 15% higher than the average chlorine plant) (Snyder, Miller, and Stavins, 2003). In our case, the demand for chlorine and other products is not changing with the regulation. In contrast, regulatory factors did not appear to influence the decision to adopt membrane technologies at existing plants. EPA does not have sufficient data to predict whether individual companies would choose to convert or close, historical responses suggest that plant closure may be an option considered by some of these facilities. Of the last four plants to stop using this process, two converted and two closed.

4.2 Market Concentration and Pricing Behavior

Of the three major chlor-alkali products discussed in Section 2, the market for potassium hydroxide is the most highly concentrated. As of 2005, there were only four producers of potassium hydroxide in the United States (FTC, 2005b). Approximately 50% is produced using mercury cells; ASHTA Chemicals, Inc. reports a market share of approximately 15% (U.S. House of Representatives Committee on Commerce and Energy, 2009). Producers of potassium hydroxide may have more ability to pass on costs of conversion than producers of other chlor-alkali products. Any closure of one or more mercury cell plants could raise concerns about competitiveness and subsequent firm pricing behavior in the KOH market; the remaining companies could have more scope to influence market prices by altering production levels. Given the small number of remaining KOH producers, removing an extra ton of KOH from the market may raise the market price and increase the profits on all the other KOH sold. If the price effect is large enough, the remaining companies may find it is more profitable to reduce

production levels below the levels that they would be choose in a market with a large number of competitors.

EPA’s review of publicly available sources also suggests that any closure would have similar market concentration consequences for a downstream commodity: potassium carbonate. ASHTA is one of only three producers of liquid potcarb and domestic entry is very difficult because it is very expensive; foreign entry (i.e., imports) has historically been limited (FTC, 2009b). In the absence of other market condition changes if ASHTA’s were to close, it would likely reduce competition and lead to higher prices in the liquid potcarb market. Although EPA does not have data to quantify the effect of higher potassium carbonate prices, we recognize that end users of potassium carbonate (e.g., specialty glasses including television tubes and the ceramics industry [Armond Products Company, 2009; ERCO Worldwide, 2009]) and the consumers of these goods could indirectly be affected by a price increase.²⁹ Industry sources already suggest that high energy costs and reduced domestic demand in the video glass industry has contributed potassium carbonate industry decline although there is some evidence that other “niche” end users are emerging (Hoffmann, 2004).

4.3 Impact on Employment

EPA does not have enough information to estimate whether individual plants will convert or close and therefore no estimate of changes in employment are provided. In the following section we provide information on each plants’ job contributions relative to the size of local labor markets and current and historical conditions. In Table 4-1, we use the latest monthly statistics about county labor forces and show the relative contributions of each plant in the context of current labor market conditions. In Figure 4-2, we compare the historical unemployment rates in the United States with unemployment rates for the counties where mercury cells are located. As shown in Figure 4-3, annual unemployment rates for three counties (Ashtabula, Richmond, and Wetzel) diverge and become higher than the national average beginning in 2004. Recent data for the month of May 2009 also suggest the relative difference between Ashtabula County and the United States is higher than historical differences.

²⁹ Companies using potassium products may also be concerned about other events that tend to increase the cost of potassium products (e.g., recent increases in the input costs of potash used to make potassium hydroxide). For example, Superior Plus (2008) notes that a current contract to purchase potash on favorable terms expired in 2009, and production costs are likely to rise once potash is purchased at current (higher) market prices. Superior plus owns ERCO Worldwide, one of the four companies that compete in the U.S. potassium hydroxide market.

Table 4-1. May 2009 County Employment Data (Not Seasonally Adjusted)

Plant	Location	Plant Employees	County Persons Employed	Plant Share of Persons Employed	County Persons Unemployed
ASHTA	Ashtabula County, OH	100	42,481	0.2%	6,526
Olin	Richmond County, GA	85	82,416	0.1%	8,634
Olin	Bradley County, TN	280	42,132	0.7%	4,397
PPG	Wetzel County, WV	540	5,663	9.5%	731

Source: U.S. Bureau of Labor Statistics. 2009b. LAU Local Area Unemployment Statistics Series Id: LAUPS39011004, LAUPS39011005, LAUPA47035004, LAUPA47035005, LAUCN13245004, LAUCN13245005, LAUCN54103004, LAUCN54103005. Accessed August 2009.

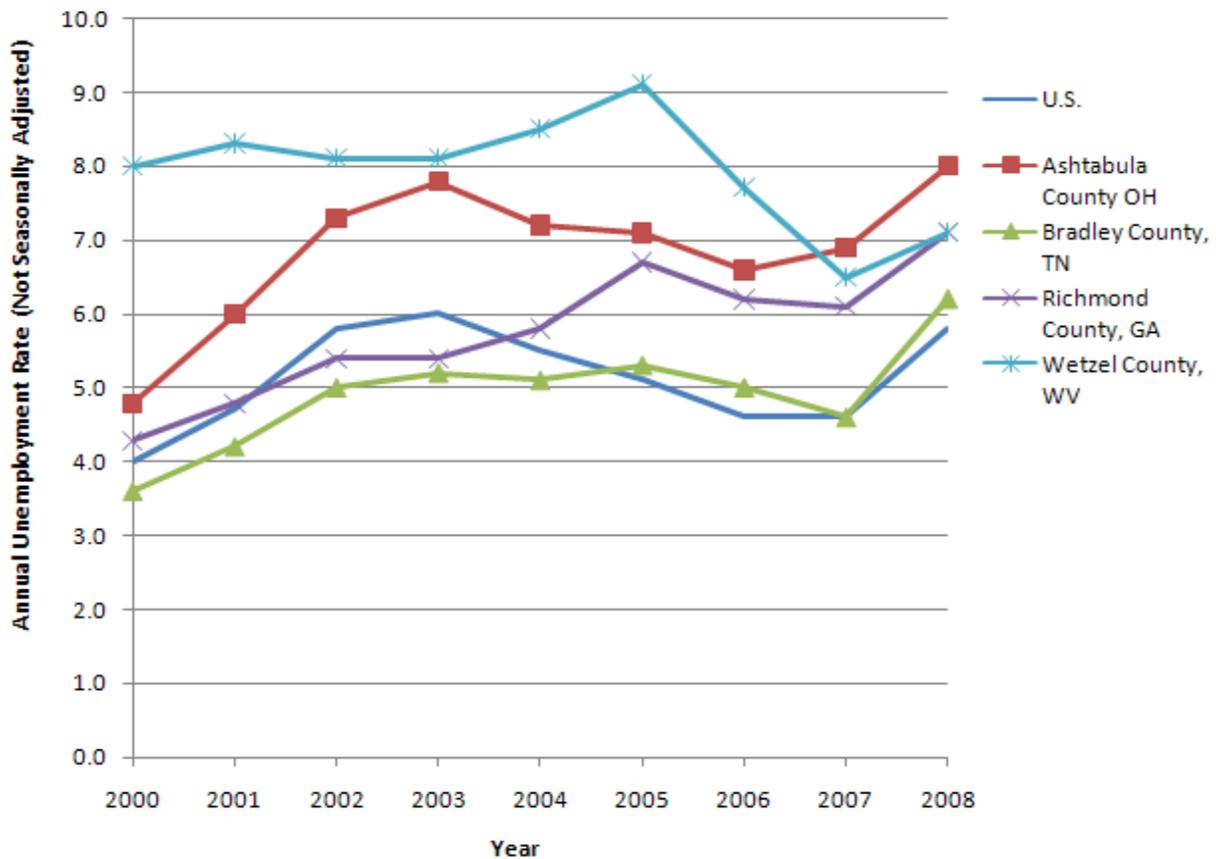


Figure 4-2. Unemployment Rates by County: 2000–2008

Sources: U.S. Bureau of Labor Statistics. 2009c. LAU Local Area Unemployment Statistics Series Id: LAUPS39011006, LAUPA47035006, LAUCN13245006, and LAUCN54103006. Accessed August 2009.
 U.S. Bureau of Labor Statistics. 2009d. Current Employment Statistics—CES (National) Series Id: LNU04000000. Accessed August 2009.

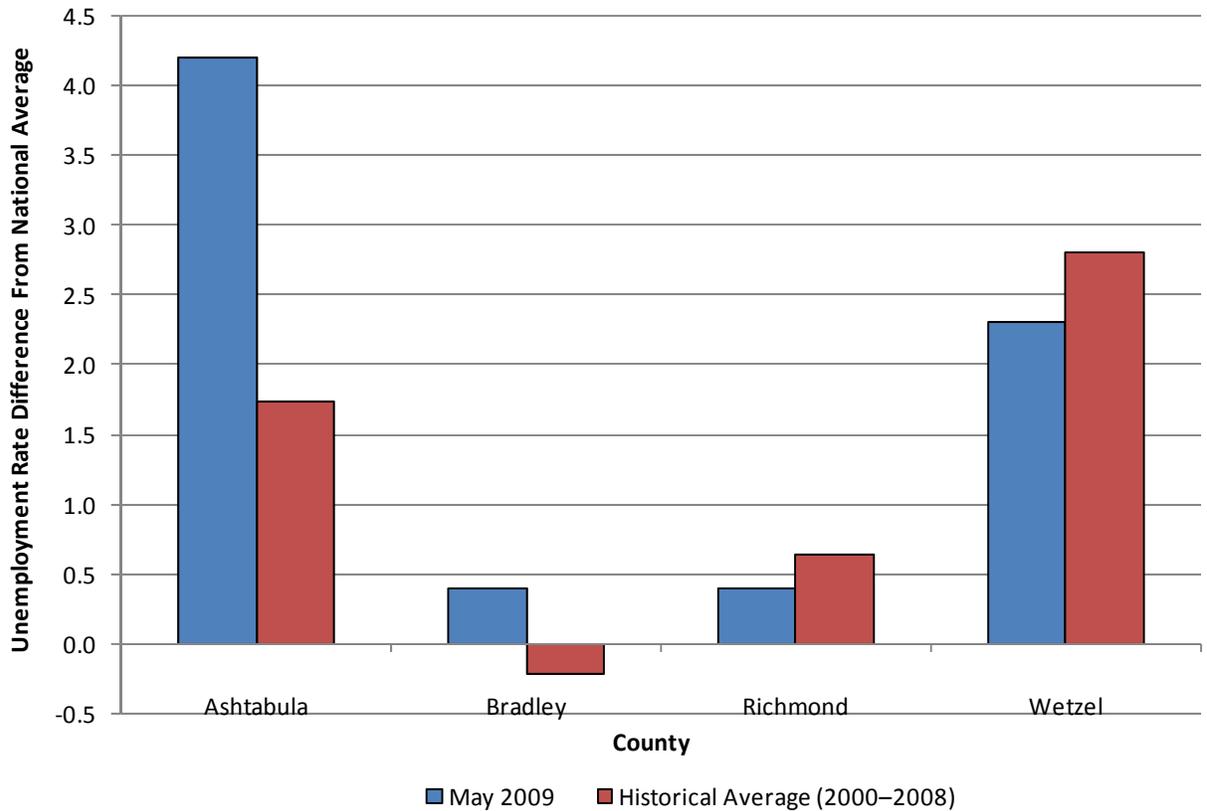


Figure 4-3. Unemployment Rate Differences from National Average: May 2009 and Historical Average: 2000-2008

Source: U.S. Bureau of Labor Statistics. 2009c. LAU Local Area Unemployment Statistics Series Id: LAUPS39011006, LAUPA47035006, LAUCN13245006, and LAUCN54103006. Accessed August 2009.

4.4 Transportation Issues Associated with Plant Closure

If one or more mercury cell plants were to close, customers with existing arrangements with the plants will have to identify another outside supply source to maintain chemical production. For example, ASHTA’s production facility sells 100% of its chlorine to an adjacent titanium dioxide plant (U.S. House of Representatives Committee on Commerce and Energy, 2009). Although other chlorine supply sources may be available, transportation will likely be more expensive because of increased shipping distances between the supply source and its destination. Depending on the mode of transportation selected, this may also indirectly increase the volume of existing shipments passing through certain urban areas.

4.5 Small Entity 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 an impact 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.

4.5.1 Identify Affected Small Entities

For the purposes of assessing the impacts of the proposed rule on small entities, a 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 mercury cell chlor-alkali facilities are categorized as small if the total number of employees at the ultimate parent company is fewer than 500; otherwise, the ultimate parent company is classified as large. As discussed in the previous section, ASHTA, Inc. is the sole entity that meets these qualifications.

4.5.2 Sales Test Analysis

EPA assessed how the regulatory program may influence the profitability of ultimate parent companies by comparing annual conversion 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:

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

where

CSR = cost-to-sales ratio

TACC = total annualized compliance costs

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 Option 1, EPA estimates that ASHTA's CSR would range from 1 to 2%, which suggests a significant economic impact. For Option 2, EPA estimates that ASHTA's CSR would be less than 0.1%. The other three plants are owned by large ultimate parent companies with significant company-wide sales. As a result, the CSRs for the large companies are below 1%. However, when plant-only sales are considered, the CSRs for plants owned by large ultimate parent companies range from 4 to 9%.

4.5.3 Profit Test Analysis

Economic models assume that a chlor-alkali company acts in the best interest of its shareholders and tries to make the company's profit (total revenue minus total costs) as large as possible. To measure of chlor-alkali profits, EPA used trade publication data for a representative ECU called the "cash margin" (CMAI, 2008). The measure approximates the average profit per metric ton of chlor-alkali product made. As shown in Figure 4-4, historical data suggest that cash margins can fluctuate over time. Assuming the market prices for chlor-alkali products do not change as a result of the proposed rule, the annual conversion costs (\$/metric ton) associated with the proposed rule will reduce the average profit for chlor-alkali products. To assess the size of this effect, EPA compared the conversion costs with economic data for a typical year (using historical industry ECU margins and capacity utilization rates from 1991 to 2005).³⁰ As shown, conversion costs could reduce the margins by 10 to 20% (Figure 4-5). EPA also considered data in weak and strong margin years; as shown, margin reductions range from 5 to 100% for these years. As a result, the analysis confirms the results associated with the sales test; plant conversion costs will likely have an economically significant effect.

4.6 Conclusions

The EIA suggests Option 1 requirements are likely to have significant economic costs. Plants will either convert or close. Predicting whether, no plant, one plant, two plants, three plants, or all four plants will close or convert is not possible with the available data.

³⁰ For a typical year, we used the observed average industry ECU cash margin (2008 dollars) and average industry utilization rate between 1991 and 2005. For weak and strong years, we considered cash margins and industry utilization rates one standard deviation (lower and higher) from the average.

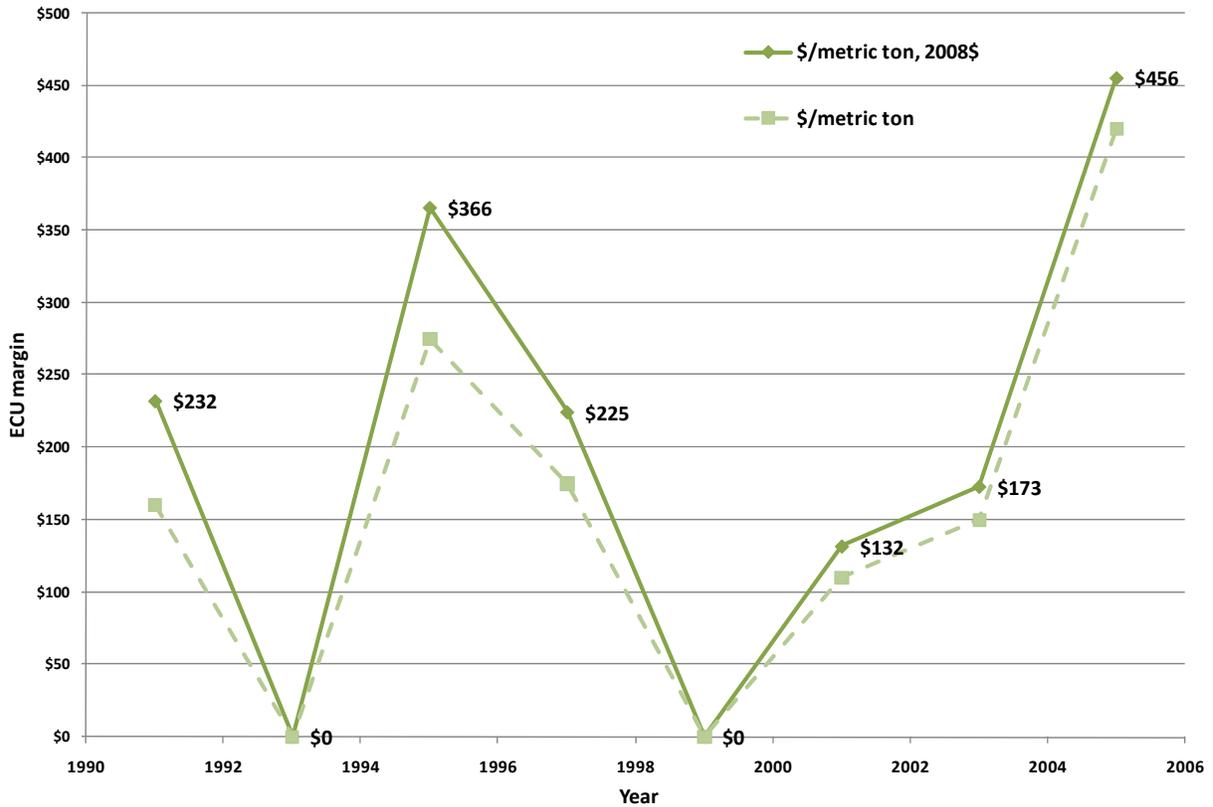


Figure 4-4. Historical ECU Cash Margins

Source: EPA estimates using data from CMAI (2008).

Closure of one or more mercury cell process plants also raises concerns about competitiveness and subsequent pricing behavior in the potassium hydroxide and potassium carbonate markets. In highly concentrated markets with few producers, nonmercury cell producers may be able to influence market prices above competitive levels by altering production decisions. Similar competitive issues have also been raised in other regulatory contexts.

The small business impact analysis shows that one of the four plants is owned by a small business. A sales test suggests this small company will be significantly affected (CSR would range from 1 to 2% for Option 1). EPA also considered profitability effects by comparing annual conversion costs to reported industry margins for a representative ECU. Even in optimistic scenarios where ECU margins are higher than historical averages, conversion costs could significantly reduce the margins.

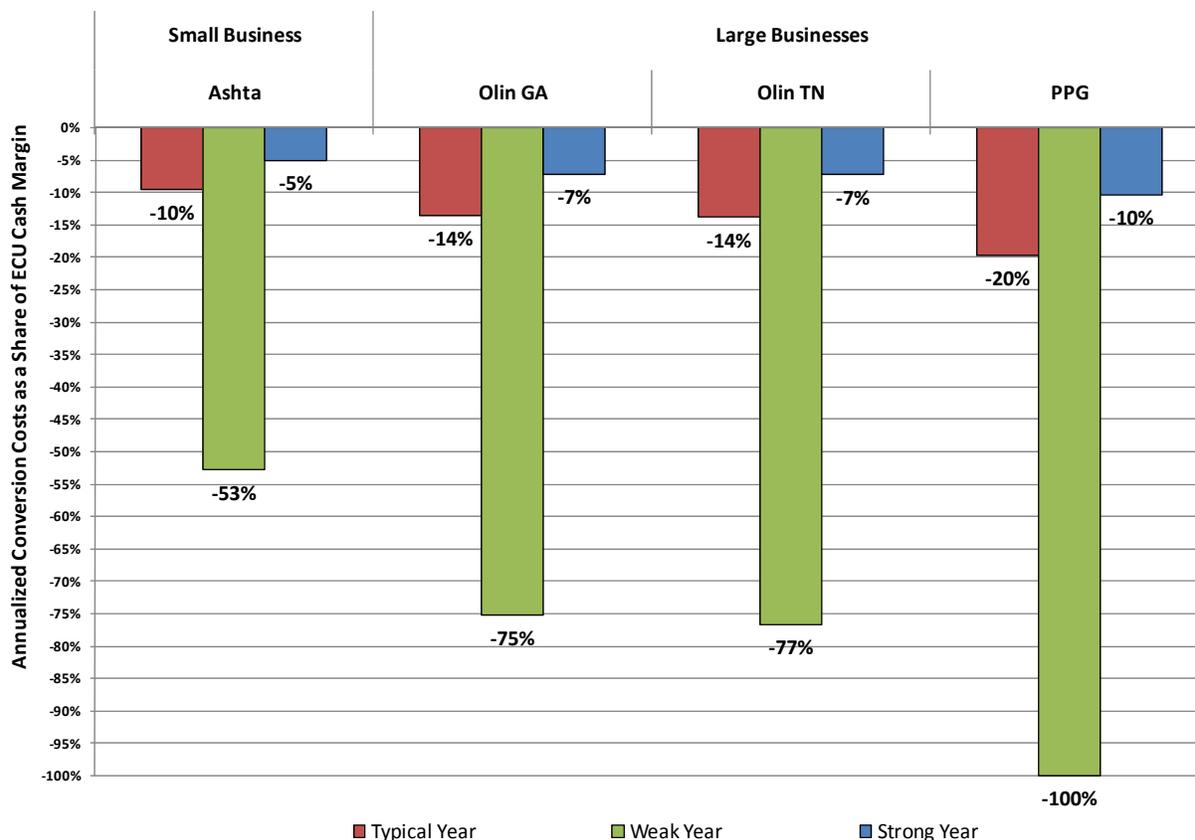


Figure 4-5. Profit Tests: ECU Cash Margin Reductions Associated with Conversion Costs

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SECTION 5

HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

5.1 Synopsis

In this section, we provide analysis of the benefits associated with the proposed Mercury Chlor Alkali NESHAP. As there are no emission reductions or energy impacts associated with Option 2 (enhanced work practice standards), the benefits in this chapter correspond to Option 1 (non-mercury technology option). The primary benefit of this regulation is the reduction of mercury emissions from these sources. Due to data, time, and resource limitations, we were unable to model mercury dispersion, deposition, methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions. In addition, this regulation would reduce electricity demand at these sources. Using benefit-per-ton estimates, we estimate the monetized human health co-benefits of reducing cases of morbidity and premature mortality among populations exposed to particulate matter (PM) associated with the decreased electricity usage. Using the social cost of carbon (SCC), we estimate the monetized benefits associated with reduced CO₂ emissions. At a 3% discount rate, we estimate the total monetized co-benefits of the proposed NESHAP to be \$22 million to \$43 million in the implementation year (2013). At a 7% discount rate, we estimate the total monetized co-benefits of the proposed NESHAP to be \$14 million to \$33 million in 2013. All estimates are in 2007\$. These estimates reflect EPA's most current interpretation of the scientific literature. Higher or lower estimates of PM_{2.5} co-benefits are possible using other assumptions; examples of this are provided in Figure 5-2 and Table 5-6. Data, resource, and methodological limitations prevented EPA from monetizing the co-benefits from several important benefit categories, including benefits from reducing ecosystem effects and visibility impairment. It is important to emphasize that these monetized co-benefits do not include the benefits associated with reducing mercury emissions.

5.2 Mercury Benefits

Mercury is a highly neurotoxic contaminant that enters the food web as a methylated compound, methylmercury (U.S. EPA, 2008c). The contaminant is concentrated in higher trophic levels, including fish eaten by humans. Mercury is emitted to the air from various man-made and natural sources. These emissions transport through the atmosphere and eventually deposit to land or water bodies. This deposition can occur locally, regionally, or globally, depending on the form of mercury emitted and other factors such as the weather. The form of mercury emitted from these sources is estimated to be about 98 percent elemental and two percent divalent mercury. Gaseous elemental mercury can be transported very long distances,

even globally, to regions far from the emissions source (becoming part of the global “pool”) before deposition occurs. Inorganic ionic (divalent) mercury has a shorter atmospheric lifetime and can deposit to land or water bodies closer to the emissions source. Furthermore, elemental mercury in the atmosphere can undergo transformation into ionic mercury, providing a significant pathway for deposition of emitted elemental mercury.

This source category emitted about 640 pounds of mercury in the air in 2008 in the U.S. Based on the EPA’s National Emission Inventory, about 103 tons of mercury were emitted from all anthropogenic sources in the U.S. in 2005. Moreover, the United Nations has estimated that about 2,100 tons of mercury were emitted worldwide by anthropogenic sources in 2005. We believe that total mercury emissions in the U.S. and globally in 2008 were about the same magnitude in 2005. Therefore, we estimate that in 2008, these sources emitted about 0.3% of the total anthropogenic mercury emissions in the U.S. and about 0.02% of the global emissions. Overall, this rule would directly reduce mercury emissions by about 640 pounds per year from current levels as well as an estimated 16 pounds per year indirectly through reduced electricity generation, and therefore, contribute to reductions in mercury exposures and health effects. Due to data, time, and resource limitations, we were unable to model mercury dispersion, deposition, methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions.

Potential exposure routes to mercury emissions include both direct inhalation and consumption of fish containing methylmercury. In the U.S., the primary route of human exposure to mercury emissions from industrial sources is generally indirectly through the consumption of fish containing methylmercury. As described above, mercury that has been emitted to the air eventually settles into water bodies or onto land where it can either move directly or be leached into waterbodies. Once deposited, certain microorganisms can change it into methylmercury, a highly toxic form that builds up in fish, shellfish and animals that eat fish. Consumption of fish and shellfish are the main sources of methylmercury exposure to humans. Methylmercury builds up more in some types of fish and shellfish than in others. The levels of methylmercury in fish and shellfish vary widely depending on what they eat, how long they live, and how high they are in the food chain. Most fish, including ocean species and local freshwater fish, contain some methylmercury. For example, in recent studies by EPA and the U.S. Geological Survey (USGS) of fish tissues, every fish sampled from 291 streams across the country contained some methylmercury (Scudder, 2009).

The majority of fish consumed in the U.S. are ocean species. The methylmercury concentrations in ocean fish species are primarily influenced by the global mercury pool. However, the methylmercury found in local fish can be due, at least partly, to mercury emissions from local sources. Research shows that most people's fish consumption does not cause a mercury-related health concern. However, certain people may be at higher risk because of their routinely high consumption of fish (e.g., tribal and other subsistence fishers and their families who rely heavily on fish for a substantial part of their diet). It has been demonstrated that high levels of methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, making the child less able to think and learn. Moreover, mercury exposure at high levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages.

Several studies suggest that the methylmercury content of fish may reduce these cardio-protective effects of fish consumption. Some of these studies also suggest that methylmercury may cause adverse effects to the cardiovascular system. For example, the NRC (2000) review of the literature concerning methylmercury health effects took note of two epidemiological studies that found an association between dietary exposure to methylmercury and adverse cardiovascular effects.³¹ Moreover, in a study of 1,833 males in Finland aged 42 to 60 years, Solonen et al. (1995) observed a relationship between methylmercury exposure via fish consumption and acute myocardial infarction (AMI or heart attacks), coronary heart disease, cardiovascular disease, and all-cause mortality.³² The NRC also noted a study of 917 seven year old children in the Faroe Islands, whose initial exposure to methylmercury was *in utero* although post natal exposures may have occurred as well. At seven years of age, these children exhibited an increase in blood pressure and a decrease in heart rate variability.³³ Based on these and other studies, NRC concluded in 2000 that, while "the data base is not as extensive for cardiovascular effects as it is for other end points (i.e., neurologic effects) the cardiovascular system appears to be a target for methylmercury toxicity."³⁴

³¹ National Research Council (NRC). 2000. Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology. National Academies Press. Washington, DC. pp. 168-173.

³² Salonen, J.T., Seppanen, K. Nyssonen et al. 1995. "Intake of mercury from fish lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular and any death in Eastern Finnish men." *Circulation*, 91 (3):645-655.

³³ Sorensen, N, K. Murata, E. Budtz-Jorgensen, P. Weihe, and Grandjean, P., 1999. "Prenatal Methylmercury Exposure As A Cardiovascular Risk Factor At Seven Years of Age", *Epidemiology*, pp370-375.

³⁴ National Research Council (NRC). 2000. Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology. National Academies Press. Washington, DC. p. 229.

Since publication of the NRC report there have been some 30 published papers presenting the findings of studies that have examined the possible cardiovascular effects of methylmercury exposure. These studies include epidemiological, toxicological, and toxicokinetic investigations. Over a dozen review papers have also been published. If there is a causal relationship between methylmercury exposure and adverse cardiovascular effects, then reducing exposure to methylmercury would result in public health benefits from reduced cardiovascular effects.

In early 2010, EPA sponsored a workshop in which a group of experts were asked to assess the plausibility of a causal relationship between methylmercury exposure and cardiovascular health effects and to advise EPA on methodologies for estimating population level cardiovascular health impacts of reduced methylmercury exposure. The report from that workshop is in preparation.

5.3 Energy Savings Co-benefits

Because the membrane cell process requires less energy than the mercury cell process, this rule is anticipated to reduce electricity generated for these facilities by over 375 million kilowatt hours. Assuming a 22% reduction in electricity demand, the emission reductions associated with reduced electricity generation are estimated to be 68 tpy of PM_{2.5}, 0.008 tpy (16 lbs) of mercury, and 287,000 tpy of CO₂. The methodology for calculating these emission reductions is provided in Appendix B of this RIA.

5.3.1 PM_{2.5} Co-benefits

The energy savings anticipated from this rule would decrease emissions of PM, thus reducing human exposure, and the incidence of PM_{2.5}-related health effects. Due to time and resource limitations, it was not possible to provide a comprehensive estimate of the PM_{2.5}-related co-benefits. Instead, we used the “benefit-per-ton” approach to estimate these co-benefits based on the methodology described in Fann, Fulcher, and Hubbell (2009). These PM_{2.5} benefit-per-ton estimates provide the total monetized human health co-benefits (the sum of premature mortality and premature morbidity) of reducing one ton of PM_{2.5} from a specified source. EPA has used the benefit per-ton technique in several previous RIAs, including the recent proposed Cement NESHAP (U.S. EPA, 2009a). For this analysis, we use the national average benefit-per-ton estimates associated with the electrical generating unit (EGU) sector. Because the anticipated emission reductions are assumed to occur across multiple EGUs, the national average benefit-per-ton estimates best represent the regional scope of the anticipated emission reductions.

Table 5-1 identifies the quantified and unquantified co-benefits captured in those benefit-per-ton estimates.

Table 5-1. Human Health and Welfare Effects of PM_{2.5}

Pollutant/ Effect	Quantified and Monetized in Primary Estimates	Unquantified Effects Changes in:
PM _{2.5}	Adult premature mortality	Subchronic bronchitis cases
	Bronchitis: chronic and acute	Low birth weight
	Hospital admissions: respiratory and cardiovascular	Pulmonary function
	Emergency room visits for asthma	Chronic respiratory diseases other than chronic bronchitis
	Nonfatal heart attacks (myocardial infarction)	Non-asthma respiratory emergency room visits
	Lower and upper respiratory illness	Visibility
	Minor restricted-activity days	Household soiling
	Work loss days	
	Asthma exacerbations (asthmatic population)	
	Infant mortality	

Consistent with the Portland Cement NESHAP (U.S. EPA, 2009a), the PM_{2.5} co-benefits estimates utilize the concentration-response functions as reported in the epidemiology literature, as well as the 12 functions obtained in EPA’s expert elicitation study as a sensitivity analysis.

- 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 et al. (2002), a study that EPA has previously used to generate its primary benefits estimate. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 µg/m³ as was done in recent (2006–2009) Office of Air and Radiation 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_{2.5} NAAQS, has been used as an alternative estimate in the PM_{2.5} NAAQS RIA and PM_{2.5} benefits estimates in RIAs completed since the PM_{2.5} NAAQS. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 µg/m³ as was done in recent (2006–2009) RIAs.
- Twelve estimates are based on the C-R functions from EPA’s expert elicitation study (IEc, 2006; Roman et al., 2008) on the PM_{2.5}-mortality relationship and interpreted for benefits analysis in EPA’s final RIA for the PM_{2.5} NAAQS. For

that study, twelve experts (labeled A through L) provided independent estimates of the PM_{2.5}-mortality concentration-response function. EPA practice has been to develop independent estimates of PM_{2.5}-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).³⁵ 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 co-benefits estimates. Previously, EPA had calculated co-benefits based on these two empirical studies, but derived the range of co-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).³⁶ Within this assessment, we include the co-benefits estimates derived from the concentration-response function provided by each of the twelve experts to better characterize the uncertainty in the concentration-response function for mortality and the degree of variability in the expert responses. Because the experts used these cohort studies to inform their concentration-response functions, co-benefits estimates using these functions generally fall between results using these epidemiology studies (see Figure 6-2). In general, the expert elicitation results support the conclusion that the co-benefits of PM_{2.5} control are very likely to be substantial.

Readers interested in reviewing the methodology for creating the benefit-per-ton estimates used in this analysis should consult Fann, Fulcher, and Hubbell (2009). As described in the documentation for the benefit per-ton estimates cited above, national per-ton estimates are developed for selected pollutant/source category combinations. The per-ton values calculated therefore apply only to tons reduced from those specific pollutant/source combinations (e.g., NO_x emitted from electric generating units; NO₂ emitted from mobile sources). Our estimate of PM_{2.5} control co-benefits is therefore based on the total PM_{2.5} emissions controlled by sector and multiplied by this per-ton value.

The 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, this analysis uses the benefit-per-ton method first applied in the Portland Cement NESHAP RIA

³⁵ These two studies specify multi-pollutant models that control for NO_x, among other pollutants.

³⁶ Please see the Section 5.2 of the Portland Cement proposal RIA in Appendix 5A for more information regarding the change in the presentation of co-benefits estimates.

(U.S. EPA, 2009a), which incorporated three updates: a new population dataset, an expanded geographic scope of the benefit-per-ton calculation, and the functions directly from the epidemiology studies without an adjustment for an assumed threshold.³⁷ Removing the threshold assumption is a key difference between the method used in this analysis of PM co-benefits and the methods used in RIAs prior to Portland Cement, and we now calculate incremental co-benefits down to the lowest modeled PM_{2.5} air quality levels.

EPA strives to use the best available science to support our benefits analyses, and we recognize that interpretation of the science regarding air pollution and health is dynamic and evolving. Based on our review of the current body of scientific literature, EPA now estimates PM-related mortality without applying an assumed concentration threshold. EPA's Integrated Science Assessment for Particulate Matter (U.S. EPA, 2009b), which was recently reviewed by EPA's Clean Air Scientific Advisory Committee (U.S. EPA-SAB, 2009a; U.S. EPA-SAB, 2009b), 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. Since then, the Health Effects Subcommittee (U.S. EPA-SAB, 2010) of EPA's Council concluded, "The HES fully supports EPA's decision to use a no-threshold model to estimate mortality reductions. This decision is supported by the data, which are quite consistent in showing effects down to the lowest measured levels. Analyses of cohorts using data from more recent years, during which time PM concentrations have fallen, continue to report strong associations with mortality. Therefore, there is no evidence to support a truncation of the CRF." In conjunction with the underlying scientific literature, this document provided a basis for reconsidering the application of thresholds in PM_{2.5} concentration-response functions used in EPA's RIAs. For a summary of these scientific review statements and the panel members commenting on thresholds since 2002, please consult the Technical Support Document (TSD) Summary of Expert Opinions on the Existence of a Threshold (U.S. EPA, 2010c).

Consistent with this finding, we have conformed the previous threshold sensitivity analysis to the current state of the PM science by incorporating a new "Lowest Measured Level" (LML) assessment. This information allows readers to determine the portion of population exposed to annual mean PM_{2.5} levels at or above the LML of each study; in general, our confidence in the estimated PM mortality decreases as we consider air quality levels further below the LML in major cohort studies that estimate PM-related mortality. While an LML

³⁷ The benefit-per-ton estimates have also been updated since the Cement RIA to incorporate a revised VSL, as discussed on the next page.

assessment provides some insight into the level of uncertainty in the estimated PM mortality benefits, EPA does not view the LML as a threshold and continues to quantify PM-related mortality impacts using a full range of modeled air quality concentrations. It is important to emphasize that we have high confidence in PM_{2.5}-related effects down to the lowest LML of the major cohort studies, which is 5.8 µg/m³. Just because we have greater confidence in the benefits above the LML, this does not mean that we have no confidence that benefits occur below the LML.

For this analysis, policy-specific air quality data is not available due to time or resource limitations. For these rules, we are unable to estimate the percentage of premature mortality associated with this specific rule's emission reductions at each PM_{2.5} level. However, we believe that it is still important to characterize the distribution of exposure to baseline air quality levels. As a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each PM_{2.5} level using the most recent modeling available from the recently proposed Transport Rule (U.S. EPA, 2010e). It is important to note that baseline exposure is only one parameter in the health impact function, along with baseline incidence rates population, and change in air quality. In other words, the percentage of the population exposed to air pollution below the LML is not the same as the percentage of the population experiencing health impacts as a result of a specific emission reduction policy. The most important aspect, which we are unable to quantify for rules without air quality modeling, is the shift in exposure associated with this specific rule. Therefore, caution is warranted when interpreting the LML assessment. For more information on the data and conclusions in the LML assessment for rules without policy-specific air quality modeling, please consult the LML TSD (U.S. EPA, 2010d). The results of this analysis are provided in Section 5.4.

As is the nature of Regulatory Impact Analyses (RIAs), the assumptions and methods used to estimate air quality co-benefits evolve over time to reflect the Agency's most current interpretation of the scientific and economic literature. For a period of time (2004–2008), the Office of Air and Radiation (OAR) valued mortality risk reductions using a value of statistical life (VSL) estimate derived from a limited analysis of some of the available studies. OAR arrived at a VSL using a range of \$1 million to \$10 million (2000\$) consistent with two meta-analyses of the wage-risk literature. The \$1 million value represented the lower end of the interquartile range from the Mrozek and Taylor (2002) meta-analysis of 33 studies. The \$10 million value represented the upper end of the interquartile range from the Viscusi and Aldy (2003) meta-

analysis of 43 studies. The mean estimate of \$5.5 million (2000\$)³⁸ was also consistent with the mean VSL of \$5.4 million estimated in the Kochi et al. (2006) meta-analysis. However, the Agency neither changed its official guidance on the use of VSL in rule-makings nor subjected the interim estimate to a scientific peer-review process through the Science Advisory Board (SAB) or other peer-review group.

During this time, the Agency continued work to update its guidance on valuing mortality risk reductions, including commissioning a report from meta-analytic experts to evaluate methodological questions raised by EPA and the SAB on combining estimates from the various data sources. In addition, the Agency consulted several times with the Science Advisory Board Environmental Economics Advisory Committee (SAB-EEAC) on the issue. With input from the meta-analytic experts, the SAB-EEAC advised the Agency to update its guidance using specific, appropriate meta-analytic techniques to combine estimates from unique data sources and different studies, including those using different methodologies (i.e., wage-risk and stated preference) (U.S. EPA-SAB, 2007).

Until updated guidance is available, the Agency determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the Agency has decided to apply the VSL that was vetted and endorsed by the SAB in the Guidelines for Preparing Economic Analyses (U.S. EPA, 2000)³⁹ while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is \$6.3 million (2000\$).⁴⁰ The Agency is committed to using scientifically sound, appropriately reviewed evidence in valuing mortality risk reductions and has made significant progress in responding to the SAB-EEAC's specific recommendations.

Figure 5-1 illustrates the relative breakdown of the monetized PM_{2.5} health co-benefits by health endpoint.

³⁸ After adjusting the VSL for a different currency year (2007\$) and to account for income growth to 2015 to the \$5.5 million value, the VSL is \$8.0 million.

³⁹ In the (draft) update of the Economic Guidelines (U.S. EPA, 2008b), EPA retained the VSL endorsed by the SAB with the understanding that further updates to the mortality risk valuation guidance would be forthcoming in the near future. Therefore, this report does not represent final agency policy.

⁴⁰ In this analysis, we adjust the VSL to account for a different currency year (2007\$) and to account for income growth to 2015. After applying these adjustments to the \$6.3 million value, the VSL is \$9.1 million.

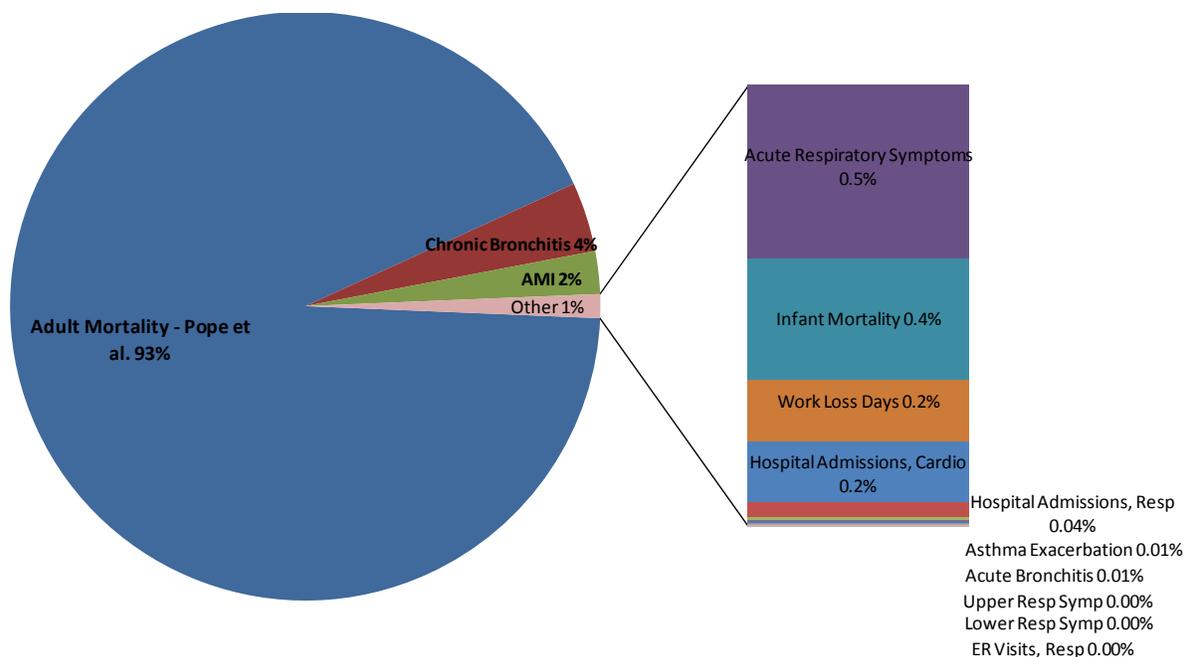


Figure 5-1. Breakdown of Monetized PM_{2.5} Health Co-Benefits using Mortality Function from Pope et al. (2002)^a

^aThis pie chart breakdown is illustrative, using the results based on Pope et al. (2002) as an example. Using the Laden et al. (2006) function for premature mortality, the percentage of total monetized co-benefits due to adult mortality would be 97%. This chart shows the breakdown using a 3% discount rate, and the results would be similar if a 7% discount rate was used.

Table 5-2 provides a general summary of the monetized co-benefits results by pollutant, including the emission reductions and benefits-per-ton estimates at discount rates of 3% and 7%.⁴¹ Table 5-3 provides a summary of the reductions in health incidences anticipated as a result of the pollution reductions. In Table 5-4, we provide the monetized co-benefits using our anchor points of Pope et al. and Laden et al. as well as the results from the expert elicitation on PM mortality. Figure 5-2 provides a visual representation of the range of monetized co-benefits estimates and the pollutant breakdown of the monetized co-benefits of the proposed option. As

⁴¹ To comply with Circular A-4, EPA provides monetized co-benefits using discount rates of 3% and 7% (OMB, 2003). These co-benefits are estimated for a specific analysis year (i.e., 2013), and most of the PM co-benefits occur within that year with two exceptions: acute myocardial infarctions (AMIs) and premature mortality. For AMIs, we assume 5 years of follow-up medical costs and lost wages. For premature mortality, we assume that there is a “cessation” lag between PM exposures and the total realization of changes in health effects. Although the structure of the lag is uncertain, EPA follows the advice of the SAB-HES to assume a segmented lag structure characterized by 30% of mortality reductions in the first year, 50% over years 2 to 5, and 20% over the years 6 to 20 after the reduction in PM_{2.5} (U.S. EPA-SAB, 2004). Changes in the lag assumptions do not change the total number of estimated deaths but rather the timing of those deaths. Therefore, discounting only affects the AMI costs after the analysis year and the valuation of premature mortalities that occur after the analysis year. As such, the monetized co-benefits using a 7% discount rate are only approximately 10% less than the monetized co-benefits using a 3% discount rate.

there are no emission reductions or energy impacts associated with Option 2 (enhanced work practice standards), the benefits in this chapter correspond to Option 1 (non-mercury technology option).

Table 5-2. Summary of Monetized PM_{2.5} Energy Co-benefits for the Proposed Mercury Chlor Alkali NESHAP in 2013 (2007\$) (Option 1)

Pollutant	Emissions Reductions (tons)	Benefit per ton (Pope, 3%)	Benefit per ton (Laden, 3%)	Benefit per ton (Pope, 7%)	Benefit per ton (Laden, 7%)	Monetized PM_{2.5} Co-benefits (millions, 3%)	Monetized PM_{2.5} Co-benefits (millions, 7%)
Direct PM _{2.5}	68	\$220,000	\$540,000	\$200,000	\$490,000	\$15 to \$37	\$14 to \$33

^a All estimates are for the implementation 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 because each ton of precursor reduced has a different propensity to become PM_{2.5}. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

Table 5-3. Summary of Reductions in Health Incidences from PM_{2.5} Co-Benefits for the Proposed Mercury Chlor Alkali NESHAP in 2013 (Option 1)^a

Avoided Premature Mortality	
Pope et al.	2
Laden et al.	5
Avoided Morbidity	
Chronic Bronchitis	1
Acute Myocardial Infarction	3
Hospital Admissions, Respiratory	0
Hospital Admissions, Cardiovascular	1
Emergency Room Visits, Respiratory	2
Acute Bronchitis	3
Work Loss Days	230
Asthma Exacerbation	31
Minor Restricted Activity Days	1,400
Lower Respiratory Symptoms	33
Upper Respiratory Symptoms	25

^a All estimates are for the analysis year (2013) and are rounded to whole numbers with two significant figures. All fine particles are assumed to have equivalent health effects, but each PM_{2.5} precursor pollutant has a different propensity to form PM_{2.5}. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

Table 5-4. All Monetized PM_{2.5} Co-Benefits Estimates for the Proposed Mercury Chlor Alkali NESHAP at discount rates of 3% and 7% in 2013 (in millions of 2007\$) (Option 1)^a

	3%	7%
Benefit-per-ton Coefficients derived from Epidemiology Literature		
Pope et al.	\$15	\$14
Laden et al.	\$37	\$33
Benefit-per-ton Coefficients Derived from Expert Elicitation		
Expert A	\$39	\$35
Expert B	\$30	\$27
Expert C	\$30	\$27
Expert D	\$21	\$19
Expert E	\$48	\$43
Expert F	\$27	\$24
Expert G	\$18	\$16
Expert H	\$22	\$20
Expert I	\$29	\$27
Expert J	\$24	\$22
Expert K	\$6	\$5
Expert L	\$22	\$20

^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 co-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. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

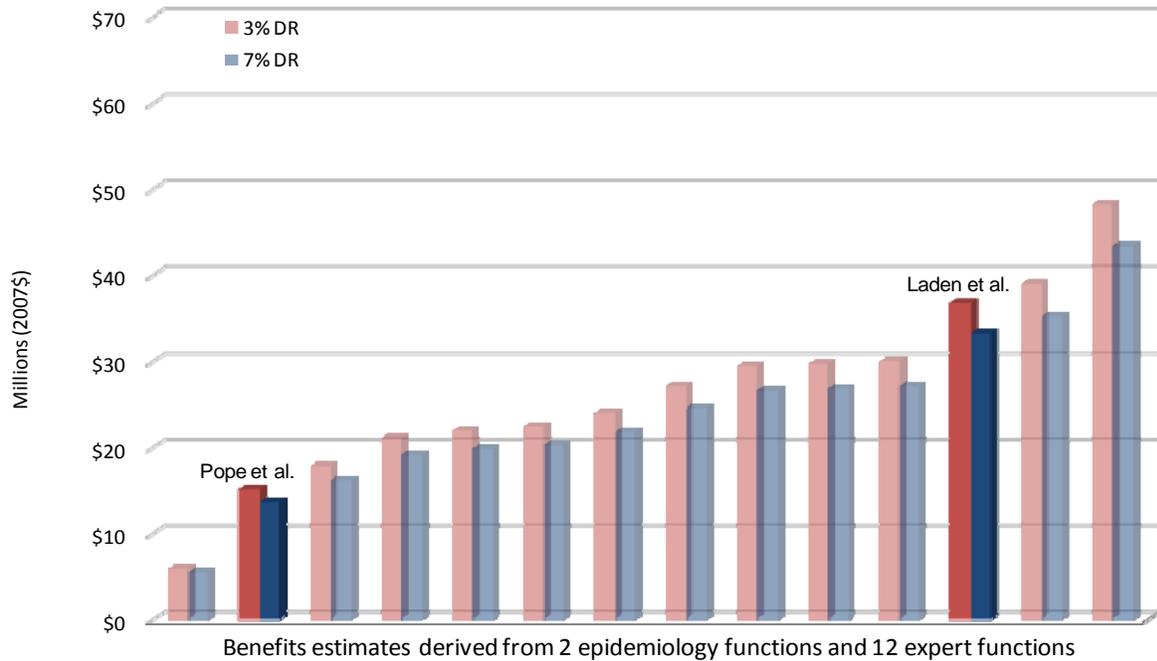


Figure 5-2. Total Monetized PM_{2.5} Co-Benefits for the Proposed Mercury Chlor Alkali NESHAP in 2013 (Option 1)

^aThis graph shows the estimated co-benefits 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.

5.3.2 Social Cost of Carbon and Greenhouse Gas Co-benefits

EPA has assigned a dollar value to reductions in carbon dioxide (CO₂) emissions using recent estimates of the “social cost of carbon” (SCC). The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The SCC estimates used in this analysis were developed through an interagency process that included EPA and other executive branch entities, and concluded in February 2010. EPA first used these SCC estimates in the co-benefits analysis for the final joint EPA/DOT Rulemaking to establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; see the rule’s preamble for discussion about application of

SCC (75 FR 25324; 5/7/10). The SCC Technical Support Document (SCC TSD) provides a complete discussion of the methods used to develop these SCC estimates.⁴²

The interagency group selected four SCC values for use in regulatory analyses, which we have applied in this analysis: \$5, \$21, \$35, and \$65 per metric ton of CO₂ emissions⁴³ in 2010, in 2007 dollars. The first three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent, respectively. SCCs at several discount rates are included because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context. The fourth value is the 95th percentile of the SCC from all three models at a 3 percent discount rate. It is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. Low probability, high impact events are incorporated into all of the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages.

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that the interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual growth rate. This helps to ensure that the estimates are internally consistent with other modeling assumptions. The SCC estimates for the analysis years of 2013, in 2007 dollars are provided in Table 5-5.

⁴² Docket ID EPA-HQ-OAR-2009-0472-114577, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, Interagency Working Group on Social Cost of Carbon, with participation by Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also available at <http://www.epa.gov/otaq/climate/regulations.htm>

⁴³ The interagency group decided that these estimates apply only to CO₂ emissions. Given that warming profiles and impacts other than temperature change (e.g., ocean acidification) vary across GHGs, the group concluded “transforming gases into CO₂-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO₂ gases” (SCC TSD, pg 13).

Table 5-5. Social Cost of Carbon (SCC) Estimates (per tonne of CO₂) for 2013^a

Discount Rate and Statistic	SCC estimate (2007\$)
5% Average	\$5.3
3% Average	\$22.8
2.5% Average	\$37.0
3% 95%ile	\$69.6

^aThe SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC, 2008) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

The interagency group noted a number of limitations to the SCC analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes the interagency modeling exercise even more difficult. The interagency group hopes that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. Additional details on these limitations are discussed in the SCC TSD.

In light of these limitations, the interagency group has committed to updating the current estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, the interagency group has set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area.

Applying the global SCC estimates to the estimated decreases in CO₂ emissions for the range of policy scenarios, we estimate the dollar value of the climate-related co-benefits captured by the models for each analysis year. For internal consistency, the annual co-benefits are discounted back to NPV terms using the same discount rate as each SCC estimate (i.e., 5%, 3%, and 2.5%) rather than 3% and 7%.⁴⁴ These estimates are provided in Table 5-6.

Table 5-6. Monetized Co-benefits of CO₂ Emission Decreases in 2013 (Option 1)^a

Discount Rate and Statistic	SCC-derived benefits (millions of 2007\$)
5% Average	\$1.5
3% Average	\$6.5
2.5% Average	\$11
3% 95%ile	\$20

^aThe SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

5.3.3 Total Monetized Co-benefits of Energy Savings

The energy savings would decrease emissions of several pollutants. In this analysis, we were able to monetize the co-benefits associated with the decreased emissions of PM and CO₂, but we were unable to monetize the co-benefits associated with the decreased emissions of mercury. We estimate that the total monetized co-benefits are \$22 to \$43 million and \$14 to \$33 million, at discount rates of 3% and 7% respectively. Figure 5-3 shows the breakdown of the monetized co-benefits by pollutant.

5.4 Characterization of Uncertainty in the Monetized PM_{2.5} Co-Benefits

In any complex analysis, there are likely to be many sources of uncertainty. Many inputs are used to derive the estimate of monetized co-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). 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. Because we used the benefit-per-ton approach for this analysis, confidence intervals are unavailable.

⁴⁴ It is possible that other co-benefits or costs of proposed regulations unrelated to CO₂ emissions will be discounted at rates that differ from those used to develop the SCC estimates.

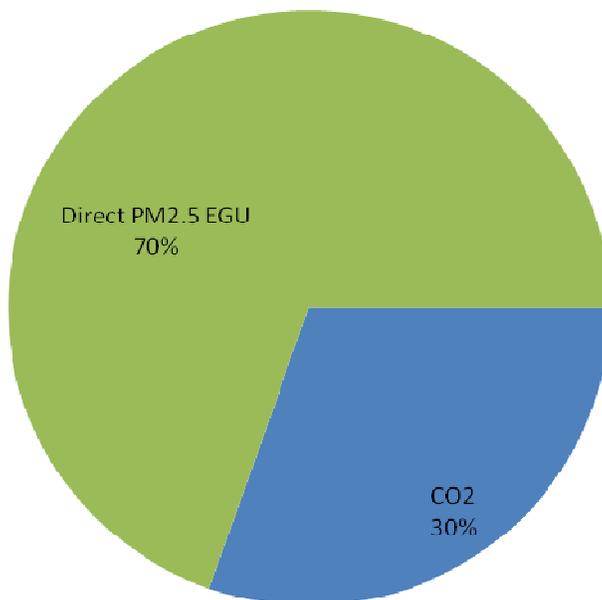


Figure 5-3. Breakdown of Monetized Co-benefits by Pollutant at 3% discount rate (Option 1)

There are uncertainties associated with each analytical step to calculate the human health benefits associated with reducing electricity consumption. Important uncertainties associated with estimating the reduction in electricity consumption include variability across facilities and variability in local energy costs.⁴⁵ Important uncertainties associated with estimating the emission reductions associated with a specific electricity consumption reduction include representativeness of historical emissions factors across regions and over time, transmission losses, electricity market response to changes in demand, and emissions trading effects.⁴⁶ Important uncertainties associated with estimating the human health benefits associated with those emission reductions include assumptions regarding the PM_{2.5}-related mortality relationship, the value-of-a-statistical-life, and average benefit-per-ton estimates.⁴⁷ It should be noted that the method used to the change in PM_{2.5} precursor emissions for this rule is consistent with the method used to calculated changes in CO₂ emissions. Given the strong desire to estimate the effects of regulations on greenhouse gas (GHG) emissions, we will continue to investigate and improve the methodology for estimating all benefits categories associated with reducing electricity consumption, to the extent feasible.

⁴⁵ These uncertainties are described in detail in Appendix B of this RIA.

⁴⁶ These uncertainties are described in detail in Appendix B of this RIA.

⁴⁷ These uncertainties are described in detail below.

Although this is the first RIA for which U.S. EPA's Office of Air and Radiation has calculated the monetized human health benefits specifically associated with a reduction in electricity consumption, there are several previous regulations that included the health benefits associated with energy changes. For example, the recently finalized Portland Cement NESHAP included the human health and climate disbenefits associated with increased electricity consumption and fuel usage from control devices (U.S. EPA, 2010i). U.S. EPA has previously calculated substantial human health benefits associated with reducing emissions from electrical generating units, including the proposed Federal Transport Rule (2010d), the SO₂ NAAQS (2010g), and the Clean Air Interstate Rule (2005). In addition, several recent regulations from U.S. EPA's Office of Transportation and Air Quality assessed the air quality changes and associated human health impacts from changes in fuel consumption and/or fuel production and distribution, including the Light Duty Vehicle GHG rule (U.S. EPA, 2010f),⁴⁸ Renewable Fuel Standard II rule (U.S. EPA, 2010e),⁴⁹ and the Locomotive Marine rule (U.S. EPA, 2008a).⁵⁰ Furthermore, the Iron and Steel Foundries NESHAP (U.S. EPA, 2003) included an estimate of the emission reductions associated with decreased energy consumption for alternate control devices, but no benefits analysis was conducted for that rule.

In addition to RIAs, other recent attempts to calculate the human health benefits associated with electricity consumption are available in the literature. For example, Levy et al. (2009) estimated the median monetized health-related damages associated with emissions of PM_{2.5}, SO₂, and NO_x from coal-fired power plants. In addition, the National Research Council (NRC) estimated the monetized health benefits associated emissions of PM, SO₂, and NO_x to be for coal and natural gas power plants. It is important to note that there are important methodological differences between these two analyses and EPA's approach to estimating PM-

⁴⁸ In addition to downstream emission reductions, the Light Duty Vehicle GHG rule accounted for the emissions associated with the processes involved in getting petroleum to the pump, including the extraction and transportation of crude oil, and the production and distribution of finished gasoline. Changes were anticipated in upstream emissions due to the expected reduction in the volume of fuel consumed. Less gasoline consumed means less gasoline transported, less gasoline refined, and less crude oil extracted and transported to refineries. Thus, the analysis accounted for reductions in the emissions associated with each of these steps in the gasoline production and distribution process.

⁴⁹ In addition to the effects of increased renewable fuel use on emissions from the vehicles and equipment that use the fuels, the RFS2 analysis accounted for shifts in the fuel production and transport/distribution methods that can have substantial impacts on emissions. These "upstream" emissions are associated with all stages of biofuel production and distribution, including biomass production (agriculture, forestry), fertilizer and pesticide production and transport, biomass transport, biomass refining (corn or cellulosic ethanol production facilities), biofuel transport to blending/distribution terminals, and distribution of finished fuels to retail outlets.

⁵⁰ The locomotive and marine engine rule accounted for idle reduction technologies that provide substantial emission reductions as well as cost savings by reducing fuel consumption. Reduced idling time results in reduced fuel consumption and reduced idle emissions. The analysis estimated annual fuel savings, the associated cost savings, and the emissions reductions that would result from the idle reduction requirements.

related monetized benefits, including characterization of secondary formation of PM_{2.5}, population growth, income growth, the VSL, the cessation lag assumed, among others. However, these studies provide additional examples of conceptually similar attempts to monetize the human health benefits associated with electricity consumption.

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) (U.S. EPA, 2006a), there are a variety of uncertainties associated with these PM co-benefits. Therefore, the estimates of annual co-benefits should be viewed as representative of the magnitude of co-benefits expected, rather than the actual co-benefits that would occur every year.

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 co-benefits modeling assumptions. For example, these estimates do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors. Use of these \$/ton values to estimate co-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 co-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 co-benefits-per-ton over the entire United States. The co-benefits-per-ton for emission reductions in specific locations may be very different than the estimates presented here.

PM_{2.5} mortality co-benefits are the largest benefit category that we monetized in this analysis. To better characterize the uncertainty associated with mortality impacts that are estimated to occur in areas with low baseline levels of PM_{2.5}, we included the LML assessment. Without policy-specific air quality modeling, we are unable to quantify the shift in exposure associated with this specific rule. For this rule, as a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each PM_{2.5} level using the most recent modeling available from the recently proposed Transport Rule (U.S. EPA, 2010e). A very large proportion of the population is exposed at or above the lowest LML of the cohort studies (Figures 5-4 and 5-5), increasing our confidence in the PM mortality analysis. Figure 5-4 shows a bar chart of the percentage of the population exposed to various air quality levels in the pre- and post-policy policy. Figure 5-5 shows a cumulative distribution function of the same data.

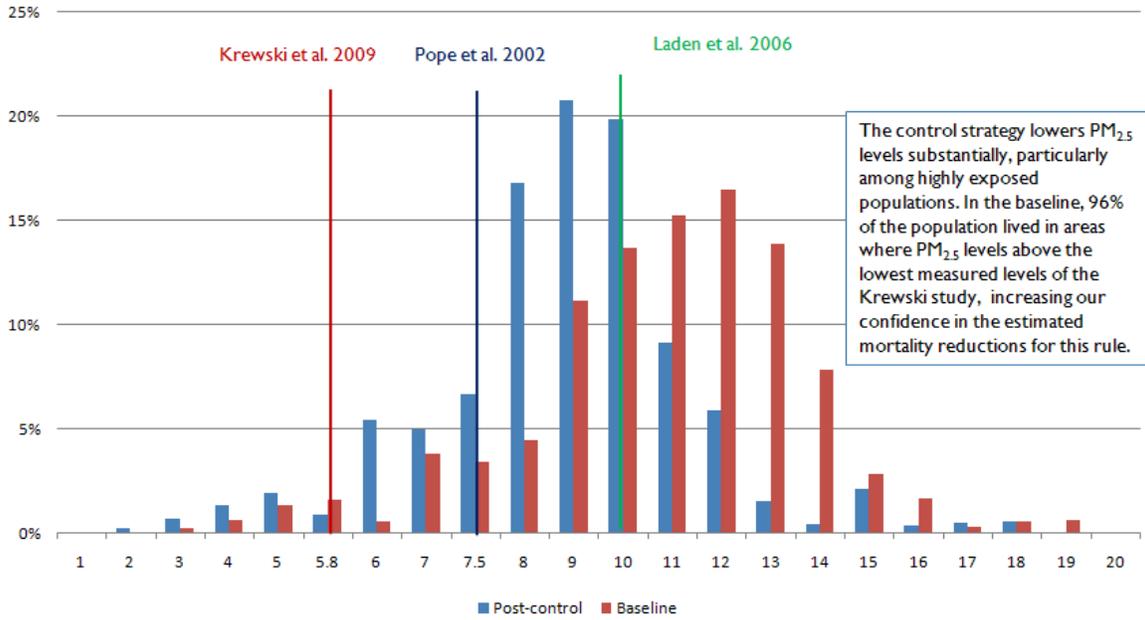


Figure 5-4. Percentage of Adult Population by Annual Mean PM_{2.5} Exposure (pre- and post-policy policy)

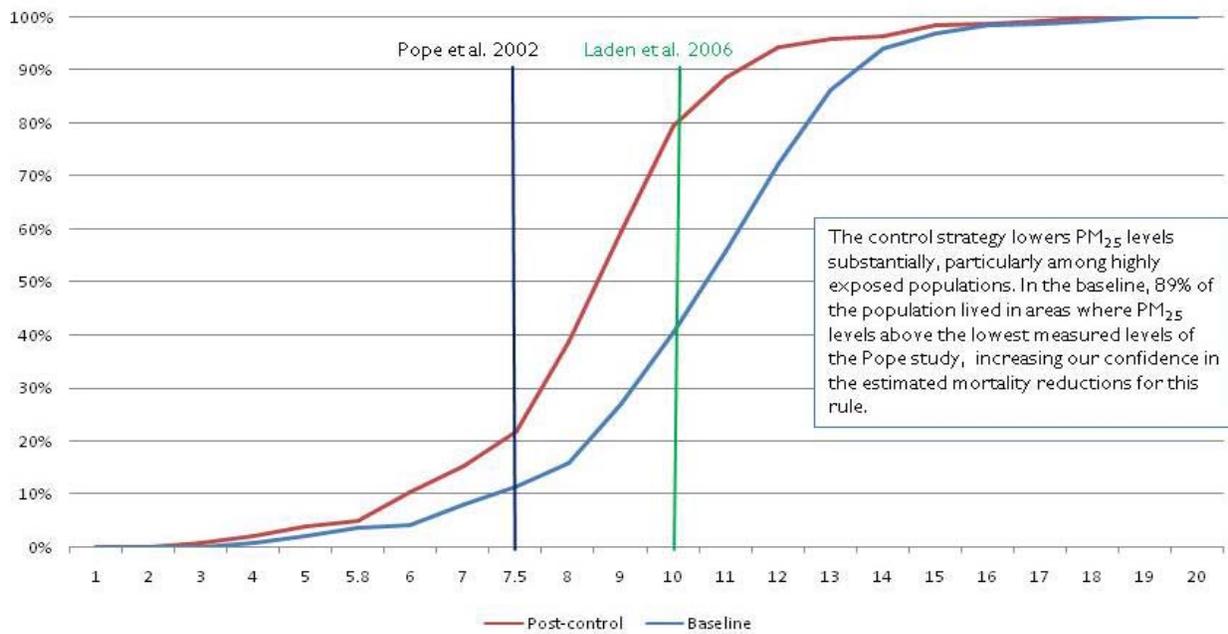


Figure 5-5. Cumulative Distribution of Adult Population at Annual Mean PM_{2.5} levels (pre- and post-policy policy)

Both figures identify the LML for each of the major cohort studies. As the policy shifts the distribution of air quality levels, fewer people are exposed to PM_{2.5} levels at or above the LML. Using the Pope et al. (2002) study, the 85% of the population is exposed to annual mean PM_{2.5} levels at or above the LML of 7.5 µg/m³. Using the Laden et al. (2006) study, 40% of the population is exposed above the LML of 10 µg/m³. As we model mortality impacts among populations exposed to levels of PM_{2.5} that are successively lower than the LML of the lowest cohort study, our confidence in the results diminishes. However, the analysis above confirms that the great majority of the impacts occur at or above the lowest cohort study's LML. It is important to emphasize that we have high confidence in PM_{2.5}-related effects down to the lowest LML of the major cohort studies. Just because we have greater confidence in the benefits above the LML, this does not mean that we have no confidence that benefits occur below the LML.

Above we present the estimates of the total monetized co-benefits, based on our interpretation of the best available scientific literature and methods and supported by the SAB-HES and the NAS (NRC, 2002). The co-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 monetized co-benefits, we were able to quantify include the following:

1. PM_{2.5} co-benefits were derived through benefit per-ton estimates, which 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 co-benefits of controlling directly emitted fine particulates.
2. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because PM_{2.5} produced via transported precursors emitted from EGUs may differ significantly from direct PM_{2.5} released from diesel engines and other industrial sources, but no clear scientific grounds exist for supporting differential effects estimates by particle type.
3. We assume that the health impact function for fine particles is linear down to the lowest air quality levels modeled in this analysis. Thus, the estimates include health co-benefits from reducing fine particles in areas with varied concentrations of PM_{2.5}, including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.
4. To characterize the uncertainty in the relationship between PM_{2.5} and premature mortality (which typically accounts for 85% to 95% of total monetized co-benefits), we include a set of twelve estimates based on results of the expert elicitation study in addition to our core estimates. Even these multiple characterizations omit the uncertainty in air quality estimates, baseline incidence rates, populations exposed and

transferability of the effect estimate to diverse locations. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the PM_{2.5} estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis. For more information on the uncertainties associated with PM_{2.5} co-benefits, please consult the PM_{2.5} NAAQS RIA (Table 5-5).

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 co-benefits model. Moreover, it was not possible to develop benefit-per-ton metrics and associated estimates of uncertainty using the co-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 co-benefits presented in Chapter 5 of the PM NAAQS RIA can provide some evidence of the uncertainty surrounding the co-benefits results presented in this analysis.

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SECTION 6

COMPARISON OF CO-BENEFITS AND COSTS

Using a 3% discount rate, we estimate the total monetized co-benefits of Option 1 of the Mercury Chlor Alkali NESHAP to be \$22 million to \$43 million in the implementation year (2013). Using a 7% discount rate, we estimate the total monetized co-benefits of this option to be \$21 million to \$40 million. The annualized social costs of this option HAP are \$13 million at a 7% interest rate.⁵¹ Thus, the net benefits of this option are \$9 million to \$30 million at a 3% discount rate and \$8 million to \$27 million at a 7% discount rate. All estimates are in 2007\$ for the year 2013.

Option 2 does not have emission reductions, thus no monetized benefits. The annualized social costs of this option HAP are \$25,000 at a 7% interest rate. Thus, the net benefits of this option are \$-25,000.

Table 6-1 shows a summary of the monetized co-benefits, social costs, and net benefits for the proposed Mercury Chlor Alkali NESHAP, respectively. Figures 6-1 and 6-2 show the full range of net benefits estimates (i.e., annual co-benefits minus annualized costs) utilizing the 14 different PM_{2.5} mortality functions at discount rates of 3% and 7%. It is important to emphasize that these monetized co-benefits do not include the benefits associated with reducing mercury emissions. EPA believes that the co-benefits are likely to exceed the costs under this rulemaking even when taking into account uncertainties in the cost and benefit estimates.

⁵¹ For more information on the annualized social costs, please refer to Section 3 of this RIA.

Table 6-1. Summary of the Monetized Co-Benefits, Social Costs, and Net benefits for the Proposed Mercury Chlor Alkali NESHAP in 2013 (thousands of 2007\$)^a

	3% Discount Rate		7% Discount Rate	
Option 1: Non-mercury Technology Option				
Total Monetized Benefits ^b	\$22,000	to	\$43,000	\$21,000 to \$40,000
Total Social Costs ^c			\$13,000	\$13,000
Net Benefits	\$9,000	to	\$30,000	8,000 to \$27,000
Non-monetized Benefits	656 pounds of mercury (including energy co-benefits)			
	Health effects from NO ₂ and SO ₂ exposure			
	Ecosystem effects			
	Visibility impairment			
Option 2: Enhanced Work Practice Standards				
Total Monetized Benefits ^b	\$0		\$0	
Total Social Costs ^c	\$25		\$25	
Net Benefits	-\$25		-\$25	

^a All estimates are for the implementation year (2013), and are rounded to two significant figures.

^b The total monetized co-benefits reflect the human health co-benefits associated with reducing exposure to PM_{2.5}. It is important to note that the monetized co-benefits include many but not all health effects associated with PM_{2.5} exposure. It is important to note that the monetized benefits include many but not all health effects associated with PM_{2.5} exposure. Benefits are shown as a range from Pope et al. (2002) to Laden et al. (2006). These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because there is no clear scientific evidence that would support the development of differential effects estimates by particle type. CO₂-related benefits were calculated using the social cost of carbon (SCC). The net present value of reduced CO₂ emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SCC at 5, 3, 2.5 percent) is used to calculate net present value of SCC for internal consistency. This table shows monetized CO₂ co-benefits at discount rates of 3 and 7 percent that were calculated using the global average SCC estimate at a 3% discount rate because the interagency workgroup on this topic deemed this marginal value to be the central value. In Section 5, we also provide the monetized CO₂ co-benefits using discount rates of 5 percent (average), 2.5 percent (average), and 3 percent (95th percentile).

^c The annual compliance costs serve as a proxy for the annual social costs of this rule given the lack of difference between the two.

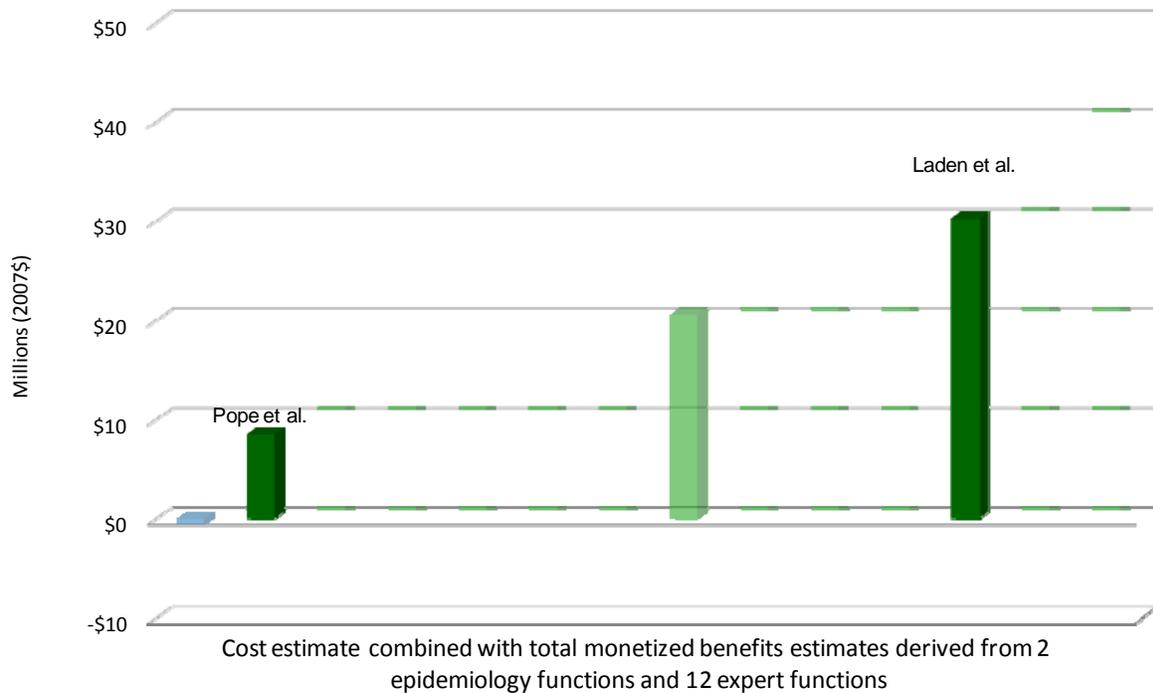


Figure 6-1. Net Benefits for the Proposed Mercury Chlor Alkali NESHAP at 3% Discount Rate (Option 1)^a

^a Net Benefits are quantified in terms of PM_{2.5} co-benefits for implementation year (2013). This graph shows 14 benefits estimates combined with the cost estimate. All combinations are treated as independent and equally probable. 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}. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles. The net benefits at a 3% discount rate also include CO₂-related benefits calculated using the social cost of carbon.

Net Benefits for Mercury Chlor Alkali in 2013 at 7% discount rate*

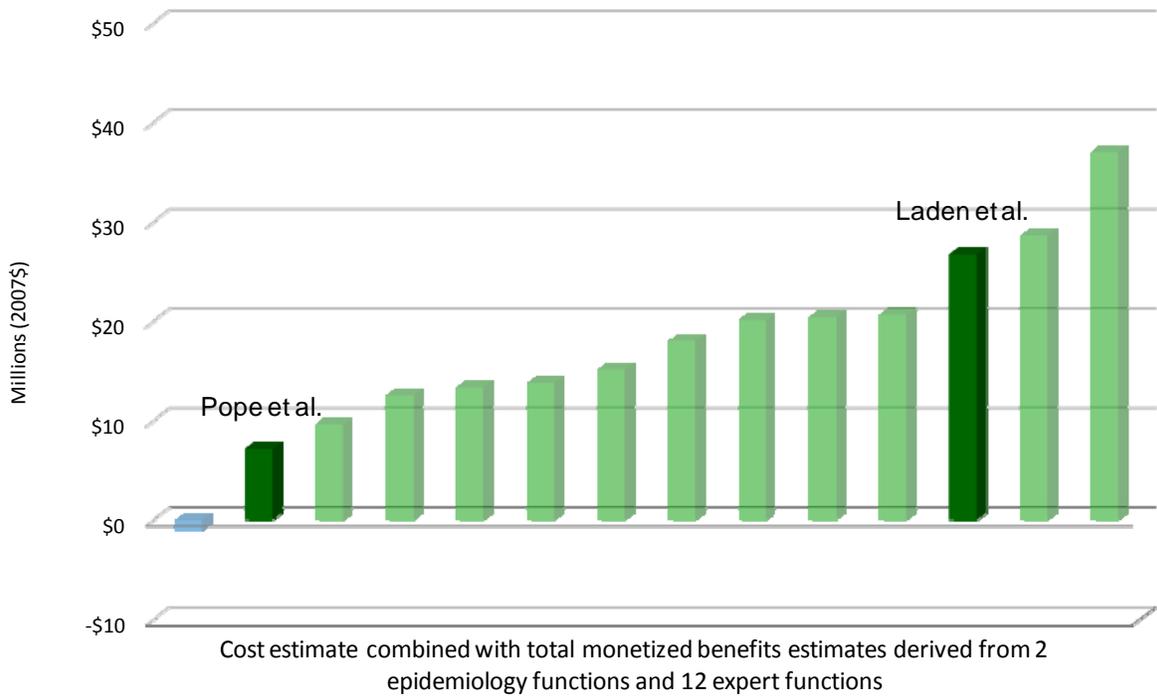


Figure 6-2. Net Benefits for the Proposed Mercury Chlor Alkali NESHAP at 7% Discount Rate (Option 1)^a

^a Net benefits are quantified in terms of PM_{2.5} co-benefits for implementation year (2013). This graph shows 14 co-benefits estimates combined with the cost estimate. All combinations are treated as independent and equally probable. 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}. The monetized co-benefits incorporate the conversion from precursor emissions to ambient fine particles. This table shows monetized CO₂ co-benefits at discount rates of 3 and 7 percent that were calculated using the global average SCC estimate at a 3% discount rate because the interagency workgroup on this topic deemed this marginal value to be the central value.

**APPENDIX A:
MERCURY EMISSIONS MEMO**

MEMORANDUM

TO: Donna Lee Jones, PhD, USEPA/OAQPS/SPPD/MMG

FROM: Phil Norwood, EC/R Incorporated

DATE: March 15, 2010

SUBJECT: Mercury Emission Reductions and Other Mercury Waste Impacts—Conversion from Mercury Cell Chlor-Alkali to Membrane Cell Chlor Alkali Technology

The purpose of this memorandum is present the mercury air emission and other mercury waste impacts that would result from the conversion of the four mercury cell chlor-alkali plants currently operating in the U.S. to non-mercury (membrane cell) technology. These plants are ASHTA Chemicals in Ashtabula, Ohio (ASHTA), Olin Corporation in Augusta, Georgia (OLIN-GA), Olin Corporation in Charleston, Tennessee (OLIN-TN), and PPG in New Martinsville, West Virginia (PPG). The first two sections address the baseline mercury air emissions and mercury releases to other media. In the event of conversion, these routine releases would be eliminated. This is followed by a discussion of the mercury releases and mercury-contaminated wastes that would be generated during the cleanup and decommissioning of the mercury cell plants. The final section summarizes these air and other media impacts.

BASELINE MERCURY AIR EMISSIONS

Table 1 shows the mercury air releases reported in EPA's Toxics Release Inventory (TRI) for 2007 and 2008 for each of the currently operating mercury cell chlor-alkali plants. In addition to the TRI information available online, the companies operating these four facilities provided emission estimates (which matched the totals in Table 1 reported to TRI) in correspondence in the summer of 2009.^{52,53,54} Later in 2009, EPA requested documentation of these emission estimates using their authority under section 114 of the Clean Air Act. In

⁵² Letter. Jackson, R.L., ASHTA Chemicals Inc., to Jones, D.L., U.S. Environmental Protection Agency. RE: Docket No. EPA-HQ-OAR-2002-0017—National Emission Standards for Hazardous Air Pollutants: Mercury Emissions from Mercury Cell Chlor-Alkali Plants—ASHTA Chemicals Inc. Comments and Rebuttal on Recent EC/R Study. June 30, 2009.

⁵³ Letter. Hall, R.K., Olin Chlor Alkali Products, to Jones, D.L., U.S. Environmental Protection Agency. June 25, 2009.

⁵⁴ Letter. Smith, T.P., PPG Industries, Inc., to Jones, D.L., U.S. Environmental Protection Agency. Re: Docket No. EPA-HQ-OAR-2002-0017—National Emission Standards for Hazardous Air Pollutants: Mercury Emissions from Mercury Cell Chlor-Alkali Plants—Memo: "Updated Cost Impacts Associated with the Conversion from Chlorine Production Utilizing Mercury Cell Chlor-Alkali Technology to Membrane Cell Technology," from Heather P. Brown, P.E. (EC/R Inc.) to Donna Lee Jones, PhD (USEPA), dated June 5, 2009." July 13, 2009.

February of 2010, this documentation was submitted to the EPA.^{55,56,57} This information, which is available in Docket EPA-HQ-OAR-2002-0017, was carefully reviewed. More discussion on the conclusions of this review is provided below.

Table 1. Mercury Air Releases Reported in TRI for 2007 and 2008

Plant	TRI Mercury Air Releases (pounds/yr)					
	2007			2008		
	Fugitive	Stack	Total	Fugitive	Stack	Total
ASHTA	0.0	0.0	0.0	0.0	0.2	0.2
OLIN-GA	119	5	124	77	9	86
OLIN-TN	353	67	420	241	43	285
PPG	145	55	200	149	58	207

Summary of Reported Facility Emissions and Supporting Information

ASHTA

As shown in Table 1, ASHTA reported no mercury releases to the air in 2007 and 0.2 pounds in 2008. In the June 30, 2009 correspondence, ASHTA submitted emission estimates for 2007 and 2008. The estimates for 2008 were consistent with those in the 2008 TRI. For 2007, ASHTA reported 0.12 pounds of point source emissions. Consistent with the TRI, they reported “0 (Trace) lbs./yr” fugitive emissions for both 2007 and 2008.

The EPA section 114 requested documentation for the point source emissions reported in the June 30, 2009 correspondence. It also questioned the report that the fugitive emissions are zero and requested that ASHTA provide a “precise, substantiated, fugitive emissions estimate.”

In their February 15, 2010 response ASHTA provided details of the calculation of the point source (i.e., stack) emissions. ASHTA conducted emissions tests on their hydrogen and cell end box air emission streams in March 2006, and they provided a copy of the report for this

⁵⁵ Letter. Jackson, R.L., ASHTA Chemicals Inc., to Jones, D.L., U.S. Environmental Protection Agency. RE: Docket Response to USEPA Questions. February 15, 2010.

⁵⁶ Letter. Hall, R.K., Olin Chlor Alkali Products, to Jones, D.L., U.S. Environmental Protection Agency. Re: Information requested pursuant to section 114 of the Clean Air Act. February 2, 2010.

⁵⁷ Letter. Smith, T.P., PPG Industries, Inc., to Jones, D.L., U.S. Environmental Protection Agency. Re: Response to Request for Information under Section 114 of the Clean Air Act, 42 U.S.C. § 7414, dated December 4, 2009, with regards to the Mercury Cell Chlor-Alkali MACT and background data to support the estimates provided to USEPA by PPG in a letter dated July 13, 2009.” February 18, 2010.

testing. ASHTA using the periodic testing alternative to demonstrate compliance with the emission limitation for by-product hydrogen streams and end-box ventilation systems, which means that they perform tests three times per week. They use alternative methods for this testing which have been approved by EPA. Results for each of the tests conducted in 2007 and 2008 were provided, along with the 52-week rolling average calculations.

The calculations show point source mercury emissions of 0.09 pounds in 2007 and 0.11 pounds in 2008. These estimates are lower than previously reported because the earlier estimates included emissions from a noncontact cooling tower and not from the mercury cell process.

ASHTA did not provide any fugitive emission estimates in response to EPA's request. They indicated that, since EPA does not have an approved method for estimating fugitive mercury emissions from a mercury cell chlor-alkali plant, they cannot provide emission estimates. ASHTA indicated that the zero emissions levels reported were determined from the annual mercury balance, the low floor level mercury levels, and the operation of mercury control systems. They said that they are "confident that the fugitive emissions collection system installed on the cell room removes large amounts of off-process mercury emissions" but they are "unable to provide the level of conclusion with any direct measurements." The EPA estimate of these emissions is discussed at the end of this section.

OLIN

The mercury emission estimates provided in Olin's June 25, 2009 correspondence for 2007 and 2008 were consistent with those reported in the TRI for both their Augusta, Georgia, and Charleson, Tennessee facilities. In their February 2, 2010 correspondence, they provided documentation for these estimates.

At both facilities, Olin utilizes continuous mercury emission monitoring systems. These units were produced by Mercury Instruments GmbH Analytical Technologies of Germany, and are equipped with factory supplied calibration gas generators. Zero calibrations are performed every hour the units are in operation as well as span checks at least once per day. These units measure and record the mercury concentrations for both the point sources and throughout the cell rooms. Stack velocity/flow rates are monitored for the point sources, and cell room flow rates are estimates using engineering equations.

For the point sources, Olin provided daily emission results for each point source, along with detailed ten-minute readings for representative days to illustrate how the daily emissions

were determined. For the fugitive emissions, Olin provided daily measured concentrations, estimated flow rates, and emissions. They also provided detailed calculation sheets illustrating how the emissions were calculated.

PPG

In their July 13, 2009 correspondence, PPG indicated that the mercury stack air releases in the TRI include 50 pounds/yr from coal-fired boilers at the site. Therefore, they indicated that the 2007 stack emissions from the mercury cell chlor-alkali plant should be 5 pounds for 2007 and 8 pounds for 2008. The fugitive emission estimates reported in this correspondence were consistent with those reported to TRI for 2007 (145 pounds) and 2008 (149 pounds). Therefore, PPG's mercury emissions from mercury cell operations total 150 pounds in 2007 and 157 pounds in 2008.

For their three point sources (Hydrogen De-gas inlet box ventilation system, Chlorine De-gas end box ventilation system, and Hydrogen Purification system), PPG operates continuous mercury emission monitors to measure the mercury concentration and flow meters to monitor the flow rate. In their February 28, 2010 correspondence PPG provided daily average measured concentrations, flow rates, and emission rates for 2007 and 2008. They also provided equations illustrating the calculations performed.

PPG also utilizes a continuous mercury monitoring system to measure mercury concentration throughout the cell room, and estimates the flow rate from the building based on the number of roof exhaust fans operating. They provided average cell room concentrations, flow rates, and emission rates for each day in 2007 and 2008. They also provided equations illustrating the calculations performed.

PPG has entered into an agreement with the Attorney General of Maryland regarding their West Virginia facility. As part of this agreement, PPG will limit mercury emissions to no more than 150 pounds/yr in 2011 and 2012, and no more than 145 pounds/yr in 2013 and beyond. Therefore, in 2011 and 2012 there will be around a 2 percent decrease from the average 2007/2008 levels and around a 6 percent decrease in 2013 and beyond.

Estimating Fugitive Emissions for ASHTA

Because ASHTA did not provide data documenting and substantiating their claim of zero fugitive emission estimates, we estimated their fugitive emissions since it is not reasonable to assume there are no emissions. The approach we used was to develop a fugitive emissions factor

based on the amount of mercury contained in their cells. Since a previous analysis found little correlation between chlorine production and fugitive mercury emissions,⁵⁸ this other approach was not considered viable.

We developed the emissions factor for fugitive mercury emissions based on the estimated amount of mercury in the cells for the other three facilities and used this factor to estimate ASHTA’s fugitive mercury emissions. These data are shown in Table 2. The data used to calculate the average factor, at approximately 0.5 pounds of fugitive mercury emissions per year per ton of mercury in the cells, shows reasonable agreement between the factors developed for the three other mercury cell facilities.

At ASHTA, there are 24 mercury cells.⁵⁹ Multiplying this number of cells by the average factor shown in Table 2 results in an estimated fugitive mercury emission estimate of 62 pounds per year for ASHTA. For purposes of estimating the emissions for the whole industry, this value was used for both the 2007 and 2008 in this analysis.

Table 2. Development of Fugitive Mercury Emissions Factor Based on Mercury in Cells

Plant	Number of Cells ^a	Mercury in Cells ^b (tons)	Fugitive Mercury Emissions (lb/yr)			Fugitive Emissions-to-Cell Mercury Factor (lb/yr emissions per ton mercury in cells)
			2007	2008	Avg	
OLIN—GA	60	298	124	86	105	0.33576
OLIN—TN	106	527	420	284	352	0.63712
PPG—WV	54	268	145	149	147	0.52229
Average						0.49839

^a From 1997 Directory of Chemical Producers (Reference ⁶⁰).

^b Using a factor of 5.2 tons of mercury per cell, which is the amount of mercury in the Chlorine Institute’s 2008 process inventory (1,376 tons) divided by the number of operating cells in 2008 (264) (Reference ⁶¹).

⁵⁸ U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. “Summary of 2005 Cell Room Mercury Emissions Data for Occidental Chemical Company Mercury Cell Chlor-Alkali Plants: Delaware City, Delaware and Muscle Shoals, Alabama.” March 2008.

⁵⁹ Reference 8.

⁶⁰ 1997 Directory of Chemical Producers—United States of America. Stanford Research Institute International. Menlo Park, CA. 1997.

⁶¹ The Chlorine Institute, Inc. “Chlor-Alkali Industry 2008. Mercury Use and Emissions in the United States (Twelfth Annual Report).” August 2009.

Summary of Baseline Air Emissions

Table 3 summarizes the mercury emissions from the four currently operating mercury cell chlor-alkali plants for 2007 and 2008.

Table 3. Baseline Mercury Emission Levels

Plant	Mercury Emissions (pounds per year)								
	2007			2008			Average 2007–2008		
	Point	Fugitive	Total	Point	Fugitive	Total	Point	Fugitive	Total
ASHTA	0.09	62	62	0.11	62	62	0.10	62	62
OLIN—GA	5	124	129	9	86	95	7	105	112
OLIN—TN	67	420	487	43	284	327	55	352	407
PPG	5	145	150*	8	149	157*	7	147	154
Total	77	751	828	60	581	641	69	666	735

Note: PPG’s emissions is limited by a court settlement to 150 pounds per year in 2001 and 2012, and 145 pounds per year in 2013 and thereafter.

BASELINE NONAIR MERCURY RELEASES

Table 4 shows the nonair mercury releases reported to the TRI for 2007 and 2008. These releases include the total amount of mercury released to water or land on or at a facility’s site and the amount that is transferred from a facility site to another site and then released to the environment via water or land. Attachment 1 includes a detailed analysis of TRI mercury release data for these four facilities.

Table 4. Total Nonair Mercury Releases Reported in the TRI

Plant	Total Nonair Mercury Releases (pounds/year)		
	2007	2008	Average
ASHTA	202	179	190
OLIN -GA	82	105	93
OLIN -TN	414	197	306
PPG	1,408	751	1,080
Total	2,106	1,232	1,669

WASTE GENERATION FROM CLEANUP/DECOMMISSIONING

In addition to the elimination of the routine mercury releases discussed above, there would be one-time environmental impacts associated with the clean-up and decommissioning of the mercury cell chlor-alkali plants. The discussion and quantification of these impacts are discussed below.

When cell rooms are closed and decommissioned, there will be some loss of mercury to the environment. The extent of the loss will be influenced by cell room design and geographic location. However, once the cells are shut down, the cell room temperature will decrease, and the evaporation rate of any exposed mercury is reduced.⁶² Therefore, we estimated that there would not be measured mercury air emissions during cleanup/decommissioning.

There is little quantitative information available to estimate the amount of mercury-containing waste that would need to be disposed of during cleanup/decommissioning. When the Borregaard mercury cell chlor-alkali plant in Norway was decommissioned, a large number of samples were taken to determine the quantity of mercury-contaminated wastes. The total quantity of contaminated waste material was estimated at 1,750 cubic meters, of which around 55 percent was contaminated process equipment such as steel and rubber-lined steel.⁶³ Assuming this level of waste is representative, this would mean approximately 7,000 cubic meters of waste could be generated during the conversion/closure of the four currently operation U.S. plants.

However, information available for the Borregaard plant provided no estimate of the mass amount of mercury in the wastes. In order to obtain an estimate of the potential mass, the release information in the TRI was examined for closed or converted facilities. There are six former mercury chlor-alkali plants in the TRI that have at least five years worth of release data to analyze. For each of these facilities, the average air releases during the years prior to the last year for which release data were reported in the TRI was compared to the air releases in the last year. If those air releases in the last year were less than 50 percent of the average air releases for the previous years for which TRI releases were reported, it was assumed that the mercury cell plant had ceased operations during that year and was in the process of cleanup/decommissioning. For those situations, the ratio of the offsite transfers during that year was calculated to represent an estimate of the amount that offsite transfers could increase during cleanup/decommissioning. This information is summarized in Table 5.

⁶² European Commission. *Integrated Pollution Prevention and Control (IPPC). Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing Industry*. December 2001. p. 96

⁶³ Reference 11, pp. 93, 97.

**Table 5. Summary of TRI Information Used to Estimate Mercury
Cleanup/Decommissioning Wastes**

Plant	Last Yr	Air Mercury Releases (pounds/yr)			Offsite Mercury Transfers (pounds/yr)		
		Avg ^a	Last Yr	Last Year ÷ Avg	Avg ^a	Last Yr	Last Year ÷ Avg
Westlake Calvert City, KY	2002	983	6	1%	10,108	27,777	275%
Occidental Muscle Shoals, AL	2008	667	322	48%	4,405	12,806	291%
Occidental New Castle, DE	2008	649	0.4	0%	3,166	16,520	522%
Holtrachem Orrington, ME	1999	660	116	18%	2,103	1,612	77%
Holtrachem Reigelwood, NC	1999	1,176	328	28%	171	176	103%
PPG Westlake, LA	2005	997	1,211	121%	b	b	b
Average							253%

^a Avg = average of all years for which data were reported except for the last year.

^b Since the air releases in the last reporting year were greater than 50 percent of the average for the previous years, it was assumed that the plant was operating during this year and the offsite transfers did not represent cleanup/decommissioning activities.

In order to estimate the mercury contaminated wastes that would be generated during cleanup/decommissioning and transferred offsite for the four currently operating mercury cell chlor-alkali plants, the average level of nonair releases for reported for all years of operation are multiplied by 253 percent. These estimates are shown in Table 6.

Therefore, it is estimated that the closure/conversion of the four currently operating mercury cell chlor-alkali plants in the U.S. could result in the generation of around 7,000 cubic meters of hazardous wastes containing over 6 tons of mercury. Given the unique aspects of each mercury cell plants, the extreme paucity of specific data on the wastes generated during mercury cell closures/conversions, and the major assumptions in this analysis, there is significant uncertainty in these estimates.

Table 6. Estimated Cleanup/Decommissioning Wastes for Mercury Cell Plants

Plant	Average Reported Nonair Releases Over All Years (pounds/yr)	Estimated Cleanup/ Decommissioning Wastes (pounds/yr)
ASHTA	620	1,571
OLIN—GA	1,264	3,203
OLIN—TN	1,364	3,457
PPG	1,651	4,185
TOTAL		12,416

SUMMARY

If the four currently operating mercury cell chlor-alkali plants converted to membrane processes, the result would be the elimination of mercury emissions, the elimination of mercury releases to the water and other media, and the termination of the creation of mercury-contaminated wastes from the routine operation of the mercury cells. As discussed above, the estimated levels of these routine releases are:

- Mercury air emissions of between 600 and 800 pounds per year.
- Nonair mercury releases of between 1,200 and 2,000 pounds per year.

During the cleanup and decommissioning, there will be mercury-contaminated wastes that will be created and that will need to be treated. A rough estimate is approximately 7,000 cubic meters of waste created during this process that contains over six tons (12,000 lb) of mercury.

ATTACHMENT 1
Detailed Analysis of Toxic Release Inventory (TRI) Data

MEMORANDUM

DATE: January 5, 2010

SUBJECT: Summary of Mercury Cell Chlor-Alkali Plant Mercury Releases Reported in the Toxics Release Inventory (TRI)

FROM: Phil Norwood, EC/R

TO: Dr. Donna Lee Jones, EPA/OAQPS/SPPD/MMG

The purpose of this memo is to present mercury release information from EPA's Toxics Release Inventory (TRI) (<http://www.epa.gov/tri/>) from the four currently operating mercury cell chlor-alkali plants in the U.S.. These plants are ASHTA Chemicals in Ashtabula, Ohio (ASHTA), Olin Corporation in Augusta, Georgia (OLIN-GA), Olin Corporation in Charleston, Tennessee (OLIN-TN), and PPG in New Martinsville, West Virginia (PPG). In addition to presenting historical release information, the final section presents what are estimated to be "typical" annual levels of Nonair mercury releases that would be eliminated in the event that these facilities ceased to operate.

TRI MERCURY RELEASE INFORMATION

These four mercury cell chlor-alkali plants have been operating since the 1970s. The TRI contains mercury release data beginning in 1988. Attachment 1 contains annual release information for each of the four plants for the 21 years from 1988 to 2008. Table 1 shows the sum of the average annual releases from these four plants for the entire 21-year period, the most recent ten years (1999–2008), and the most recent two years (1997 and 1998), and Figure 1 shows the 21 year trends for total mercury releases for each of the four plants. Table 2 provides more detailed plant-specific averages. As can be seen in Tables 1 and 2, Figure 1, and Attachment A, mercury releases from these four mercury cell chlor-alkali plants have steadily decreased in the 21 year period from 1988 to 2008.

There appears to be an anomaly in the offsite releases for the PPG facility in 2001 (see Figure 1 and Attachment A). In 2001, PPG reported almost 17,000 pounds released offsite (While not shown in the table, the specific release reported was attributed to "Offsite Landfill/Surface Impoundment). This value is over 12 times higher than the next highest level of offsite mercury release for any year in the 10-year period. We believe it is reasonable to assume

the activities in 2001 that resulted in this large release represent a unique and nonroutine event. Therefore, the PPG average release for the period 1999–2008 was calculated excluding the 2001 values, and a separate total of the plant-specific averages calculated. This was shown in Table 2. Therefore, both the 10-year total and the 2007–2008 total Nonair releases were just under 2,000 pounds per year.

Table 1. Total Average Mercury Releases from Mercury Cell Chlor-Alkali Plants

Period	Sum of Average Mercury Releases (pounds/yr)		
	Total Releases	Total Air Releases	Total Nonair Releases
1988–2008	9,410	4,510	4,900
1999–2008	6,839	3,459	3,380
2007–2008	2,331	661	1,669

Note: These plants are ASHTA Chemicals in Ashtabula, Ohio (ASHTA), Olin Corporation in Augusta, Georgia (OLIN-GA), Olin Corporation in Charleston, Tennessee (OLIN-TN), and PPG in New Martinsville, West Virginia (PPG).

Figure 1. Total Mercury Releases Reported in TRI for 1988 - 2008 for Four Currently Operating Mercury Cell Chlor-Alkali Plants

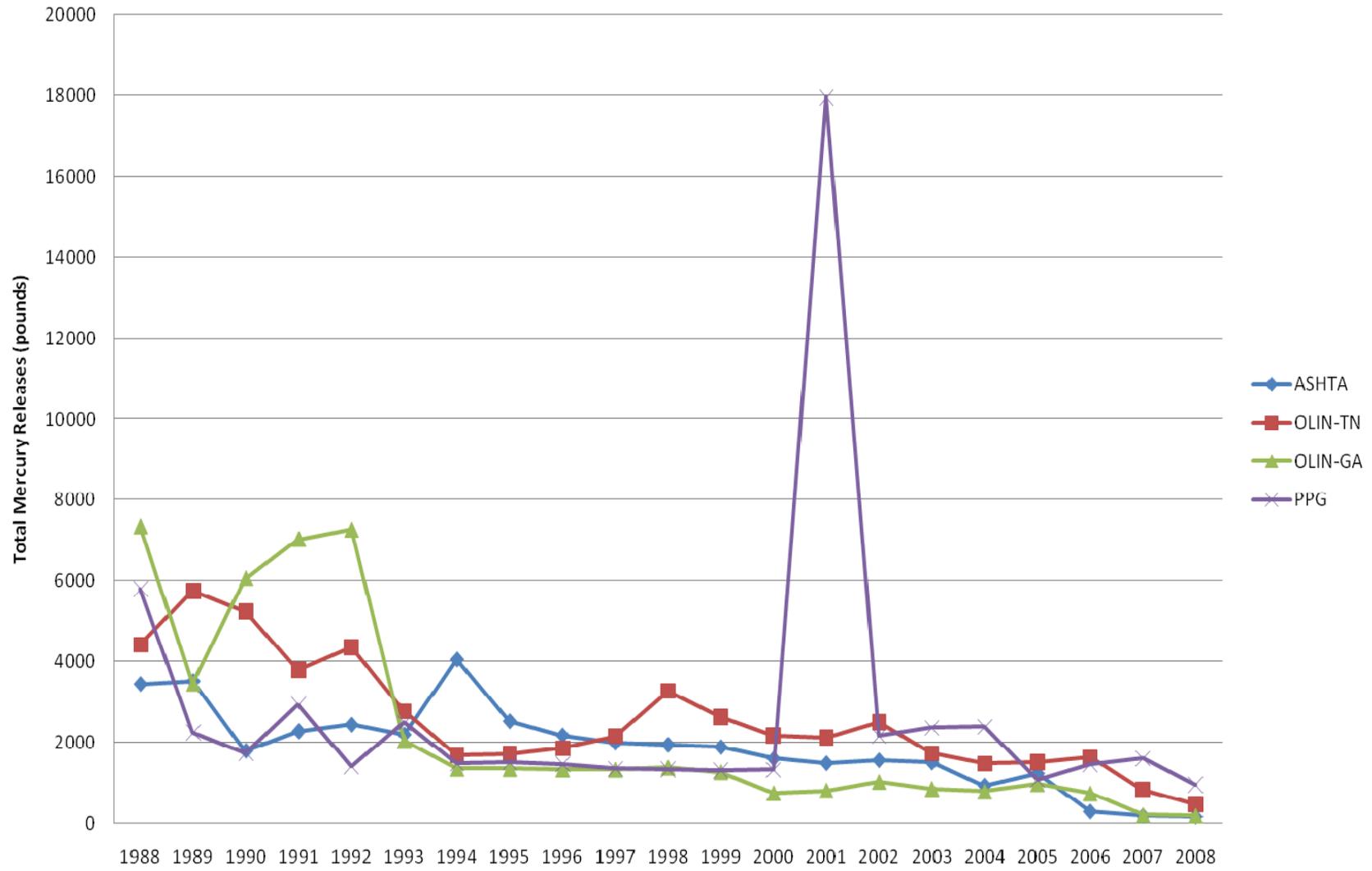


Table 2. Average Mercury Release Values

	Average Mercury Releases (pounds/yr)					
	Total (On & Off Site)	Total Nonair (On & Off Site)	Onsite Air	Onsite Nonair	Onsite Water	Offsite
<u>21-Year Average (1988–2008)</u>						
ASHTA	1,875	620	1,255	102	2	518
OLIN –GA	2,263	1,264	1,000	10	10	1,254
OLIN –TN	2,583	1,364	1,218	1,333	21	31
PPG	2,689	1,651	1,037	60	59	1,591
Total of Averages	9,410	4,900	4,510	1,505	92	3,394
Total of Averages (excluding PPG 2001)	8,646	4,148	4,498	1,507	94	2,641
<u>10-Year Average (1999–2008)</u>						
ASHTA	1,096	212	885	0	0	212
OLIN –GA	761	106	655	10	10	96
OLIN –TN	1,716	648	1,068	584	11	64
PPG	3,265	2,414	852	27	25	2,387
Total of Averages	6,839	3,380	3,459	621	46	2,759
Total of Averages (excluding PPG 2001)	5,207	1,794	3,413	621	46	1,173
<u>2007–2008 Average</u>						
ASHTA	191	190	0	0	0	190
OLIN -GA	199	93	105	11	11	82
OLIN -TN	658	306	352	305	7	1
PPG	1,283	1,080	204	23	23	1,057
Total	2,331	1,669	661	340	41	1,329

ATTACHMENT A. Annual Mercury Release Data from TRI 1988–2008

Facility	Year	Mercury Releases Reported in TRI (pounds/yr)									
		Onsite Releases							Off Site Releases	Total Releases (On & Off Site)	Total Nonair Releases (On & Off Site)
		Total Onsite Releases	Fugitive Air	Stack Air	Total Air	Onsite Nonair	Water	Land			
ASHTA	1988	1,569	1,046	516	1,562	7	6	1	1,877	3,446	1,884
ASHTA	1989	1,303	1,046	250	1,296	7	6	1	2,215	3,518	2,222
ASHTA	1990	1,804	1,046	750	1,796	8	6	2	0	1,804	8
ASHTA	1991	1,306	1,046	250	1,296	10	5	5	978	2,284	988
ASHTA	1992	1,653	1,046	595	1,641	12	7	5	792	2,445	804
ASHTA	1993	1,652	1,046	596	1,642	10	5	5	551	2,203	561
ASHTA	1994	2,871	1,046	614	1,660	1,211	6	1,205	1,177	4,048	2,388
ASHTA	1995	2,530	1,046	608	1,654	876	5	871	0	2,530	876
ASHTA	1996	1,658	1,046	607	1,653	5	5	0	524	2,182	529
ASHTA	1997	1,654	1,046	607	1,653	1	1	0	347	2,001	348
ASHTA	1998	1,653	1,046	607	1,653	0	0	0	297	1,950	297
ASHTA	1999	1,653	1,046	607	1,653	0	0	0	242	1,895	242
ASHTA	2000	1,390	1,046	344	1,390	0	0	0	219	1,609	219
ASHTA	2001	1,396	1,046	350	1,396	0	0	0	100	1,496	100
ASHTA	2002	1,395	1,046	349	1,395	0	0	0	173	1,568	173
ASHTA	2003	1,383	1,046	337	1,383	0	0	0	128	1,511	128
ASHTA	2004	813	464	349	813	0	0	0	134	947	134
ASHTA	2005	813	464	349	813	0	0	0	434	1,247	434
ASHTA	2006	2	0	2	2	0	0	0	306	308	306
ASHTA	2007	0	0	0	0	0	0	0	202	202	202

ATTACHMENT A. Annual Mercury Release Data from TRI 1988–2008

Facility	Year	Mercury Releases Reported in TRI (pounds/yr)									
		Onsite Releases							Off Site Releases	Total Releases (On & Off Site)	Total Nonair Releases (On & Off Site)
		Total Onsite Releases	Fugitive Air	Stack Air	Total Air	Onsite Nonair	Water	Land			
ASHTA	2008	0	0	0	0	0	0	0	179	179	179
OLIN-GA	1988	1,329	1,048	271	1,319	10	10	0	6,014	7,343	6,024
OLIN-GA	1989	1,327	1,046	271	1,317	10	10	0	2,129	3,456	2,139
OLIN-GA	1990	1,331	1,046	271	1,317	14	14	0	4,730	6,061	4,744
OLIN-GA	1991	1,285	1,000	270	1,270	15	15	0	5,740	7,025	5,755
OLIN-GA	1992	1,329	1,046	271	1,317	12	12	0	5,933	7,262	5,945
OLIN-GA	1993	1,324	1,046	271	1,317	7	7	0	712	2,036	719
OLIN-GA	1994	1,328	1,046	271	1,317	11	10	1	23	1,351	34
OLIN-GA	1995	1,325	1,046	271	1,317	8	8	0	23	1,348	31
OLIN-GA	1996	1,324	1,046	271	1,317	7	7	0	8	1,332	15
OLIN-GA	1997	1,323	1,046	271	1,317	6	6	0	5	1,328	11
OLIN-GA	1998	1,326	1,046	271	1,317	9	9	0	50	1,376	59
OLIN-GA	1999	1,245	1,046	189	1,235	10	10	0	23	1,268	33
OLIN-GA	2000	730	562	157	719	11	11	0	21	751	32
OLIN-GA	2001	773	608	158	766	7	7	0	39	812	46
OLIN-GA	2002	746	585	154	739	7	7	0	282	1,028	289
OLIN-GA	2003	742	563	169	732	10	10	0	114	856	124
OLIN-GA	2004	753	563	182	745	8	8	0	36	789	44
OLIN-GA	2005	835	563	261	824	11	11	0	136	971	147
OLIN-GA	2006	591	493	86	578	13	13	0	149	740	162

ATTACHMENT A. Annual Mercury Release Data from TRI 1988–2008

Facility	Year	Mercury Releases Reported in TRI (pounds/yr)									
		Onsite Releases							Off Site Releases	Total Releases (On & Off Site)	Total Nonair Releases (On & Off Site)
		Total Onsite Releases	Fugitive Air	Stack Air	Total Air	Onsite Nonair	Water	Land			
OLIN-GA	2007	138	119	5	124	14	14	0	68	206	82
OLIN-GA	2008	96	77	9	87	9	9	0	96	192	105
OLIN-TN	1988	4,421	1,046	282	1,328	3,093	26	3,067	0	4,421	3,093
OLIN-TN	1989	5,750	1,045	249	1,294	4,456	25	4,431	0	5,750	4,456
OLIN-TN	1990	5,236	1,045	240	1,285	3,951	25	3,926	5	5,241	3,956
OLIN-TN	1991	3,780	1,045	378	1,423	2,357	22	2,335	12	3,792	2,369
OLIN-TN	1992	4,353	1,045	180	1,225	3,128	17	3,111	3	4,356	3,131
OLIN-TN	1993	2,777	1,045	192	1,237	1,540	26	1,514	0	2,777	1,540
OLIN-TN	1994	1,704	1,045	464	1,509	195	53	142	0	1,704	195
OLIN-TN	1995	1,719	1,045	488	1,533	186	43	143	0	1,719	186
OLIN-TN	1996	1,868	1,045	249	1,294	574	40	534	0	1,868	574
OLIN-TN	1997	2,165	1,045	428	1,473	692	31	661	0	2,165	692
OLIN-TN	1998	3,279	1,045	255	1,300	1,979	15	1,964	0	3,279	1,979
OLIN-TN	1999	2,640	1,045	584	1,629	1,011	13	998	0	2,640	1,011
OLIN-TN	2000	2,185	1,045	369	1,414	771	7	764	1	2,186	772
OLIN-TN	2001	2,126	1,045	85	1,130	996	8	988	0	2,126	996
OLIN-TN	2002	2,137	1,045	85	1,130	1,007	14	993	375	2,512	1,382
OLIN-TN	2003	1,711	1,046	85	1,131	580	18	562	26	1,737	606
OLIN-TN	2004	1,455	1,049	105	1,154	301	14	287	30	1,485	331
OLIN-TN	2005	1,517	1,046	204	1,250	267	12	255	5	1,522	272

ATTACHMENT A. Annual Mercury Release Data from TRI 1988–2008

Facility	Year	Mercury Releases Reported in TRI (pounds/yr)									
		Onsite Releases							Off Site Releases	Total Releases (On & Off Site)	Total Nonair Releases (On & Off Site)
		Total Onsite Releases	Fugitive Air	Stack Air	Total Air	Onsite Nonair	Water	Land			
OLIN-TN	2006	1,440	1,032	109	1,141	299	13	286	198	1,638	497
OLIN-TN	2007	834	353	67	420	414	8	406	0	834	414
OLIN-TN	2008	481	241	43	285	196	6	191	1	482	197
PPG	1988	1,500	1,000	250	1,250	250	250	0	4,300	5,800	4,550
PPG	1989	1,500	1,000	250	1,250	250	250	0	750	2,250	1,000
PPG	1990	1,500	1,000	250	1,250	250	250	0	250	1,750	500
PPG	1991	1,145	1,000	85	1,085	60	60	0	1,800	2,945	1,860
PPG	1992	1,163	1,045	85	1,130	33	33	0	250	1,413	283
PPG	1993	1,152	1,045	85	1,130	22	22	0	1,340	2,492	1,362
PPG	1994	1,256	1,045	193	1,238	18	18	0	230	1,486	248
PPG	1995	1,266	1,045	192	1,237	29	29	0	250	1,516	279
PPG	1996	1,275	1,045	190	1,235	40	40	0	191	1,466	231
PPG	1997	1,254	1,045	188	1,233	21	21	0	102	1,356	123
PPG	1998	1,258	1,045	189	1,234	24	24	0	80	1,338	104
PPG	1999	1,254	1,045	187	1,232	22	22	0	62	1,316	84
PPG	2000	1,239	1,045	182	1,227	12	12	0	93	1,332	105
PPG	2001	1,301	1,045	227	1,272	29	29	0	16,658	17,959	16,687
PPG	2002	1,267	1,045	188	1,233	34	34	0	900	2,167	934
PPG	2003	1,238	1,045	177	1,222	16	16	0	1,130	2,368	1,146
PPG	2004	1,248	1,045	171	1,216	32	32	0	1,145	2,393	1,177

ATTACHMENT A. Annual Mercury Release Data from TRI 1988–2008

Facility	Year	Mercury Releases Reported in TRI (pounds/yr)									
		Onsite Releases							Off Site Releases	Total Releases (On & Off Site)	Total Nonair Releases (On & Off Site)
		Total Onsite Releases	Fugitive Air	Stack Air	Total Air	Onsite Nonair	Water	Land			
PPG	2005	425	169	231	400	25	25	0	657	1,082	682
PPG	2006	356	172	134	306	50	34	0	1,115	1,471	1,165
PPG	2007	230	145	55	200	30	30	0	1,378	1,608	1,408
PPG	2008	223	149	58	207	16	16	0	735	958	751

APPENDIX B:
**EMISSIONS REDUCTIONS ASSOCIATED WITH REDUCED MERCURY CELL
CHLOR-ALKALI PLANT ELECTRICITY CONSUMPTION**

As discussed in Section 3 of the RIA, EPA analysis estimates that electricity requirements may be 700 to 1,211 kWh per short ton of chlorine lower after conversion, which corresponds to a 22% and 37.5% reduction in electricity consumption, respectively.⁶⁴ Using the range of estimates and plant chlorine capacities, EPA calculated changes in the annual electricity consumption for four chlorine plants: OLIN Corporation (facilities in Augusta, GA and Charleston, TN), PPG Industries (New Martinsville, WV), and ASHTA Chemicals (Ashtabula, OH). This corresponds to a reduction of approximately 350 million kilowatt hours per year of reduced electricity consumption associated with converting the four existing mercury chlor-alkali plants to membrane cells.

Due to transmission and distribution losses, electrical generating units (EGU) supplying the electricity grid need to generate more electricity (and emissions) to meet each plant's electricity consumption. EPA has assumed approximately 10% of power is lost during transmission and distribution. This factor is commonly used to approximate losses and selected using professional judgment. To account for the possible losses and convert consumption changes to equivalent electricity generation changes, we divided the kWh consumption reductions by 0.9 (electricity generated = electricity consumed / (1-fraction transmission and distribution loss)) (Table B-1). Therefore, the total amount of reduced electricity generation associated with converting the four existing mercury chlor-alkali plants to membrane cells is estimated to be 375 million kilowatt hours per year. Depending on assumed capacity factors, this is approximately equivalent to the electricity produced annually by a 40 to 60 megawatt power plant.

B.1 Share of Electricity Generation by Fuel Type

EPA recognizes there are alternative methods for determining electricity generation by fuel type (i.e., the fuel mix that produced the electricity). As a result, we have documented the results and sources of the information to allow comparisons with the other methods (e.g., use of NERC region electricity grid generation statistics by fuel type). EPA's analysis reviewed the

⁶⁴ As discussed in Section 3, EPA believes that the 22 percent electricity reduction represents is the best estimate of reduced electricity demand, but we provide estimates based on the 37.5 percent electricity reduction to represent the data provided by Oceana.

Table B-1. Estimated Changes in Electricity Generation

Chlorine Plant	Assumed Electricity Provider	Capacity	Change in Electricity Generation (kWh) for a	
			22 % Consumption reduction ^a	37.5 % consumption reduction ^b
OLIN Corp. (Augusta, GA)	Southern Company	47,421	36,883,000	63,807,590
OLIN Corp. (Charleston, TN)	TVA	119,031	92,579,667	160,162,823
PPG Industries (New Martinsville, WV)	American Electric Power	262,451	189,839,557 ^c	328,422,433 ^c
ASHTA Chemicals (Ashtabula, OH)	First Energy	72,848	56,659,556	98,021,031
Total			375,961,779	650,413,877

^a Electricity Consumption = Capacity (tpy) × 700 (kwh/ton) / (0.9).

^b Electricity Consumption = Capacity (tpy) × 1,211 (kwh/ton) / (0.9).

^c PPG produces 70 percent of its electricity requirements. The remaining 30 percent is purchased from Wheeling Electric Co., a subsidiary of American Electric Power.

location for the four facilities and used the Homeland Security Information Program (Gold), a multiple layer geospatial database, to identify the two closest power plants and companies (DHS, 2009).⁶⁵ Using physical location information and engineering assessments EPA selected a power company that most likely provides the electricity to each plant (Table B-1, Column 2). In the case of PPG Industries New Martinsville, WV facility generates 70% of their electricity demand. Therefore, EPA assumes only 30% of the plant's electricity requirements are provided by another power company.

B.2 Electricity Generation by Fuel

For each power company, the share of electricity generation provided by fuel type is reported in Table B-2. EPA collected the latest historical information (2009) from electricity provider websites including annual reports⁶⁶ and the engineering assessment considers it representative for the analysis year (2013) and the fuel mix of the electricity generated to meet the chlorine plants electricity requirements.

⁶⁵ http://proceedings.esri.com/library/userconf/feduc08/papers/hifld_hsip_overview_esri_feduc_feb_2008_jms.pdf

⁶⁶ American Electric Power.,(2009), First Energy (2009), Southern Company (2009). And the Tennessee Valley Authority (2009).

Table B-2. Share of Electricity Generation by Fuel 2009

Utility	Coal	Gas	Nuclear	Hydro	Purchased
Southern Company	57%	23%	16%	4%	NA
TVA	46%	2%	23%	7%	13%
American Electric Power	88%	6%	5%	1%	NA
First Energy	54%	12%	29%	3%	NA

B.3 Emission Factors

EPA's eGRID2007 Version 1.1 provided pollutant emission factors (e.g., short tons per kWh) for several pollutants, including NO_x, SO₂, CO₂, and Hg, from EGUs in the U.S. (U.S. EPA, 2008).⁶⁷ The emissions data contained within eGRID2007 Version 1.1 represents the year 2005 and also includes operator, parent company, owner, and electric grid configuration as of December 31, 2007. It is the latest version available. eGRID2010 covering year 2007 data is expected to be published at the end of 2010. We applied the appropriate conversion factors to eGRID2007's reported power company emissions factors in common units (short tons) (Table B-3 and Table B-4). The emissions data contained within eGRID reflect EPA's Emissions Tracking System/Continuous Emissions Monitoring data. The engineering assessment considers the emissions factors representative and reasonable for the analysis given the physical location of chlorine plants and the power companies and the power companies fuel mix used to meet its customer's electricity requirements.

⁶⁷ The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems. The preeminent source of air emissions data for the electric power sector, eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID integrates many different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). Emissions data from EPA are carefully integrated with generation data from EIA to produce useful values like pounds per megawatt-hour (lb/MWh) of emissions, which allows direct comparison of the environmental attributes of electricity generation. eGRID also provides aggregated data by state, U.S. total, company, and by three different sets of electric grid boundaries. For more information on eGRID, please see <http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html>

Table B-3. Power Company Emission Factors: Fuel=Coal (Short tons per kWh)

Power Company	NO _x	SO ₂	CO ₂	Hg
American Electric Power Co	1.72E-06	5.71E-06	9.71E-04	2.96E-11
First Energy Corp	1.64E-06	6.41E-06	1.03E-03	3.76E-11
Southern Company Services Inc	1.39E-06	6.41E-06	1.03E-03	2.60E-11
Tennessee Valley Authority	1.89E-06	4.50E-06	1.07E-03	2.15E-11

Table B-4. Power Company Emission Factors: Fuel=Natural Gas (Short tons per kWh)

Power Company	NO _x	SO ₂	CO ₂
American Electric Power Co	1.48E-06	9.15E-09	6.30E-04
First Energy Corp	1.73E-07	2.45E-08	5.70E-04
Southern Company Services Inc	1.23E-07	2.68E-08	4.66E-04
Tennessee Valley Authority	1.14E-07	2.80E-09	4.86E-04

Emission factors could not be identified for PM_{2.5}, NH₃, and VOCs in eGRID. As a result, EPA calculated the emission factors using information from two different sources. The first source, Co-Benefits Risk Assessment model (COBRA), provided total U.S. emissions estimates by fuel type and by pollutant for 2010 (U.S. EPA, 2009).⁶⁸ The model contains detailed emissions estimates projected for the years 2010 and 2015 that were developed by EPA for its 2005 regulatory analysis of the Clean Air Interstate Rule (CAIR) (U.S. EPA, 2005). Emissions data undergoes quality assurance at both the state and federal level.

The second source, the EIA's Annual Energy Outlook 2009 (Table 8), reports electricity supply, disposition, prices, and emissions and provides 2010 electricity generation (billion kWh) by fuel. EPA calculated emission factors by fuel type by dividing COBRA emissions estimates by the Energy Information Administration's (EIA) electricity generation estimates (Table B-5) (EIA, 2009).

⁶⁸ The Co-Benefits Risk Assessment (COBRA) screening model is a stand-alone Windows application that enables policy analysts to quickly obtain a first-order approximation of the costs and benefits of different emission scenarios and to compare outcomes in terms of changes in ambient particulate matter (PM) concentrations, related health effects, and monetary impacts. For more information on COBRA, please see <http://www.epa.gov/statelocalclimate/resources/cobra.html>

Table B-5. Emission Factor Calculations: 2010

Variable	Coal	Gas	Petroleum
Generation (billion kWh) AEO 2009			
Electricity	2,057	814	56
Emissions (Short tons) COBRA Model			
PM _{2.5}	506,294	6,696	17
NH ₃	390	1,762	0
VOC	36,135	5,360	0
Emission Factor (Short tons per kWh) EPA Calculations			
PM _{2.5}	2.46E-07	8.22E-09	3.02E-10
NH ₃	1.90E-10	2.16E-09	0
VOC	1.76E-08	6.58E-09	0

B.4 Emissions Reductions

Emission reductions were calculated in three steps. First, we allocate each change in electricity generation (Table B-1) by fuel source using the share data (Table B-2). The engineering assessment concluded it was reasonable to assume electricity demand declines proportionally for all fuel types. In reality, power companies would presumably reduce generation at the EGU with the highest average production costs. However, data was not available to refine the analysis. Next, we multiplied the generation reduction by fuel by the appropriate fuel emission factors (Tables B-3, B-4, B-5). Since the reductions in kWh requirements per ton of chlorine is uncertain, EPA considered two scenarios: a 22% reduction (Table B-6) and 37% reduction (Table B-7).

It is important to note that we assume that these emission reductions occur across the multiple EGUs associated with the presumed electricity provider. Although we identify the location of the mercury chlor alkali plant that would consume less electricity in the tables below, those locations do not reflect the location of the emission reductions from the EGUs. Because the emission reductions occur across multiple EGUs over a large geographic area, these estimates are representative of regional emission reductions.

Table B-6. Emission Reductions by Plant (22 percent reduction)

Chlorine Plant	Emission Sources (Short Tons)						
	PM_{2.5}	NH₃	VOC	NO_x	SO₂	CO₂	Hg
OLIN Corp. (Augusta, GA)	5.2	0.02	0.4	30.2	135.0	25,508	0.001
OLIN Corp. (Charleston, TN)	10.5	0.01	0.8	80.7	191.4	46,400	0.001
PPG Industries (New Martinsville, WV)	45.1	0.04	3.2	320.5	1,045.0	179,882	0.005
ASHTA Chemicals (Ashtabula, OH)	7.6	0.02	0.6	51.3	196.4	35,207	0.001
Total	68.4	0.10	5.0	482.6	1,567.8	286,997	0.008

Table B-7. Emission Estimates by Plant (37 percent reduction)

Chlorine Plant	Emission Sources (Short Tons)						
	PM_{2.5}	NH₃	VOC	NO_x	SO₂	CO₂	Hg
OLIN Corp. (Augusta, GA)	9.1	0.04	0.7	52.2	233.5	44,129	0.001
OLIN Corp. (Charleston, TN)	18.2	0.02	1.3	139.6	331.2	80,272	0.002
PPG Industries (New Martinsville, WV)	78.0	0.07	5.6	554.4	1,807.8	311,195	0.009
ASHTA Chemicals (Ashtabula, OH)	13.1	0.03	1.0	88.8	339.7	60,907	0.002
Total	118.3	0.17	8.7	835.0	2,712.3	496,504	0.014

B.5 Uncertainties

This appendix provides sufficient documentation to reproduce the calculations of emission reductions anticipated to occur as a result of this proposed regulation. In any complex analysis, there can be many sources of uncertainty that could affect the results, especially if the analysis involves predicting future behaviors. In addition, there are always analytical choices that could have incorporated alternate assumptions. Below, we include a qualitative discussion of some of the main sources of uncertainty, including the direction and general magnitude of the potential bias to the extent feasible given data limitations.

- There are several uncertainties associated with the estimate of reduced electricity demand. As shown in this appendix, assuming a 37.5% reduction as suggested by Oceana would nearly double the magnitude of the emission reductions.
- EPA has assumed a 10 percent transmission and distribution loss factor. In 2007, the national average transmission loss was 6.5%, but varied by state (EIA, 2008). Using the EIA reported value lowers emission reductions by approximately 2 percent.
- The underlying historical data from analyses/models represent different points of time (between 2005 and 2010). EPA has assumed they are reasonable representations of the analysis year (2013). To our knowledge, forecasts of portfolio mixes and emission factors for the analysis year are not readily available. Although it is possible that current year or projected data may more accurately reflect the regulatory scenario, this analysis is based on the best available data.
- There are a variety of sources of uncertainty implicit within the emissions factors, including changes over time. For example, new emissions reduction technologies may be introduced earlier than planned and reduce emission factors. Other regulations on EGUs may result in lower emissions factors in the future. In contrast, higher natural gas prices relative to fuels like coal may change power company generation portfolios with higher emission rates. To the extent the emissions factors are higher than those used, the current analysis understates emissions reductions. In contrast, if the emissions factors are lower, the current analysis overstates emissions reductions.
- Since NO_x and SO₂ are covered by capped emissions trading programs, we're only estimating Pm_{2.5} emission reductions from reduced electricity demand.
- The analysis of energy savings assumes that the four facilities all convert rather than close. If one or more were to close, the reduction in electricity use would be greater at the facility (e.g., rather than a 22% reduction for the process there would be a 100% reduction). However, if the facility closing no longer provided chlorine and caustic, most of it would be produced elsewhere with an associated increase in electricity use in another place. Since this would have to be at a facility that uses a process similar to the one the closing facility would have converted to, the national electricity savings would be expected to be similar for either conversion or closure although the resulting pollution reductions would differ spatially. If closure of the process led to closing other processes being produced at the same facility, the same reasoning would apply. Therefore, it is likely that in the event of closure, the emissions reductions would be similar. However if prices increased as a result closure and overall quantities decreased then emission reductions would have been underestimated by the amount of emissions associated with the reduced production.

- There are other pre-existing conditions in electricity markets such as taxes and imperfect competition and taxes. EPA has only accounted for the externality associated with selected pollutant emissions reductions. While these other factors may influence benefit-cost analysis, we believe that they are likely to be small compared to the health effects associated with the emissions from the pollutants considered in the analysis.

B.6 References

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