Regulatory Impact Analysis (RIA) for Existing Stationary Spark Ignition (SI) RICE NESHAP

Final Report

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Regulatory Impact Analysis (RIA) for Existing Stationary Spark Ignition RICE NESHAP

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SECTION 1
EXECUTIVE SUMMARY

This final action promulgates NESHAP for existing stationary SI RICE with a site rating of less than or equal to 500 HP located at major sources, and existing stationary SI RICE of any site rating located at area sources. EPA is finalizing these standards to meet its statutory obligation to address HAP emissions from these sources under sections 112(d), 112(c)(3) and 112(k) of the CAA. The final NESHAP for stationary RICE will be promulgated under 40 CFR part 63, subpart ZZZZ, which already contains standards applicable to new and reconstructed stationary RICE and some existing stationary RICE.

EPA estimates that complying with the final national emission standards for hazardous air pollutants (NESHAP) for stationary spark-ignition (SI) reciprocating internal combustion engines (RICE) will have an annualized cost of approximately $253 million per year (2009 dollars) in the year of full implementation of the rule (2013). Using these costs, EPA estimates in its economic impact analysis that the NESHAP will have limited impacts on the industries affected and their consumers. Using sales data obtained for affected small entities in an analysis of the impacts of this rule on small entities, EPA expects that the NESHAP will not result in a SISNOSE (significant economic impacts for a substantial number of small entities). EPA also does not expect significant adverse energy impacts based on Executive Order 13211, an Executive Order that requires analysis of energy impacts for rules such as this one that are economically significant under Executive Order 12866.

In the year of full implementation (2013), EPA estimates that the total monetized benefits of the final NESHAP are $510 million to $1.2 billion and $460 million to $1.1 billion, at 3% and 7% discount rates, respectively (Table 1-1). All estimates are in 2009 dollars 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. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 109,000 tons of carbon monoxide and 6,000 tons of hazardous air pollutants (HAPs) each year. In addition, ecosystem benefits and visibility benefits have not been monetized in this analysis.

In the year of full implementation (2013), EPA estimates the net benefits of the final NESHAP are $250 million to $980 million and $210 million to $860 million, at 3% and 7% discount rates, respectively (Table 1-1). All estimates are in 2009 dollars for the year 2013. The final NESHAP is the MACT floor level of control for all major SI RICE non-emergency sources and the GACT level of control for area SI RICE sources. We also show results for an alternative (referred to as Alternative 2) which is more stringent than the final NESHAP for major sources. In Alternative 2, the MACT level of control is applied to all SI RICE major non-emergency sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the required level of control is above the MACT floor, and the GACT level of control is applied for area SI RICE sources.

It should be noted that there is a difference between the annualized social costs estimated at 3% and 7%. We approximate the annualized social costs with the compliance costs of the rule for the RIA, as we mention later in Section 5. The annualized compliance costs of the rule are estimated to be $244 million (2009 dollars) using a 3% interest rate. Thus, the annualized social costs for a 3% rate are also $244 million using our approximation, and this estimate is very close to the annualized social cost estimate at a 7% rate.

Table 1-1. Summary of the Monetized Co-Benefits, Social Costs, and Net benefits for the Final SI RICE NESHAP in 2013 (millions of 2009$)[1]

	3% Discount Rate	7% Discount Rate
Final NESHAP: Major[4]		
Total Monetized Benefits[2]	$8.2 to $20	$7.4 to $18
Total Social Costs[3]	$88	$88
Net Benefits	-$80 to -$68	-$81 to -$70
Non-monetized Benefits	12,500 tons of carbon monoxide 1,300 tons of hazardous air pollutants (HAPs) Ecosystem effects Visibility impairment	
Alternative 2: Major		
Total Monetized Benefits[2]	$48 to $120	$43 to $110
Total Social Costs[3]	$95	$95
Net Benefits	-$47 to $22	-$52 to $11
Non-monetized Benefits	17,800 tons of carbon monoxide 1,400 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	
Final NESHAP: Area[5]		
Total Monetized Benefits[2]	$500 to $1,200	$450 to $1,100
Total Social Costs[3]	$166	$166
Net Benefits	$330 to $1,100	$290 to $930
Non-monetized Benefits	97,000 tons of carbon monoxide 4,700 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	
Final Major and Area Source NESHAP		
Total Monetized Benefits[2]	$510 to $1,200	$460 to $1,100
Total Social Costs[3]	$253	$253
Net Benefits	$250 to $980	$210 to $860
Non-monetized Benefits	109,000 tons of carbon monoxide 6,000 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	

[1] All estimates are for the implementation year (2013), and are rounded to two significant figures.

[2] The total monetized co-benefits reflect the human health co-benefits associated with reducing exposure to $PM_{2.5}$ through reductions of $PM_{2.5}$ precursors such as NOx and VOC. 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.

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

[4] The final NESHAP is the MACT floor level of control for all major SI RICE non-emergency sources, and the GACT level of control for area SI RICE sources.

[5] All of the benefits for area sources are attributable to reductions expected from 4SLB and 4SRB non-emergency engines above 500 HP.

SECTION 2
INTRODUCTION

EPA is promulgating NESHAP for existing stationary SI RICE that either are located at area sources of hazardous air pollutant emissions or that have a site rating of less than or equal to 500 horsepower and are located at major sources of hazardous air pollutant emissions.

The rule is economically significant according to Executive Order 12866. As part of the regulatory process of preparing these standards, EPA has prepared a regulatory impact analysis (RIA). This analysis includes an analysis of impacts to small entities as part of compliance with the Small Business Regulatory Enforcement Fairness Act (SBREFA) and an analysis of impacts on energy consumption and production to comply with Executive Order 13211 (Statement of Energy Effects).

2.1 Organization of this Report

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

- Section 3 presents a profile of the affected industries.
- Section 4 presents a summary of regulatory alternatives considered in the final rule, and provides the compliance costs of the rule.
- Section 5 describes the estimated costs of the regulation and describes the economic impact analysis (EIA) methodology and reports market, welfare, and energy impacts.
- Section 6 presents estimated impacts on small entities.
- Section 7 presents the benefits estimates.
- Appendices A and B present technical support documents related to the benefits estimates

SECTION 3
INDUSTRY PROFILE

This section provides an introduction to the industries affected by the rule, i.e., industries in which the spark-ignition (SI) RICE being regulated are found. SI RICE generate electric power, pump gas or other fluids, or compress air for machinery. The primary non-utility application of internal combustion (IC) engines is in the natural gas industry to power compressors used for pipeline transportation, field gathering (collecting gas from wells), underground storage tanks, and in-gas processing plants. RICEs are separated into three design classes: 2 cycle (stroke) lean burn, 4-stroke lean burn, and 4-stroke rich burn. Each of these has design differences that affect both baseline emissions as well as the potential for emissions control.

These industries include the following:

- electric power generation, transmission, and distribution (NAICS 2211),
- oil and gas extraction (including marginal wells) (NAICS 211), and
- pipeline transportation of natural gas (NAICS 48621).

These three industries incur over 80 percent of the annualized costs of the rule. The purpose is to give the reader a general understanding of the economic aspects of the industry; their relative size, relationships with other sectors in the economy, trends for the industries, and financial statistics.

3.1 Electric Power Generation, Transmission, and Distribution

3.1.1 Overview

Electric power generation, transmission, and distribution (NAICS 2211) is an industry group within the utilities sector (NAICS 22). It includes establishments that produce electrical energy or facilitate its transmission to the final consumer.

From 2002 to 2007, revenues from electric power generation grew about 18% to over $440 billion ($2007) (Table 3-1).[1] At the same time, payroll rose about 7% and the number of employees decreased by around 4%. The number of establishments rose by about 3%. Industrial production within NAICS 2211 has increased 26% since 1997 (Figure 3-1).

[1] We provide revenues from electric power generation for the years 2002 and 2007 for these are years of the Economic Census. We reference data from these Economic Censuses frequently in this industry profile and show revenues from this industry over this time frame due to availability of such data.

Electric utility companies have traditionally been tightly regulated monopolies. Since 1978, several laws and orders have been passed to encourage competition within the electricity market. In the late 1990s, many states began the process of restructuring their utility regulatory framework to support a competitive market. Following market manipulation in the early 2000s, however, several states have suspended their restructuring efforts. The majority (58%) of power generators controlled by combined heat and power (CHP) or independent power producers are located in states undergoing active restructuring (Figure 3-2).

Table 3-1. Key Statistics: Electric Power Generation, Transmission, and Distribution (NAICS 2211) ($2007)

	2002	2007
Revenue ($\$10^6$)	373,309	440,355
Payroll ($\$10^6$)	40,842	43,792
Employees	535,675	515,335
Establishments	9,394	9,642

Source: U.S. Census Bureau; American FactFinder; "Sector 22: EC0722I2: Utilities: Industry Series: Preliminary Comparative Statistics for the United States (2002 NAICS Basis): 2007 and 2002." http://factfinder.census.gov

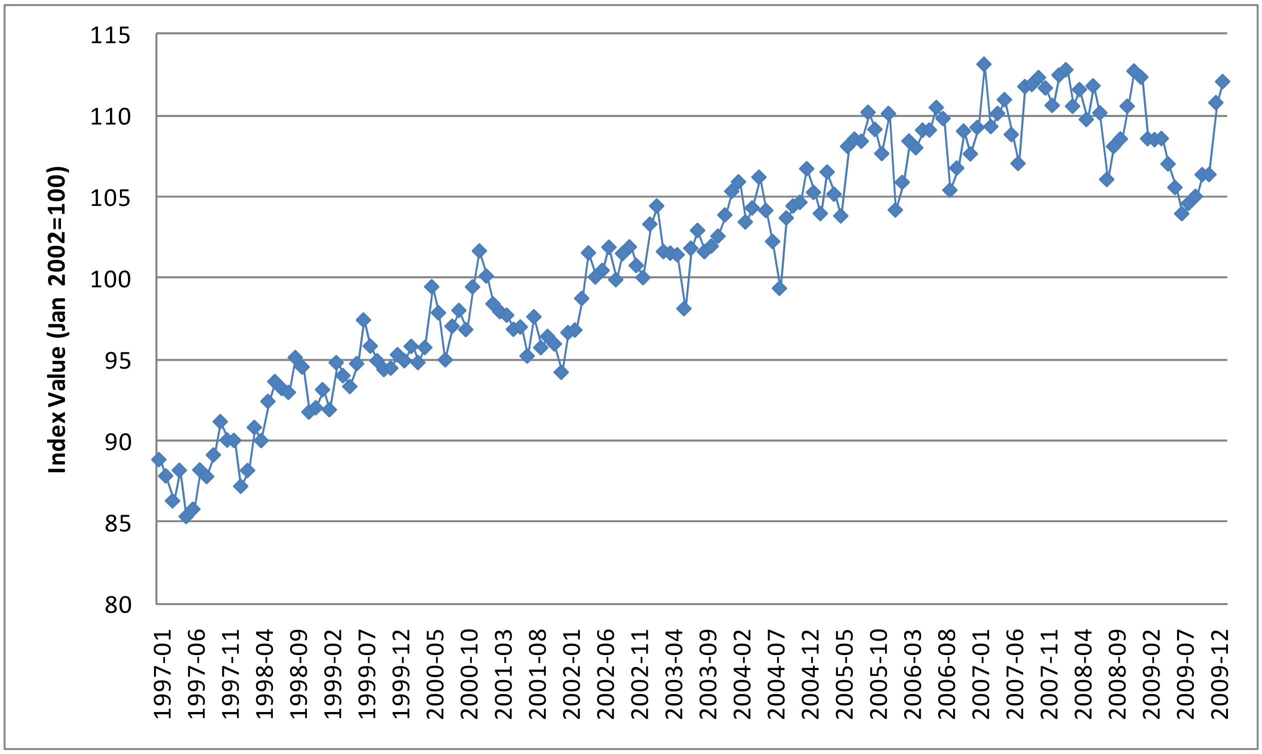

Figure 3-1. Industrial Production Index (NAICS 2211)

Source: The Federal Reserve Board. "Industrial Production and Capacity Utilization: Industrial Production" Series ID: G17/IP_MINING_AND_UTILITY_DETAIL/IP.G2211.S <http://www.federalreserve.gov/datadownload/>. (January 27, 2010).

3.1.2 Goods and Services Used

In Table 3-2, we use the latest detailed benchmark input-output data report by the Bureau of Economic Analysis (BEA) (2002) to identify the goods and services used in electric power generation. As shown, labor and tax requirements represent a significant share of the value of power generation. Extraction, transportation, refining, and equipment requirements potentially

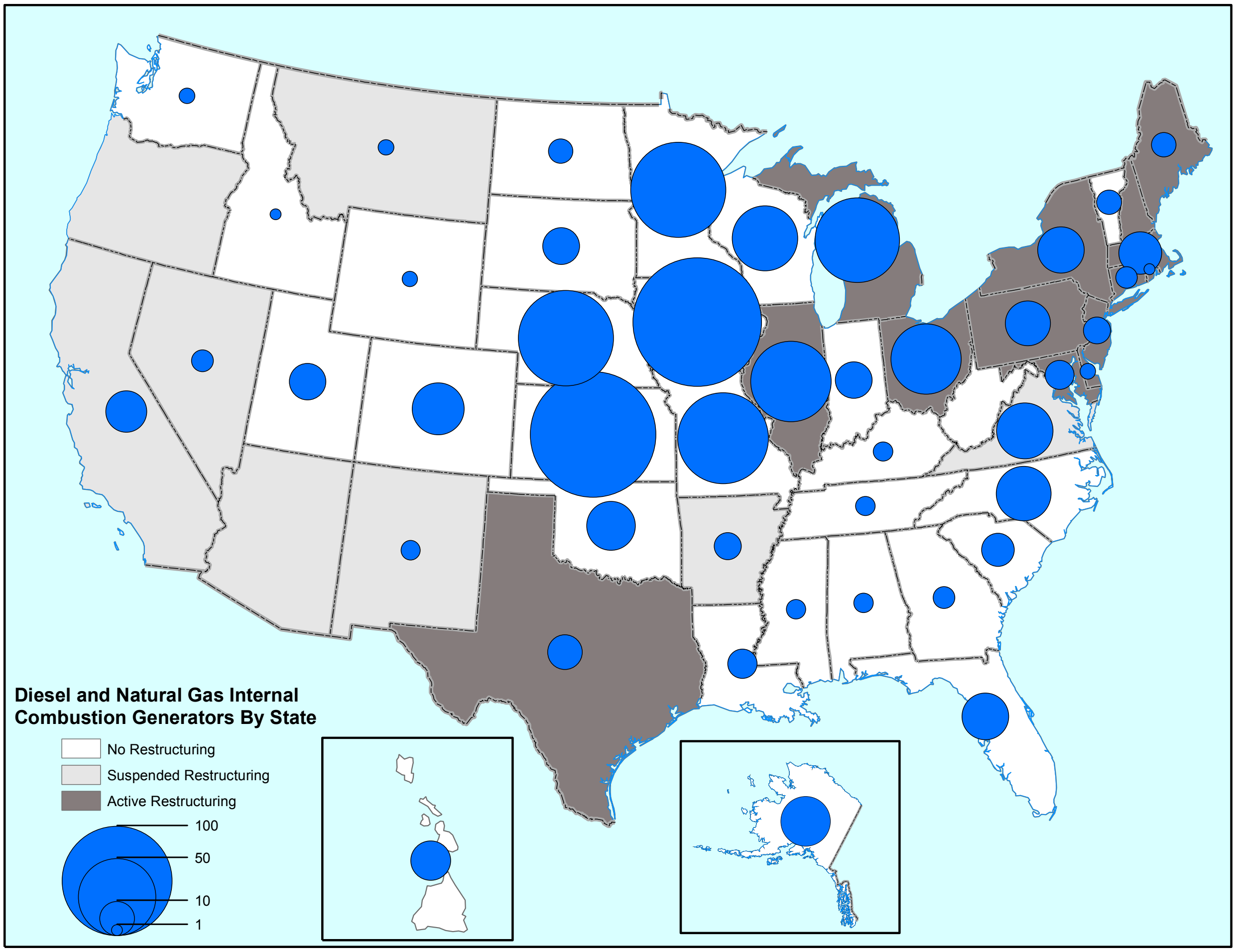

Figure 3-2. Internal Combustion Generators by State: 2006

Source: U.S. Department of Energy, Energy Information Administration. 2007. "2006 EIA-906/920 Monthly Time Series."

associated with reciprocating internal combustion engines (oil and gas extraction, pipeline transportation, petroleum refineries, and turbine manufacturing) represent around 10% of the value of services.

3.1.3 Business Statistics

The U.S. Economic Census and Statistics of U.S. Businesses (SUSB) programs provide national information on the distribution of economic variables by industry, location, and size of business. Throughout this section and report, we use the following definitions:

- *Establishment*: An establishment is a single physical location where business is conducted or where services or industrial operations are performed.

Table 3-2. Direct Requirements for Electric Power Generation, Transmission, and Distribution (NAICS 2211): 2002

Commodity	Commodity Description	Direct Requirements Coefficients[a]
V00100	Compensation of employees	20.52%
V00200	Taxes on production and imports, less subsidies	13.71%
211000	Oil and gas extraction	6.16%
212100	Coal mining	5.86%
482000	Rail transportation	3.01%
230301	Nonresidential maintenance and repair	2.83%
486000	Pipeline transportation	1.70%
722000	Food services and drinking places	1.40%
52A000	Monetary authorities and depository credit intermediation	1.39%
541100	Legal services	1.13%

[a] These values show the amount of the commodity required to produce $1.00 of the industry's output. The values are expressed in percentage terms (coefficient ×100).

Source: U.S. Bureau of Economic Analysis. 2002. 2002 Benchmark Input-Output Accounts: Detailed Make Table, Use Table and Direct Requirements Table. Tables 4 and 5.

- *Receipts*: Receipts (net of taxes) are defined as the revenue for goods produced, distributed, or services provided, including revenue earned from premiums, commissions and fees, rents, interest, dividends, and royalties. Receipts exclude all revenue collected for local, state, and federal taxes.

- *Firm*: A firm is a business organization consisting of one or more domestic establishments in the same state and industry that were specified under common ownership or control. The firm and the establishment are the same for single-establishment firms. For each multiestablishment firm, establishments *in the same industry within a state* are counted as one firm; the firm employment and annual payroll are summed from the associated establishments.

- *Enterprise*: An enterprise is a business organization consisting of one or more domestic establishments that were specified under common ownership or control. The enterprise and the establishment are the same for single-establishment firms. Each multiestablishment company forms one enterprise; the enterprise employment and annual payroll are summed from the associated establishments. Enterprise size designations are determined by the summed employment of all associated establishments.

In 2002, Texas had almost 1,000 power establishments, while California, Georgia, and Ohio all had between 400 and 500 (Figure 3-3). Hawaii, Nebraska, and Rhode Island all had fewer than 20 establishments in their states.

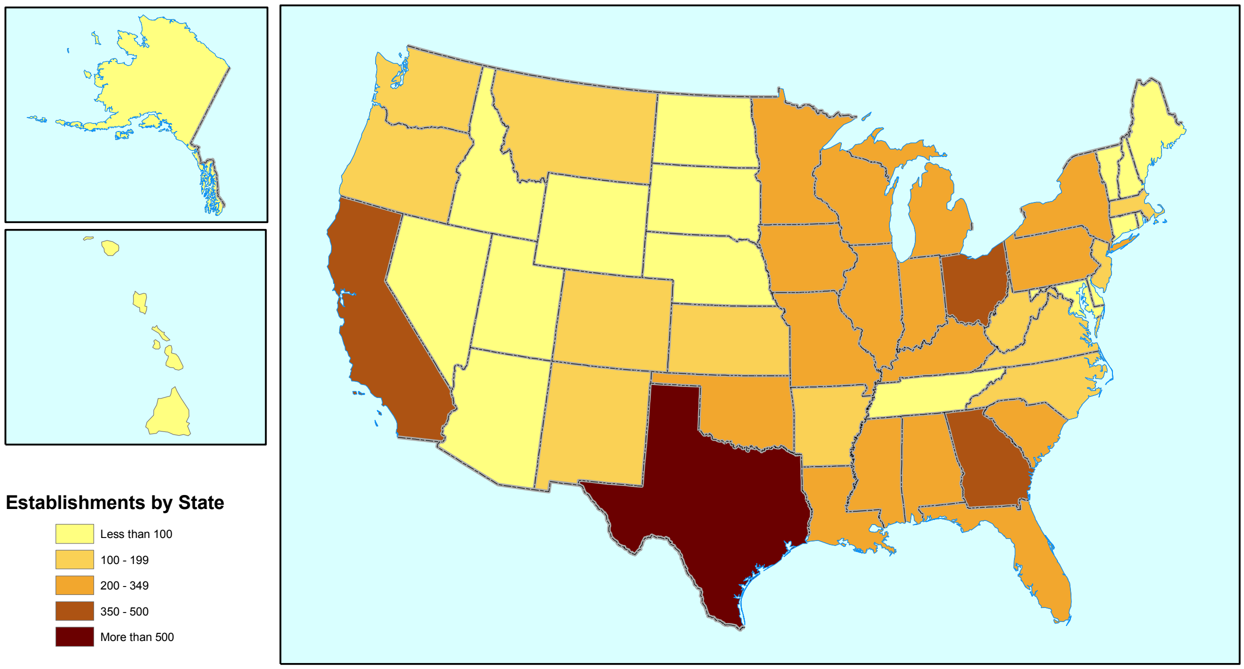

Figure 3-3. 2002 Regional Distribution of Establishments: Electric Power Generation, Transmission, and Distribution Industry (NAICS 2211)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 22: Utilities: Geographic Area Series: Summary Statistics: 2002." <http://factfinder.census.gov>; (November 10, 2008)..

As shown in Table 3-3, the four largest firms owned over 1,200 establishments and accounted for about 16% of total industry receipts/revenue. The 50 largest firms accounted for almost 6,000 establishments and about 78% of total receipts/revenue.

Investor-owned energy providers accounted for only 2% of retail electricity sold in the United States in 2008 (Table 3-4). In 2008, investor-owned energy provider companies with less than 50% of their assets regulated were unprofitable overall, while other companies in this category were profitable. (Table 3-5). In 2008, enterprises within NAICS 2211 had a pre-tax profit margin of 8.1% (Table 3-6).

In 2002, about 82% of firms generating, transmitting, or distributing electric power had receipts of under $50 million (Table 3-7). However, these firms accounted for only 11% of employment, with 89% of employees working for firms with revenues in excess of $100 million.

Table 3-3. Firm Concentration for Electric Power Generation, Transmission, and Distribution (NAICS 2211): 2002

		Receipts/Revenue			
Commodity	Establishments	Amount ($\$10^6$)	Percentage of Total	Number of Employees	Employees per Establishment
All firms	9,394	$325,028	100.0%	535,675	57
4 largest firms	1,260	$52,349	16.1%	68,432	54
8 largest firms	2,566	$95,223	29.3%	151,575	59
20 largest firms	3,942	$173,207	53.3%	271,393	69
50 largest firms	5,887	$253,015	77.8%	408,021	69

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 22: Utilities: Subject Series—Estab & Firm Size: Concentration by Largest Firms for the United States: 2002." <http://factfinder.census.gov>; (November 21, 2008).

Table 3-4. United States Retail Electricity Sales Statistics: 2008

Item	Full-Service Providers					Other Providers		Total
	Investor-Owned	Public	Federal	Cooperative	Facility	Energy	Delivery	
Number of entities	3	62	1	25	1	NA	NA	92
Number of retail customers	46,985	2,160,220	36	940,697	1	NA	NA	3,147,939
Retail sales (10^3 megawatthours)	2,257	70,303	9,625	21,868	117	NA	NA	104,170
Percentage of retail sales	2	67	9	21	0	—	—	100
Revenue from retail sales ($\$10^6$)	113	5,934	473	1,994	6	NA	NA	8,520
Percentage of revenue	1.33	69.65	5.55	23.41	0.07	—	—	100
Average retail price (cents/kWh)	5.01	8.44	4.91	9.12	5.25	NA	NA	8.18

Source: U.S. Department of Energy, Energy Information Administration. 2009. "State Electricity Profiles 2008." DOE/EIA-0348(01)/2. p. 260. < http://www.eia.doe.gov/cneaf/electricity/st_profiles/sep2008.pdf>.

Table 3-5. FY 2007 Financial Data for 70 U.S. Shareholder-Owned Electric Utilities

	Profit Margin	Net Income	Operating Revenues
Investor-Owned Utilities	4.81%	$20,677	$430,037
Regulated[a]	7.25%	$12,129	$167,194
Mostly regulated[b]	8.50%	$17,704	$208,288
Diversified[c]	-16.78%	-$9,156	$54,554

[a] 80%+ of total assets are regulated.

[b] 50% to 80% of total assets are regulated.

[c] Less than 50% of total assets are regulated.

Source: Edison Electric Institute. "Income Statement: Q4 2008 Financial Update. Quarterly Report of the U.S. Shareholder-Owned Electric Utility Industry." <http://www.eei.org>.

Table 3-6. Aggregate Tax Data for Accounting Period 7/07–6/08: NAICS 2211

Number of enterprises[a]	1,187
Total receipts (10^3)	$361,177,861
Net sales(10^3)	$328,017,143
Profit margin before tax	8.1%
Profit margin after tax	5.4%

[a] Includes corporations with and without net income.

Source: Internal Revenue Service, U.S. Department of Treasury. 2010. "Corporation Source Book: Data Files 2004–2007." <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>; (May 2, 2010). 3.2.2 Goods and Services Used.

Table 3-7. Key Enterprise Statistics by Receipt Size for Electric Power Generation, Transmission, and Distribution (NAICS 2211): 2002

		Owned by Enterprises with								
Variable	**All Enterprises**	**0–99K Receipts**	**100–499.9K Receipts**	**500–999.9K Receipts**	**1,000–4,999.9K Receipts**	**5,000,000–9,999,999K Receipts**	**<10,000K Receipts**	**10,000–49,999K Receipts**	**50,000–99,999K Receipts**	**100,000K+ Receipts**
Firms	1,756	129	250	80	232	205	896	538	112	210
Establishments	9,493	129	250	85	245	262	971	978	403	7,141
Employment	515,769	429	834	3,139	2,712	5,620	12,734	31,573	14,858	456,604
Receipts ($\$10^3$)	$320,502,670	$5,596	$63,339	$57,363	$627,414	$1,472,405	$2,226,117	$12,171,098	$7,607,166	$298,498,289
Receipts/firm ($\$10^3$)	$182,519	$43	$253	$717	$2,704	$7,182	$2,485	$22,623	$67,921	$1,421,420
Receipts/establishment ($\$10^3$)	$33,762	$43	$253	$675	$2,561	$5,620	$2,293	$12,445	$18,876	$41,801
Receipts/employment ($)	$621,407	$13,044	$75,946	$18,274	$231,347	$261,994	$174,817	$385,491	$511,991	$653,736

Source: U.S. Census Bureau. 2008. “Firm Size Data from the Statistics of U.S. Businesses: U.S. All Industries Tabulated by Receipt Size: 2002.” <http://www.census.gov/csd/susb/susb02.htm>.

3.2 Oil and Gas Extraction

3.2.1 Overview

Oil and gas extraction (NAICS 211) is an industry group within the mining sector (NAICS 21). It includes establishments that operate or develop oil and gas field properties through such activities as exploring for oil and gas, drilling and equipping wells, operating on-site equipment, and conducting other activities up to the point of shipment from the property.

Oil and gas extraction consists of two industries: crude petroleum and natural gas extraction (NAICS 211111) and natural gas liquid extraction (NAICS 211112). Crude petroleum and natural gas extraction is the larger industry; in 2002, it accounted for 93% of establishments and 75% of oil and gas extraction revenues.

Industrial production in this industry is particularly sensitive to hurricanes in the Gulf Coast. In September of both 2005 and 2008, production dropped 14% from the previous month. However, production is currently 3% higher than it was in 2002 (Figure 3-4).

From 2002 to 2007, revenues from crude petroleum and natural gas extraction (NAICS 211111) grew over 117% to almost $215 billion ($2007) (Table 3-8). At the same time, payroll grew 55% and the number of employees grew by 48%. The number of establishments dropped by over 17%; as a result, the average establishment revenue increased by 162%. Materials costs were approximately 18% of revenue over the period.

From 2002 to 2007, revenue from natural gas liquid extraction (NAICS 211112) grew over 26% to about $42 billion (Table 3-9). At the same time, payroll dropped 18% and the number of employees dropped by 24%. The number of establishments dropped by 43%, resulting in an increase of revenue per establishment of about 122%.

3.2.2 Goods and Services Used

The oil and gas extraction industry has similar labor and tax requirements as the electric power generation sector. Extraction, support, power, and equipment requirements potentially associated with RICE (oil and gas extraction, support activities, electric power generation, machinery and equipment rental and leasing, and pipeline transportation) represent around 8% of the value of services (Table 3-10).

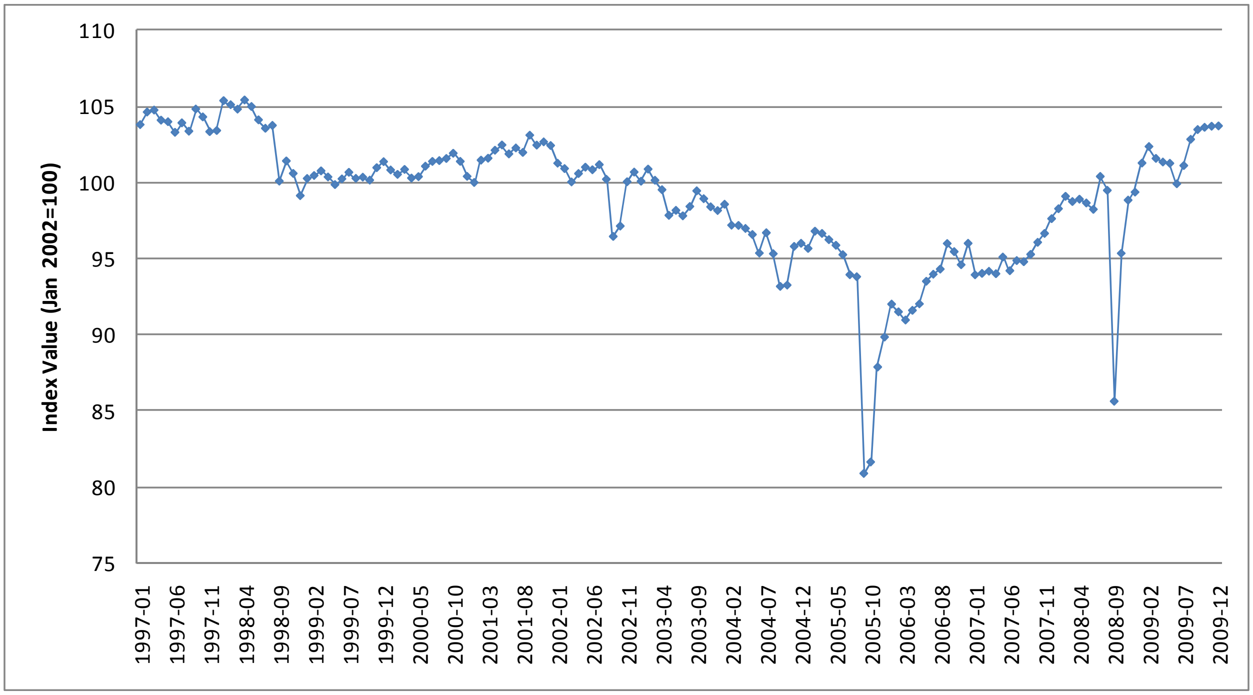

Figure 3-4. Industrial Production Index (NAICS 211)

Source: The Federal Reserve Board. "Industrial Production and Capacity Utilization: Industrial Production" Series ID: G17/IP_MINING_AND_UTILITY_DETAIL/IP.G211.S <http://www.federalreserve.gov/datadownload/>. (January 27, 2010).

Table 3-8. Key Statistics: Crude Petroleum and Natural Gas Extraction (NAICS 211111): ($2007)

	2002	2007
Revenue ($$10^6$)	$98,667	$214,198
Payroll ($$10^6$)	$5,785	$8,980
Employees	94,886	140,160
Establishments	7,178	5,956

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 21: Mining: Industry Series: Historical Statistics for the Industry: 2002 and 1997." <http://factfinder.census.gov>; (November 26, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 21: EC0721I1: Mining: Industry Series: Detailed Statistics by Industry for the United States: 2007 " <http://factfinder.census.gov>; (April 27, 2010).

Table 3-9. Key Statistics: Natural Gas Liquid Extraction (NAICS 211112) ($2007)

	2002	2007
Revenue ($$10^6$)	$33,579	$42,363
Payroll ($$10^6$)	$607	$501
Employees	9,693	7,343
Establishments	511	291

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 21: Mining: Industry Series: Historical Statistics for the Industry: 2002 and 1997." <http://factfinder.census.gov>; (November 26, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 21: EC0721I1: Mining: Industry Series: Detailed Statistics by Industry for the United States: 2007 " <http://factfinder.census.gov>; (April 27, 2010).

Table 3-10. Direct Requirements for Oil and Gas Extraction (NAICS 211): 2002

Commodity	Commodity Description	Direct Requirements Coefficients[a]
V00200	Taxes on production and imports, less subsidies	8.93%
V00100	Compensation of employees	6.67%
230301	Nonresidential maintenance and repair	6.36%
211000	Oil and gas extraction	1.91%
213112	Support activities for oil and gas operations	1.51%
221100	Electric power generation, transmission, and distribution	1.47%
541300	Architectural, engineering, and related services	1.24%
532400	Commercial and industrial machinery and equipment rental and leasing	1.20%
33291A	Valve and fittings other than plumbing	1.10%
541511	Custom computer programming services	0.99%

[a] These values show the amount of the commodity required to produce $1.00 of the industry's output. The values are expressed in percentage terms (coefficient ×100).

Source: U.S. Bureau of Economic Analysis. 2002. 2002 Benchmark Input-Output Accounts: Detailed Make Table, Use Table and Direct Requirements Table. Tables 4 and 5.

3.2.3 Business Statistics

The U.S. Economic Census and SUSB programs provide national information on the distribution of economic variables by industry, location, and size of business. Throughout this section and report, we use the following definitions:

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- *Receipts*: Receipts (net of taxes) are defined as the revenue for goods produced, distributed, or services provided, including revenue earned from premiums, commissions and fees, rents, interest, dividends, and royalties. Receipts exclude all revenue collected for local, state, and federal taxes.

- *Firm*: A firm is a business organization consisting of one or more domestic establishments in the same state and industry that were specified under common ownership or control. The firm and the establishment are the same for single-establishment firms. For each multiestablishment firm, establishments in the same industry within a state are counted as one firm; the firm employment and annual payroll are summed from the associated establishments.

- *Enterprise*: An enterprise is a business organization consisting of one or more domestic establishments that were specified under common ownership or control. The enterprise and the establishment are the same for single-establishment firms. Each multiestablishment company forms one enterprise; the enterprise employment and annual payroll are summed from the associated establishments. Enterprise size designations are determined by the summed employment of all associated establishments.

In 2002, Texas had almost 2,500 crude petroleum and natural gas extraction establishments, Oklahoma had about 900, and every other state had under 400 (Figure 3-5). Twenty-two states had fewer than 10 establishments. Similarly, Texas had 830 natural gas liquid extraction establishments, Oklahoma had 41, Louisiana had 37, and every other state had under 25 (Figure 3-6). Only seven states had 10 or more establishments, and 24 had no establishments.

According to the SUSB, 89% of crude petroleum and natural gas extraction firms had fewer than 500 employees in 2002 (Table 3-11). Sixty-three percent of natural gas liquid extraction firms had fewer than 500 employees in 2002 (Table 3-12).

Enterprises within this industry generated $193 billion in total receipts in 2008. Including those enterprises without net income, the industry averaged an after-tax profit margin of 8.5% (Table 3-13).

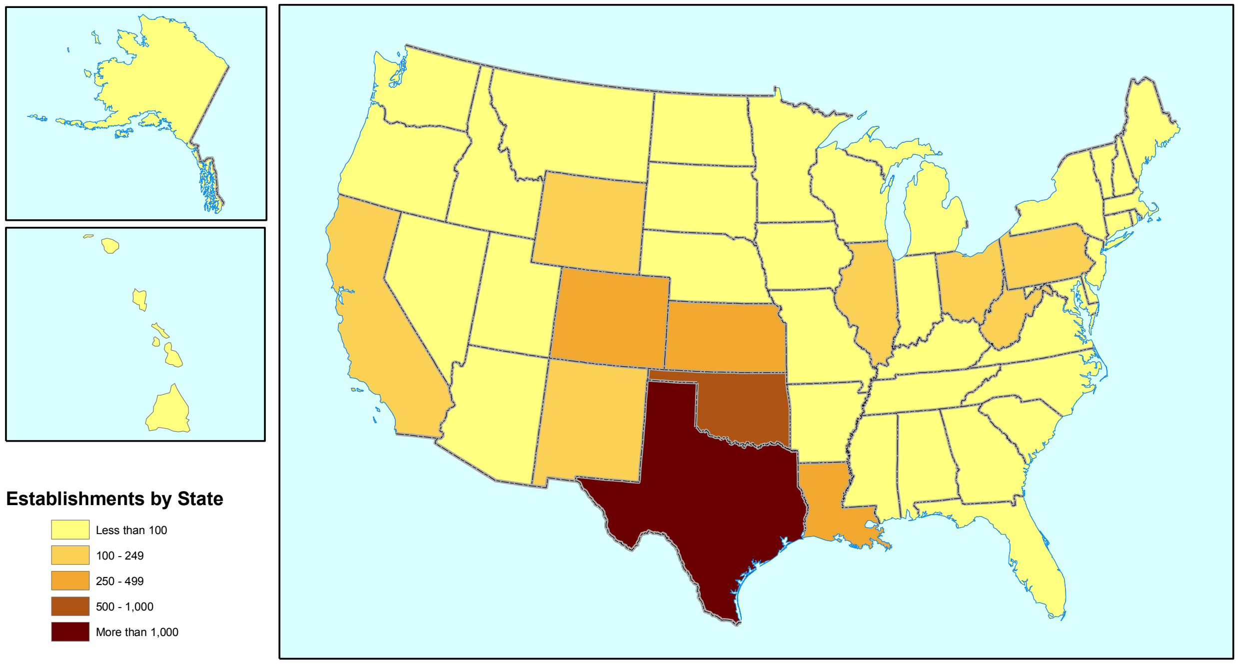

Figure 3-5. 2002 Regional Distribution of Establishments: Crude Petroleum and Natural Gas Extraction Industry (NAICS 211111)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 21: Mining: Geographic Area Series: Industry Statistics for the State or Offshore Areas: 2007." <http://factfinder.census.gov>; (January 27, 2010).

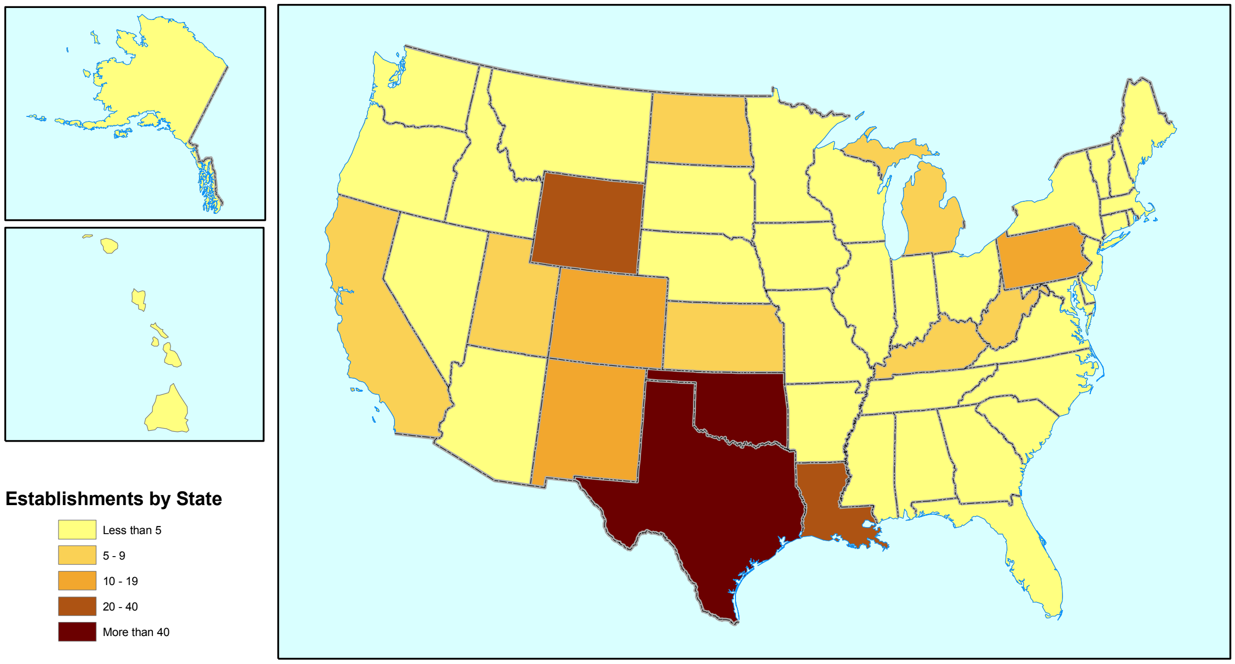

Figure 3-6. 2002 Regional Distribution of Establishments: Natural Gas Liquid Extraction Industry (NAICS 211112)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 21: Mining: Geographic Area Series: Industry Statistics for the State or Offshore Areas: 2007.” <http://factfinder.census.gov>; (January 27, 2010).

Table 3-11. Key Enterprise Statistics by Employment Size for Crude Petroleum and Natural Gas Extraction (NAICS 211111): 2002

Variable	All Enterprises	Owned by Enterprises with 1–20 Employees	20–99 Employees	100–499 Employees	500–749 Employees	750–999 Employees	1,000–1,499 Employees
Firms	6,238	5,130	348	85	11	11	5
Establishments	7,135	5,185	449	254	37	63	25
Employment	76,794	5,825	5,171	2,757	Not disclosed	Not disclosed	Not disclosed
Receipts ($\$10^3$)	$88,388,300	$2,353,181	$2,559,239	$2,051,860	Not disclosed	Not disclosed	Not disclosed
Receipts/firm ($\$10^3$)	$14,169	$459	$7,354	$24,140	Not disclosed	Not disclosed	Not disclosed
Receipts/establishment ($\$10^3$)	$12,388	$454	$5,700	$8,078	Not disclosed	Not disclosed	Not disclosed
Receipts/employment ($)	$1,150,979	$403,980	$494,921	$744,236	Not disclosed	Not disclosed	Not disclosed

Source: U.S. Census Bureau. 2008a. Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002. http://www2.census.gov/csd/susb/2002/02us_detailed%20sizes_6digitnaics.txt.

Table 3-12. Key Enterprise Statistics by Employment Size for Crude Natural Gas Liquid Extraction (NAICS 211112): 2002

Variable	All Enterprises	Owned by Enterprises with 1–20 Employees	20–99 Employees	100–499 Employees	500–749 Employees	750–999 Employees	1,000–1,499 Employees
Firms	113	54	7	10	2	1	2
Establishments	494	54	7	38	23	1	6
Employment	11,486	65	Not disclosed	241	Not disclosed	Not disclosed	Not disclosed
Receipts ($\$10^3$)	$72,490,930	$13,862	Not disclosed	$383,496	Not disclosed	Not disclosed	Not disclosed
Receipts/firm ($\$10^3$)	$641,513	$257	Not disclosed	$38,350	Not disclosed	Not disclosed	Not disclosed
Receipts/establishment ($\$10^3$)	$146,743	$257	Not disclosed	$10,092	Not disclosed	Not disclosed	Not disclosed
Receipts/employment ($)	$6,311,242	$213,262	Not disclosed	$1,591,270	Not disclosed	Not disclosed	Not disclosed

Source: U.S. Census Bureau. 2008a. Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002. <http://www2.census.gov/csd/susb/2002/02us_detailed%20sizes_6digitnaics.txt>.

3.2.4 Case Study: Marginal Wells

To provide additional context for understanding energy sectors that use reciprocating internal combustion engines, we examine one segment of the oil and gas sector: marginal wells. This industry includes small-volume wells that are mature in age, are more difficult to extract oil or natural gas from than other types of wells, and generally operate at very low levels of

Table 3-13. Aggregate Tax Data for Accounting Period 7/07–6/08: NAICS 211

Number of enterprises[a]	19,441
Total receipts (10^3)	$193,230,241
Net sales(10^3)	$166,989,539
Profit margin before tax	12.9%
Profit margin after tax	8.5%

[a] Includes corporations with and without net income.

Source: Internal Revenue Service, U.S. Department of Treasury. 2010. "Corporation Source Book: Data Files 2004-2007." <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>; (May 2, 2010).

profitability. As a result, well operations can be quite responsive to small changes in the benefits and costs of their operation.

In 2007, there were approximately 400,000 marginal oil wells and 320,000 marginal gas wells (Interstate Oil and Gas Compact Commission [IOGCC], 2008). These wells provide the United States with 4% of all oil and 8% of all natural gas consumed (IOGCC, 2008). Data for 2007 show that revenue from the over 700,000 wells was approximately $30.6 billion (Table 3-14).

Table 3-14. Reported Gross Revenue Estimates from Marginal Wells: 2007

Well Type	Number of Wells	Production from Marginal Wells	Estimated Gross Revenue ($\$10^9$)
Oil	396,537	291.067592 MMbbls	$18.6
Natural gas	322,160	1763.592746 MCF	$12.0
Total	718,697		$30.6

Source: Interstate Oil & Gas Compact Commission. 2008. "Marginal Wells: Fuel for Economic Growth." Available at <http://iogcc.publishpath.com/Websites/iogcc/pdfs/2007-Marginal-Well-Report.pdf>.

Historical data show marginal oil production fluctuated between 1997 and 2007, reflecting the industry's sensitivity to changes in economic conditions of fuel markets (see Figure 3-7). In contrast, the number of marginal gas wells has continually increased during the past decade; the IOGCC estimates that daily production levels from these wells reached a 10-year high in 2005. Although we have been unable to find data on what fraction of these marginal wells are operated by small businesses, the IOGCC states that many are run by "mom and pop operators" (IOGCC, 2007).

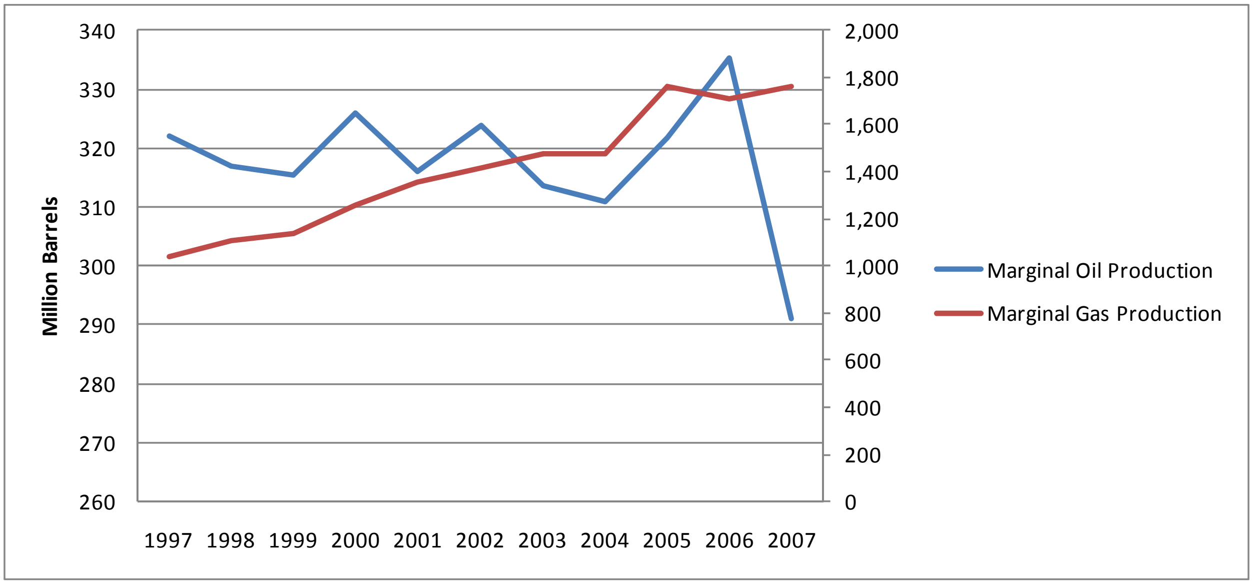

Figure 3-7. Trends in Marginal Oil and Gas Production: 1997 to 2006

Source: Interstate Oil & Gas Compact Commission. 2008. "Marginal Wells: Fuel for Economic Growth." Available at < http://iogcc.publishpath.com/Websites/iogcc/pdfs/2008-Marginal-Well-Report.pdf>.

3.3 Pipeline Transportation of Natural Gas

3.3.1 Overview

Pipeline transportation of natural gas (NAICS 48621) is an industry group within the transportation and warehousing sector (NAICS 48-49), but more specifically in the pipeline transportation subsector (486). It includes the transmission of natural gas as well as the distribution of the gas through a local network to participating businesses.

From 2002 to 2007, natural gas transportation revenues fell by 29% to just over $16 billion ($2007) (Table 3-15). At the same time, payroll decreased by 14%, while the number of paid employees decreased by nearly 25%. The number of establishments also fell by 8% from 1,701 establishments in 2002 to 1,560 in 2007.

3.3.2 Goods and Services Used

The BEA reports pipeline transportation of natural gas only for total pipeline transportation (3-digit NAICS 486). In addition to pipeline transportation of natural gas (NAICS 4862), this industry includes pipeline transportation of crude oil (NAICS 4861) and other pipeline transportation (NAICS 4869). However, the BEA data are likely representative of the affected sector since pipeline transportation of natural gas accounts for 60% of NAICS 486 establishments and 66% of revenues (Figures 1-8 and 1-9).

Table 3-15. Key Statistics: Pipeline Transportation of Natural Gas (NAICS 48621) ($2007)

Year	1997	2002
Revenue ($$10^6$)	22,964	16,368
Payroll ($$10^6$)	2,438	2,086
Employees	32,542	24,519
Establishments	1,701	1,560

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48: Transportation and Warehousing: Industry Series: Comparative Statistics for the United States (1997 NAICS Basis): 2002 and 1997. <http://factfinder.census.gov>; (December 12, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48: EC0748I1: Transportation and Warehousing: Industry Series: Preliminary Summary Statistics for the United States: 2007." http://factfinder.census.gov (January 27, 2010).

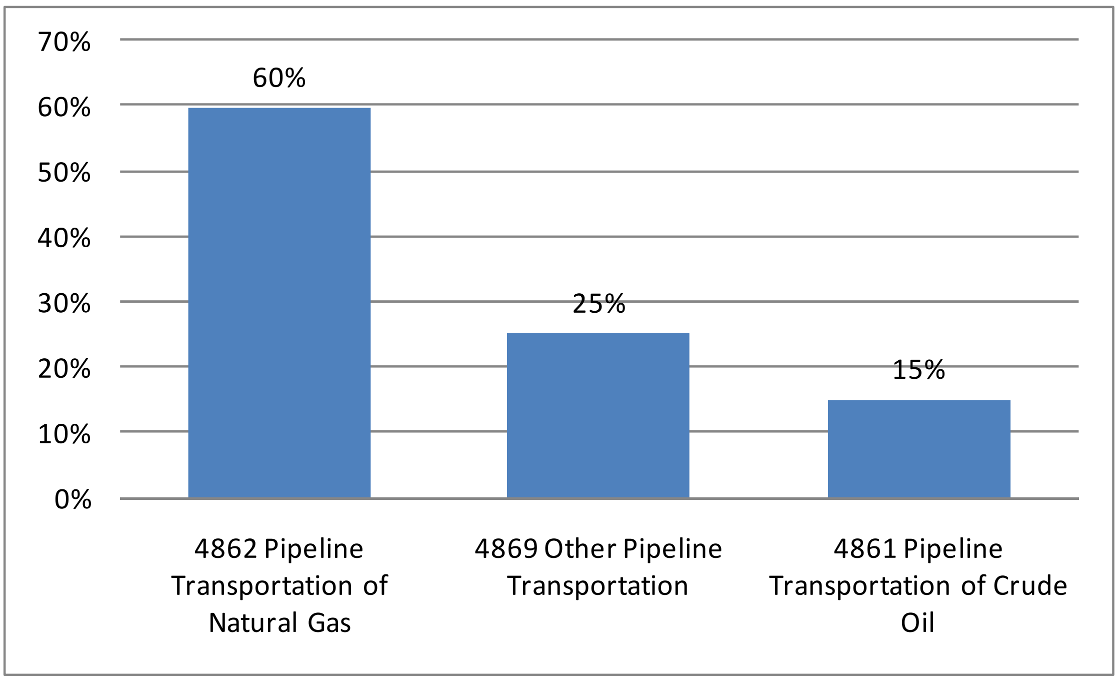

Figure 3-8. Distribution of Establishments within Pipeline Transportation (NAICS 486)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48: Transportation and Warehousing: Industry Series: Summary Statistics for the United States: 2002 <http://factfinder.census.gov>; (January 27, 2010).

In Table 3-16, we use the latest detailed benchmark input-output data report by the BEA (2002) to identify the goods and services used by pipeline transportation (NAICS 486). As shown, labor, refineries, and maintenance requirements represent significant share of the cost associated with pipeline transportation. Power and equipment requirements potentially associated with reciprocating internal combustion engines (electric power generation and distribution) represent less than 2% of the value of services.

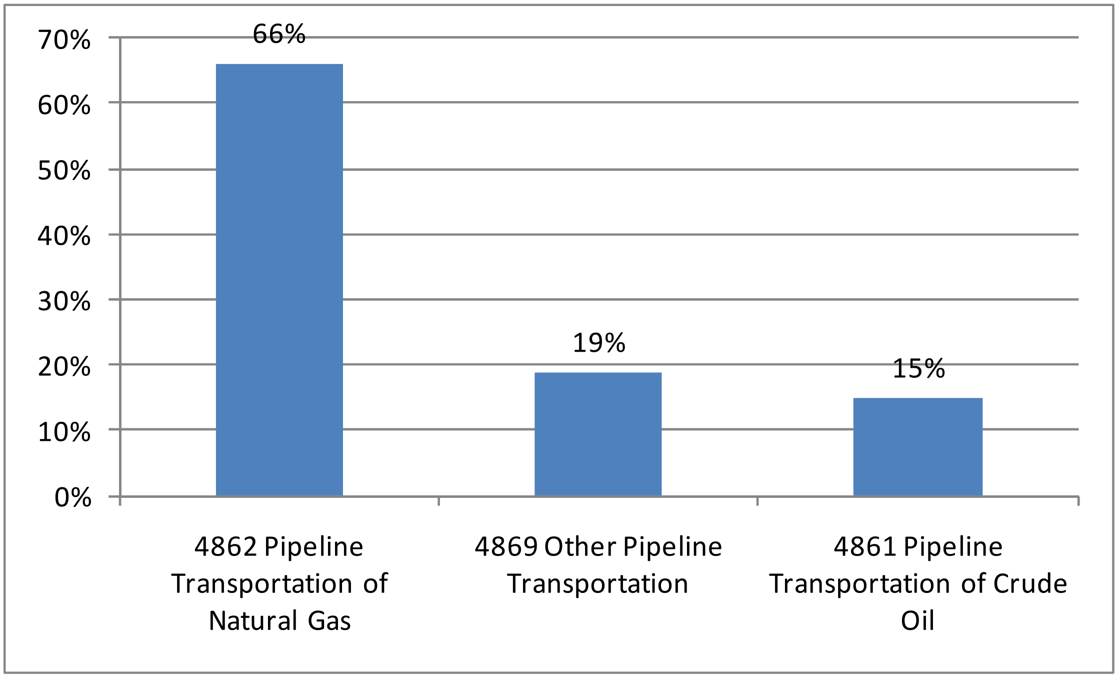

Figure 3-9. Distribution of Revenue within Pipeline Transportation (NAICS 486)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48: Transportation and Warehousing: Industry Series: Summary Statistics for the United States: 2002" <http://factfinder.census.gov>; (January 27, 2010).

3.3.3 Business Statistics

The pipeline transportation of natural gas is clearly concentrated in the two states closest to the refineries in the Gulf of Mexico. In 2002, Texas and Louisiana contributed to 31% of all pipeline transportation establishments in the United States (Figure 3-10) and 41% of all U.S. revenues. Other larger contributors with over 50 establishments in their states include Oklahoma, Pennsylvania, Kansas, Mississippi, and West Virginia.

According to 2002 U.S. Census data, about 86% of transportation of natural gas establishments were owned by corporations and about 8% were owned by individual proprietorships. About 6% were owned by partnerships (Figure 3-11). As shown in Table 3-17, the four largest firms accounted for nearly half of the establishments, and just over half, 51%, of total revenue. The 50 largest firms accounted for over 1,354 establishments and about 99% of total revenue. The average number of employees per establishment was approximately 17 across all groups of firms.

Enterprises within pipeline transportation (NAICS 486) generated $11.1 billion in total receipts in 2008. Including those enterprises without net income, the industry averaged an after-tax profit margin of 9.6% (Table 3-18).

Table 3-16. Direct Requirements for Pipeline Transportation (NAICS 486): 2002

Commodity	Commodity Description	Direct Requirements Coefficients[a]
V00100	Compensation of employees	14.78%
324110	Petroleum refineries	13.55%
230301	Nonresidential maintenance and repair	6.07%
211000	Oil and gas extraction	4.94%
333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	4.40%
561300	Employment services	4.26%
5416A0	Environmental and other technical consulting services	3.04%
541300	Architectural, engineering, and related services	3.04%
420000	Wholesale trade	2.79%
332310	Plate work and fabricated structural product manufacturing	2.72%
5419A0	All other miscellaneous professional, scientific, and technical services	2.48%
524100	Insurance carriers	2.38%
531000	Real estate	2.33%
52A000	Monetary authorities and depository credit intermediation	1.76%
V00200	Taxes on production and imports, less subsidies	1.41%
541100	Legal services	1.19%
221100	Electric power generation, transmission, and distribution	1.13%

[a] These values show the amount of the commodity required to produce $1.00 of the industry's output. The values are expressed in percentage terms (coefficient ×100).

Source: U.S. Bureau of Economic Analysis. 2002. 2002 Benchmark Input-Output Accounts: Detailed Make Table, Use Table and Direct Requirements Table. Tables 4 and 5.

The 2002 SUSB shows that 47% of all firms in this industry made under $5 million in revenue. Enterprises with revenue over $100 million provided an overwhelming share of employment in this industry (98%) (Table 3-19).

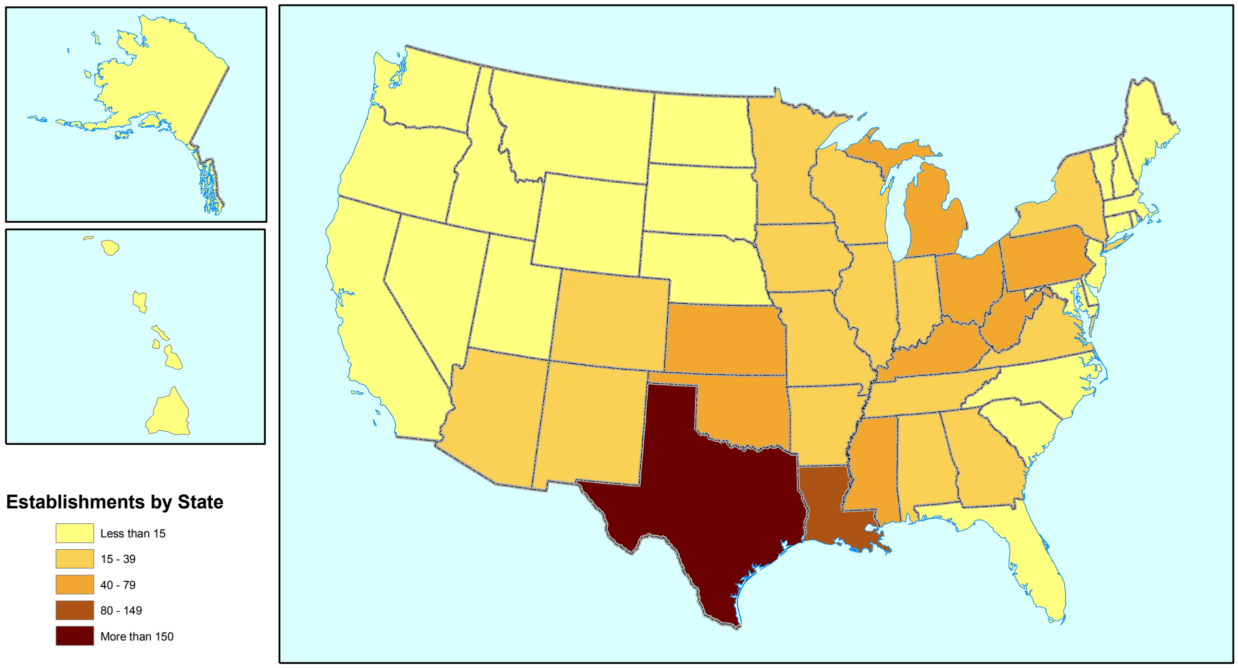

Figure 3-10. 2002 Regional Distribution of Establishments: Pipeline Transportation (NAICS 486)

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48-49: Geographic Distribution—Pipeline transportation of natural gas: 2002. <http://factfinder.census.gov>; (November 10, 2008).

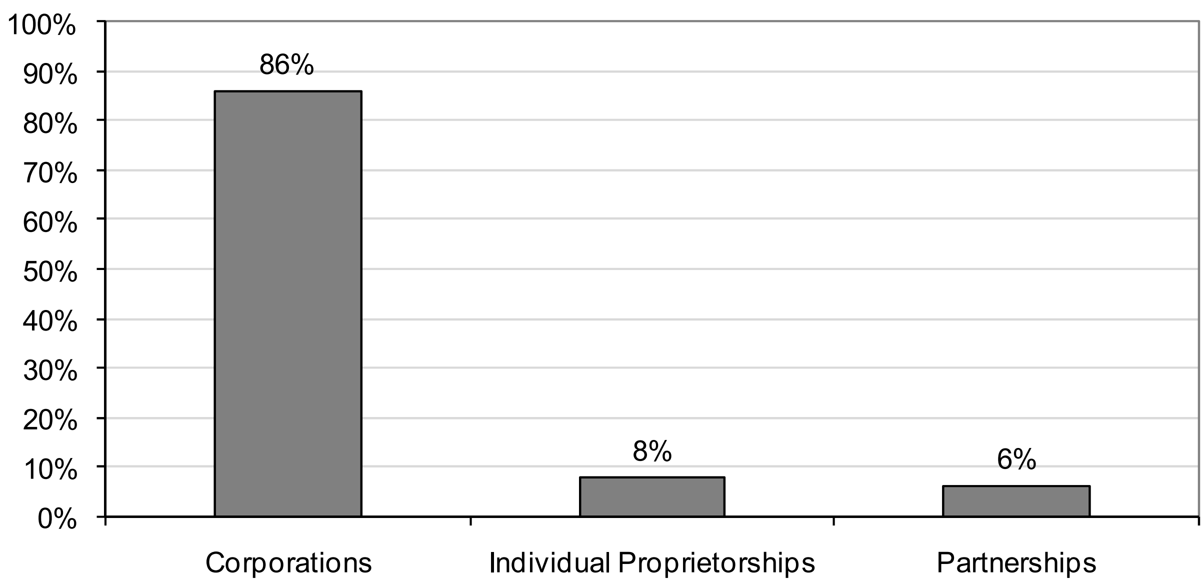

Figure 3-11. Share of Establishments by Legal Form of Organization in the Pipeline Transportation of Natural Gas Industry (NAICS 48621): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48-49: Transportation and Warehousing: Subject Series—Estab & Firm Size: Legal Form of Organization for the United States: 2002. <http://factfinder.census.gov>; (December 12, 2008).

Table 3-17. Firm Concentration for Pipeline Transportation of Natural Gas (NAICS 48621): 2002

Commodity	Establishments	Receipts/Revenue: Amount ($\$10^6$)	Receipts/Revenue: Percentage of Total	Number of Employees	Employees per Establishment
All firms	1,431	$14,797	100%	23,677	16.5
4 largest firms	698	$7,551	51%	11,814	16.9
8 largest firms	912	$10,059	68%	15,296	16.8
20 largest firms	1,283	$13,730	93%	21,792	17.0
50 largest firms	1,354	$14,718	99%	23,346	17.2

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 48: Transportation and Warehousing: Subject Series—Estab & Firm Size: Concentration by Largest Firms for the United States: 2002" <http://factfinder.census.gov>; (December 12, 2008).

Table 3-18. Aggregate Tax Data for Accounting Period 7/07–6/08: NAICS 486

Number of enterprises[a]	321
Total receipts (10^3)	$11,062,608
Net sales (10^3)	$10,210,083
Profit margin before tax	13.2%
Profit margin after tax	9.6%

[a] Includes corporations with and without net income.

Source: Internal Revenue Service, U.S. Department of Treasury. 2010. "Corporation Source Book: Data Files 2004-2007." <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>; (May 2, 2010).

Table 3-19. Key Enterprise Statistics by Receipt Size for Pipeline Transportation of Natural Gas (NAICS 48621): 2002

Variable	All Enterprises	Owned by Enterprises with 0–99K Receipts	100–499.9K Receipts	500–999.9K Receipts	1,000–4,999.9K Receipts	5,000,000–9,999,999K Receipts	<10,000K Receipts	10,000–49,999K Receipts	50,000–99,999K Receipts	100,000K+ Receipts
Firms	154	8	32	10	22	6	78	11	4	61
Establishments	1,936	8	32	10	22	7	79	21	4	1,832
Employment	37,450	15	58	69	138	88	368	216	274	36,592
Receipts ($$10^3$)	$35,896,535	$524	$8,681	$7,451	$46,429	$40,967	$104,052	$188,424	$154,384	$35,449,675
Receipts/firm ($$10^3$)	$233,094	$66	$271	$745	$2,110	$6,828	$1,334	$17,129	$38,596	$581,142
Receipts/establishment ($$10^3$)	$18,542	$66	$271	$745	$2,110	$5,852	$1,317	$8,973	$38,596	$19,350
Receipts/employment ($)	$958,519	$34,933	$149,672	$107,986	$336,442	$465,534	$282,750	$872,333	$563,445	$968,782

Source: U.S. Census Bureau. 2008b. Firm Size Data from the Statistics of U.S. Businesses, U.S. All Industries Tabulated by Receipt Size: 2002. http://www2.census.gov/csd/susb/2002/usalli_r02.xls.

SECTION 4
REGULATORY ALTERNATIVES, COSTS, AND EMISSION IMPACTS

4.1 Background

This action promulgates NESHAP for existing stationary SI RICE with a site rating of less than or equal to 500 HP located at major sources, and existing stationary SI RICE of any site rating located at area sources. EPA is finalizing these standards to meet its statutory obligation to address HAP emissions from these sources under sections 112(d), 112(c)(3) and 112(k) of the CAA. The final NESHAP for stationary RICE will be promulgated under 40 CFR part 63, subpart ZZZZ, which already contains standards applicable to new and reconstructed stationary RICE and some existing stationary RICE.

EPA promulgated NESHAP for existing, new, and reconstructed stationary RICE greater than 500 HP located at major sources on June 15, 2004 (69 FR 33474). EPA promulgated NESHAP for new and reconstructed stationary RICE that are located at area sources of HAP emissions and for new and reconstructed stationary RICE that have a site rating of less than or equal to 500 HP that are located at major sources of HAP emissions on January 18, 2008 (73 FR 3568). On March 3, 2010, EPA promulgated NESHAP for existing stationary compression ignition (CI) RICE with a site rating of less than or equal to 500 HP located at major sources, existing non-emergency CI engines with a site rating greater than 500 HP at major sources, and existing stationary CI RICE of any site rating located at area sources (75 FR 9674).

4.2 Summary of the Final Rule

4.2.1 What Is the Source Category Regulated by the Final Rule?

The final rule addresses emissions from existing stationary SI engines less than or equal to 500 HP located at major sources and all existing stationary SI engines located at area sources. A major source of HAP emissions is generally a stationary source that emits or has the potential to emit 10 tons per year or more of any single HAP or 25 tons per year or more of any combination of HAP. An area source of HAP emissions is a stationary source that is not a major source.

This action revises the regulations at 40 CFR part 63, subpart ZZZZ. Through this action, we are adding to 40 CFR part 63, subpart ZZZZ requirements for: existing SI stationary RICE less than or equal to 500 HP located at major sources of HAP and existing SI stationary RICE located at area sources of HAP.

4.2.1.1 Existing Stationary SI RICE ≤500 HP at Major Sources of HAP

This action revises 40 CFR part 63, subpart ZZZZ, to address HAP emissions from existing stationary SI RICE less than or equal to 500 HP located at major sources of HAP. For stationary engines less than or equal to 500 HP at major sources, EPA must determine what is the appropriate maximum achievable control technology (MACT) for those engines under sections 112(d)(2) and (d)(3) of the CAA.

EPA has divided stationary SI RICE less than or equal to 500 HP located at major sources of HAP into the following subcategories:

- Non-emergency 2-stroke lean burn (2SLB) stationary SI RICE 100-500 HP;
- Non-emergency 4-stroke lean burn (4SLB) stationary SI RICE 100-500 HP;
- Non-emergency 4-stroke rich burn (4SRB) stationary SI RICE 100-500 HP;
- Non-emergency landfill and digester gas stationary SI RICE 100-500 HP;
- Non-emergency stationary SI RICE <100 HP; and
- Emergency stationary SI RICE.

4.2.1.2 Existing Stationary SI RICE at Area Sources of HAP

This action revises 40 CFR part 63, subpart ZZZZ, in order to address HAP emissions from existing stationary SI RICE located at area sources of HAP. Section 112(d) of the CAA requires EPA to establish NESHAP for both major and area sources of HAP that are listed for regulation under CAA section 112(c). As noted above, an area source is a stationary source that is not a major source.

Section 112(k)(3)(B) of the CAA calls for EPA to identify at least 30 HAP that, as a result of emissions of area sources, pose the greatest threat to public health in the largest number of urban areas. EPA implemented this provision in 1999 in the Integrated Urban Air Toxics Strategy (64 FR 38715, July 19, 1999). Specifically, in the Strategy, EPA identified 30 HAP that pose the greatest potential health threat in urban areas, and these HAP are referred to as the "30 urban HAP." Section 112(c)(3) of the CAA requires EPA to list sufficient categories or subcategories of area sources to ensure that area sources representing 90 percent of the emissions of the 30 urban HAP are subject to regulation. EPA implemented these requirements through the Integrated Urban Air Toxics Strategy (64 FR 38715, July 19, 1999). The area source stationary engine source category was one of the listed categories. A primary goal of the Strategy is to achieve a 75 percent reduction in cancer incidence attributable to HAP emitted from stationary sources.

Under CAA section 112(d)(5), EPA may elect to promulgate standards or requirements for area sources "which provide for the use of generally available control technologies or management practices by such sources to reduce emissions of hazardous air pollutants." Additional information on generally available control technologies (GACT) and management practices is found in the Senate report on the legislation (Senate report Number 101-228, December 20, 1989), which describes GACT as:

> . . . methods, practices and techniques which are commercially available and appropriate for application by the sources in the category considering economic impacts and the technical capabilities of the firms to operate and maintain the emissions control systems.

Consistent with the legislative history, EPA can consider costs and economic impacts in determining GACT, which is particularly important when developing regulations for source categories, like this one, that have many small businesses.

Determining what constitutes GACT involves considering the control technologies and management practices that are generally available to the area sources in the source category. EPA also considers the standards applicable to major sources in the same industrial sector to determine if the control technologies and management practices are transferable and generally available to area sources. In appropriate circumstances, EPA may also consider technologies and practices at area and major sources in similar categories to determine whether such technologies and practices could be considered generally available for the area source category at issue. Finally, as EPA has already noted, in determining GACT for a particular area source category, EPA considers the costs and economic impacts of available control technologies and management practices on that category.

The urban HAP that must be regulated from stationary SI RICE to achieve the CAA section 112(c)(3) requirement to regulate categories accounting for 90 percent of the urban HAP are: 7 polycyclic aromatic hydrocarbons (PAH), formaldehyde, and acetaldehyde.

Similar to existing stationary SI RICE at major sources, EPA has also divided the existing stationary SI RICE at area sources into subcategories in order to properly take into account the differences between these engines. The subcategories for stationary SI RICE at area sources are as follows:

- Non-emergency 2SLB stationary SI RICE

- Non-emergency 4SLB stationary SI RICE
  - ≤500 HP
  - >500 HP
- Non-emergency 4SRB stationary SI RICE
  - ≤500 HP
  - >500 HP
- Non-emergency landfill and digester gas stationary SI RICE
- Emergency stationary SI RICE.

4.2.2 What Are the Pollutants Regulated by the Rule?

The final rule regulates emissions of HAP. Available emissions data show that several HAP, which are formed during the combustion process or which are contained within the fuel burned, are emitted from stationary engines. The HAP which have been measured in emission tests conducted on SI stationary RICE include: formaldehyde, acetaldehyde, acrolein, methanol, benzene, toluene, 1,3-butadiene, 2,2,4-trimethylpentane, hexane, xylene, naphthalene, PAH, methylene chloride, and ethylbenzene. EPA described the health effects of these HAP and other HAP emitted from the operation of stationary RICE in the preamble to 40 CFR part 63, subpart ZZZZ, published on June 15, 2004 (69 FR 33474). These HAP emissions are known to cause, or contribute significantly to air pollution, which may reasonably be anticipated to endanger public health or welfare.

For the standards being finalized in this action, EPA believes that previous determinations regarding the appropriateness of using formaldehyde and carbon monoxide (CO) both in concentration (parts per million [ppm]) levels as surrogates for HAP for stationary RICE are still valid. Consequently, EPA is promulgating CO or formaldehyde standards in order to regulate HAP emissions.

In addition to reducing HAP, the emission control technologies that will be installed on stationary RICE to reduce HAP will also reduce CO and VOC, and for rich burn engines will also reduce NOx.

4.2.3 What Are the Final Requirements?

4.2.3.1 Existing Stationary SI RICE ≤500 HP at Major Sources

The numerical emission standards that are being finalized for existing stationary non-emergency SI RICE less than or equal to 500 HP located at major sources of HAP are shown in Table 4-1. The emission standards are in units of ppm by volume, dry basis (ppmvd).

Table 4-1. Emission Standards for Existing Stationary SI RICE ≤500 HP Located at Major Sources of HAP

Subcategory	Except during Periods of Startup
2SLB Non-Emergency 100≤HP≤500	225 ppmvd CO at 15% O_2
4SLB Non-Emergency 100≤HP≤500	47 ppmvd CO at 15% O_2
4SRB Non-Emergency 100≤HP≤500	10.3 ppmvd formaldehyde at 15% O_2
Landfill/Digester Gas Non-Emergency 100≤HP≤500	177 ppmvd CO at 15% O_2

EPA is finalizing work practice standards for existing emergency stationary SI RICE less than or equal to 500 HP located at major sources of HAP and existing non-emergency stationary SI RICE less than 100 HP located at major sources of HAP. Existing stationary emergency SI RICE less than or equal to 500 HP located at major sources of HAP are subject to the following work practices:

- Change oil and filter every 500 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;
- Inspect spark plugs every 1000 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.

Existing stationary SI RICE less than 100 HP located at major sources of HAP that are not 2SLB stationary RICE are subject to the following work practices:

- Change oil and filter every 1,440 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;

- Inspect spark plugs every 1,440 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 1,440 hours of operation or annually, whichever comes first, and replace as necessary.

Existing 2SLB stationary SI RICE less than 100 HP located at major sources of HAP are subject to the following work practices:

- Change oil and filter every 4,320 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;
- Inspect spark plugs every 4,320 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 4,320 hours of operation or annually, whichever comes first, and replace as necessary.

Sources also have the option to use an oil change analysis program to extend the oil change frequencies specified above. The analysis program must at a minimum analyze the following three parameters: Total Acid Number, viscosity, and percent water content. The analysis must be conducted at the same frequencies specified for changing the engine oil. If the condemning limits provided below are not exceeded, the engine owner or operator is not required to change the oil. If any of the condemning limits are exceeded, the engine owner or operator must change the oil within two days of receiving the results of the analysis; if the engine is not in operation when the results of the analysis are received, the engine owner or operator must change the oil within two days or before commencing operation, whichever is later. The condemning limits are as follows:

- Total Acid Number increases by more than 3.0 milligrams (mg) potassium hydroxide per gram (KOH/g) from Total Acid Number of the oil when new; or
- viscosity of the oil changes by more than 20 percent from the viscosity of the oil when new; or
- percent water content (by volume) is greater than 0.5.

Pursuant to the provisions of 40 CFR 63.6(g), sources can also request that the Administrator approve alternative work practices.

4.2.3.2 Existing Stationary SI RICE at Area Sources of HAP.

The numerical emission standards that EPA is finalizing for non-emergency 4SLB stationary SI RICE and non-emergency 4SRB stationary SI RICE located at area sources of HAP are shown in Table 4-2.

Table 4-2. Numerical Emission Standards for Existing Non-Emergency Stationary 4SLB and 4SRB SI RICE >500 HP Located at Area Sources of HAP

Subcategory	Except during Periods of Startup
4SLB Non-Emergency >500 HP that operate more than 24 hours per calendar year	47 ppmvd CO at 15% O_2 or 93% CO reduction
4SRB Non-Emergency >500 HP that operate more than 24 hours per calendar year	2.7 ppmvd formaldehyde at 15% O_2 or 76% formaldehyde reduction

EPA is finalizing management practices for existing non-emergency 4SLB stationary SI RICE less than or equal to 500 HP located at area sources of HAP, existing non-emergency 4SLB stationary SI RICE greater than 500 HP located at area sources of HAP that operate 24 hours or less per calendar year, existing non-emergency 4SRB stationary SI RICE less than or equal to 500 HP located at area sources of HAP, existing non-emergency 4SRB stationary SI RICE greater than 500 HP located at area sources of HAP that operate 24 hours or less per calendar year, existing 2SLB non-emergency stationary SI RICE located at area sources of HAP, existing non-emergency landfill and digester gas stationary RICE located at area sources of HAP, and existing emergency stationary SI RICE located at area sources of HAP.

Existing non-emergency 4SLB and 4SRB stationary SI RICE less than or equal to 500 HP located at area sources of HAP and existing landfill or digester gas non-emergency stationary SI RICE located at area sources of HAP are subject to the following management practices:

- Change oil and filter every 1,440 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;
- Inspect spark plugs every 1,440 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 1,440 hours of operation or annually, whichever comes first, and replace as necessary.

Existing stationary 2SLB non-emergency engines located at area sources of HAP are subject to the following work practices:

- Change oil and filter every 4,320 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;
- Inspect spark plugs every 4,320 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 4,320 hours of operation or annually, whichever comes first, and replace as necessary.

Existing stationary emergency SI RICE located at area sources of HAP and existing non-emergency 4SLB and 4SRB stationary SI RICE greater than 500 HP located at area sources of HAP that operate 24 hours or less per calendar year are subject to the following work practices:

- Change oil and filter every 500 hours of operation or annually, whichever comes first, except that sources can extend the period for changing the oil if the oil is part of an oil analysis program as discussed below and none of the condemning limits are exceeded;
- Inspect spark plugs every 1,000 hours of operation or annually, whichever comes first, and replace as necessary; and
- Inspect all hoses and belts every 500 hours of operation or annually, whichever comes first, and replace as necessary.

As discussed above for major sources, these sources may utilize an oil analysis program in order to extend the specified oil change requirement specified above. Also, sources have the option to work with state permitting authorities pursuant to EPA's regulations at 40 CFR subpart E ("Approval of State Programs and Delegation of Federal Authorities") for approval of alternative management practices. 40 CFR subpart E implements section 112(l) of the CAA, which authorizes EPA to approve alternative state/local/tribal HAP standards or programs when such requirements are demonstrated to be no less stringent than EPA promulgated standards.

4.2.3.3 Startup Requirements

Existing stationary SI RICE less than or equal to 500 HP located at major sources of HAP and existing stationary SI RICE located at area sources of HAP must meet specific operational standards during engine startup. Engine startup is defined as the time from initial start until applied load and engine and associated equipment reaches steady state or normal operation. For stationary engines with catalytic controls, engine startup means the time from initial start until applied load and engine and associated equipment reaches steady state, or normal operation, including the catalyst. Owners and operators must minimize the engine's time spent at idle and minimize the engine's startup to a period needed for appropriate and safe loading of the engine, not to exceed 30 minutes, after which time the engine must meet the otherwise applicable emission standards. These requirements will limit the HAP emissions during periods of engine startup. Pursuant to the provisions of 40 CFR 63.6(g), engines at major sources may petition the Administrator for an alternative work practice. An owner or operator of an engine at an area source can work with its State permitting authority pursuant to EPA's regulations at 40 CFR subpart E for approval of an alternative management practice. See 40 CFR subpart E (setting forth requirements for, among other things, equivalency by permit, rule substitution).

4.2.4 What Are the Operating Limitations?

In addition to the standards discussed above, EPA is finalizing operating limitations for stationary non-emergency 4SLB and 4SRB RICE that are greater than 500 HP and located at an area source of HAP and operated more than 24 hours per calendar year. Owners and operators of engines that are equipped with oxidation catalyst or non-selective catalytic reduction (NSCR) must maintain the catalyst so that the pressure drop across the catalyst does not change by more than 2 inches of water from the pressure drop across the catalyst that was measured during the initial performance test. If the engine is equipped with oxidation catalyst, owners and operators must also maintain the temperature of the stationary RICE exhaust so that the catalyst inlet temperature is between 450 and 1,350 degrees Fahrenheit (°F). If the engine is equipped with NSCR, owners and operators must maintain the temperature of the stationary RICE exhaust so that the NSCR inlet temperature is between 750 and 1,250 °F. Owners and operators may petition for a different temperature range; the petition must demonstrate why it is operationally necessary and appropriate to operate below the temperature range specified in the final rule (see 40 CFR 63.8(f)). Owners and operators of engines that are not using oxidation catalyst or NSCR must comply with any operating limitations approved by the Administrator.

4.2.5 What Are the Requirements for Demonstrating Compliance?

The following sections describe the requirements for demonstrating compliance under the final rule.

4.2.5.1 Existing Stationary SI RICE ≤500 at Major Sources of HAP.

Owners and operators of existing stationary non-emergency SI RICE located at major sources that are less than 100 HP and existing stationary emergency SI RICE located at major sources must operate and maintain their stationary RICE and aftertreatment control device (if any) according to the manufacturer's emission-related written instructions or develop their own maintenance plan. The maintenance plan must specify how the work practices will be met and provide to the extent practicable for the maintenance and operation of the engine in a manner consistent with good air pollution control practices for minimizing emissions. Owners and operators of existing stationary non-emergency SI RICE located at major sources that are less than 100 HP and existing stationary emergency SI RICE located at major sources do not have to conduct any performance testing because they are not subject to numerical emission standards.

Owners and operators of existing stationary non-emergency SI RICE located at major sources that are greater than or equal to 100 HP and less than or equal to 500 HP must conduct an initial performance test to demonstrate that they are achieving the required emission standards.

4.2.5.2 Existing Stationary SI RICE at Area Sources of HAP

Owners and operators of existing stationary RICE located at area sources of HAP that are subject to management practices do not have to conduct any performance testing; they must develop a maintenance plan that specifies how the management practices will be met and provides to the extent practicable for the maintenance and operation of the engine in a manner consistent with good air pollution control practices for minimizing emissions. Owners and operators of existing 4SLB and 4SRB non-emergency stationary SI RICE that are greater than 500 HP and located at an area source of HAP , and operated more than 24 hours per calendar year must conduct an initial performance test to demonstrate compliance with the applicable emission limitations and must conduct subsequent performance testing every 8,760 hours of operation or 3 years, whichever comes first. Owners and operators of existing 4SLB and 4SRB non-emergency stationary SI RICE that are greater than 500 HP and located at an area source of HAP , and operated more than 24 hours per calendar year must continuously monitor and record the inlet temperature of the oxidation catalyst or NSCR and also take monthly measurements of the pressure drop across the oxidation catalyst or NSCR. If an oxidation catalyst or NSCR is not being used on the engine, the owner or operator must continuously monitor and record the operating parameters (if any) approved by the Administrator. As discussed in the March 3, 2010, final NESHAP for existing stationary CI RICE (75 FR 9648) and in section V.E. of the preamble, EPA is finalizing performance specification requirements in 40 CFR part 63, subpart ZZZZ for the continuous parametric monitoring systems used for continuous catalyst inlet temperature monitoring.

4.2.6 What Are the Reporting and Recordkeeping Requirements?

The following sections describe the reporting and recordkeeping requirements that are required under the final rule.

Owners and operators of existing stationary emergency SI RICE that do not meet the requirements for non-emergency engines are required to keep records of their hours of operation. Owners and operators of existing stationary emergency SI RICE must install a non-resettable hour meter on their engines to record the hours of operation of the engine.

Owners and operators of existing stationary SI RICE located at major sources that are subject to work practices and existing stationary SI RICE located at area sources that are subject to management practices are required to keep records that show that the work or management practices that are required are being met. These records must include, at a minimum: oil and filter change dates and engine hours of operation; inspection and replacement dates for spark plugs, hoses, and belts; and records of other emission-related repairs and maintenance performed.

In terms of reporting requirements, owners and operators of existing non-emergency stationary SI RICE greater than or equal to 100 HP and less than or equal to 500 HP located at major sources of HAP and existing non-emergency 4SLB and 4SRB stationary RICE greater than 500 HP located at area sources of HAP that are operated more than 24 hours per calendar year must submit the notifications required in Table 8 of 40 CFR part 63, subpart ZZZZ, which lists the NESHAP General Provisions applicable to this rule. (40 CFR part 63, subpart A) These notifications include an initial notification, notification of performance test, and a notification of compliance for each stationary RICE which must comply with the specified emission limitations. Owners and operators of existing stationary non-emergency SI RICE greater than or equal to 100 HP and less than or equal to 500 HP located at major sources of HAP and existing stationary 4SLB and 4SRB non-emergency SI RICE greater than 500 HP located at area sources of HAP that are operated more than 24 hours per calendar year must submit semiannual compliance reports.

4.3 Summary of Significant Changes Since Proposal

4.3.1 Applicability

A change from the proposal is that the final rule is not applicable to existing stationary emergency engines at area sources that are located at residential, commercial, or institutional facilities. These engines are not subject to any requirements under the final rule because they are not part of the regulated source category. EPA has found that existing stationary emergency engines located at residential, commercial, and institutional facilities that are area sources were not included in the original Urban Air Toxics Strategy inventory and were not included in the listing of urban area sources. More information on this issue can be found in the memorandum titled, "Analysis of the Types of Engines Used to Estimate the CAA Section 112(k) Area Source Inventory for Stationary Reciprocating Internal Combustion Engines," available from the rulemaking docket. In the March 3, 2010, final NESHAP for existing stationary CI RICE (75 FR 9648), EPA included a definition for residential/commercial/institutional emergency stationary RICE. After the final rule was promulgated, EPA received numerous questions regarding the definition and whether certain types of facilities would meet the definition. In the final rule, EPA is separating the definition into individual definitions for residential emergency stationary RICE, commercial emergency stationary RICE, and institutional emergency stationary RICE, and is also providing additional examples of the types of facilities that would be included under those categories in the definitions. EPA has also prepared a memorandum to provide further guidance regarding the types of facilities that would or would not be considered residential, commercial, or institutional facilities. The memorandum is titled, "Guidance Regarding Definition of Residential, Commercial, and Institutional Emergency Stationary RICE in the NESHAP for Stationary RICE," and is available in the rulemaking docket.

4.3.2 Final Emission Standards

4.3.2.1 Existing Stationary SI Engines ≤500 HP Located at Major Sources of HAP

EPA is revising the emission standards that it proposed for the subcategories of stationary SI engines less than or equal to 500 HP located at major sources. As discussed in section V.B. of the preamble, numerous commenters indicated that EPA's dataset used to establish the proposed emission limits was insufficient and urged EPA to gather more data to obtain a more complete representation of emissions from existing stationary SI engines. Commenters also questioned the emission standard setting approach that EPA used at proposal and claimed that the proposed standards did not take into account emissions variability. For the final rule, EPA has obtained additional test data for existing stationary SI engines and has included this additional data in the MACT floor analysis. EPA is also using an approach that better considers emissions variability, as discussed below. EPA is also not using the Population Database to determine a percentage of engines that have emission controls installed, as it did at proposal. The Population Database has not been updated since 2000. It contains information regarding whether or not an engine has emission controls, but does not generally contain other types of emission-related information, like engine-out emissions or operational controls, and it does not include any emissions concentration data, which is necessary to determine the MACT floor. EPA determined that it would be more appropriate and more defensible to base the MACT floor analysis directly on the emissions data that EPA has for stationary SI engines.

For 2SLB non-emergency engines, EPA proposed a limit of 85 ppmvd CO for engines from 50 to 249 HP and 8 ppmvd CO or 90 percent CO reduction for engines greater than or equal to 250 HP. EPA is finalizing an emission limit of 225 ppmvd CO for 2SLB non-emergency engines from 100 to 500 HP. For 4SLB non-emergency engines, EPA proposed a limit of 95 ppmvd CO for engines from 50 to 249 HP and 9 ppmvd CO or 90 percent CO reduction for engines greater than or equal to 250 HP. EPA is finalizing an emission limit of 47 ppmvd CO for 4SLB non-emergency engines from 100 to 500 HP. For 4SRB non-emergency engines from 50 to 500 HP, EPA proposed an emission limit of 200 ppbvd (parts per billion by volume, dry basis) formaldehyde or 90 percent formaldehyde reduction. EPA is finalizing an emission limit of 10.3 ppmvd formaldehyde for 4SRB non-emergency engines from 100 to 500 HP. For landfill and digester gas engines, EPA proposed an emission limit of 177 ppmvd CO; EPA is finalizing an emission limit of 177 ppmvd CO.

For the proposed rule, EPA required existing stationary engines less than 50 HP that are located at major sources to meet a formaldehyde emission standard. As discussed in the final rule published on March 3, 2010, for existing stationary CI RICE (75 FR 9674), EPA is not finalizing a formaldehyde emission standard for stationary SI engines less than 50 HP, but is instead requiring compliance with work practices. In addition, in light of several comments asserting that the level at which EPA subcategorized small engines at major sources was inappropriate, EPA is finalizing a work practice standard for engines less than 100 HP. These work practices are described in section III.C. of the preamble to the final rule. EPA believes that work practices are appropriate and justified for this group of stationary engines because the application of measurement methodology is not practicable due to technological and economic limitations. Further information on EPA's decision can be found in the memorandum titled, "MACT Floor and MACT Determination for Existing Stationary Non-Emergency SI RICE <100 HP and Existing Stationary Emergency SI RICE Located at Major Sources and GACT for Existing Stationary SI RICE Located at Area Sources," which is available from the rulemaking docket.

For existing stationary emergency engines located at major sources, EPA proposed that these engines be subject to a 2 ppmvd formaldehyde emission standard. In the final rule, existing stationary emergency SI engines located at major sources of HAP must meet work practices. These work practices are described in section III.C. of the preamble to the final rule. EPA believes that work practices are appropriate and justified for this group of stationary engines because the application of measurement methodology is not practicable due to technological and economic limitations. Further information on EPA's decision can be found in the memorandum titled, "MACT Floor and MACT Determination for Existing Stationary Non-Emergency SI RICE <100 HP and Existing Stationary Emergency SI RICE Located at Major Sources and GACT for Existing Stationary SI RICE Located at Area Sources," which is available from the rulemaking docket.

4.3.2.2 Existing Stationary SI Engines Located at Area Sources of HAP

EPA proposed numerical emission standards for the following stationary SI engines located at area sources of HAP: non-emergency 2SLB and 4SLB greater than or equal to 250 HP, non-emergency 4SRB greater than or equal to 50 HP, landfill and digester gas fired greater than 500 HP, and emergency greater than 500 HP. For the remaining engines at area sources, EPA proposed management practice standards.

In the final rule, EPA is promulgating numerical emission standards for non-emergency 4SLB and 4SRB stationary SI RICE larger than 500 HP located at area sources of HAP emissions that operate more than 24 hours per calendar year. For non-emergency 4SLB engines greater than 500 HP located at area sources of HAP, EPA proposed an emission limit of 9 ppmvd CO or 90 percent CO reduction; EPA is finalizing an emission limit of 47 ppmvd CO or 93 percent CO reduction. For non-emergency 4SRB engines greater than 500 HP located at area sources of HAP, EPA proposed an emission limit of 200 ppbvd formaldehyde or 90 percent formaldehyde reduction and is finalizing an emission limit of 2.7 ppmvd formaldehyde or 76 percent formaldehyde reduction. For stationary SI RICE located at area sources of HAP that are non-emergency 2SLB stationary SI RICE greater than or equal to 250 HP, non-emergency 4SLB stationary SI RICE between 250 and 500 HP, non-emergency 4SRB stationary SI RICE between 50 and 500 HP, landfill/digester gas stationary SI RICE greater than 500 HP, or emergency stationary SI RICE greater than 500 HP, EPA is finalizing management practices rather than numeric emission limitations as proposed. EPA is also finalizing management practices for non-emergency 4SLB and 4SRB stationary SI RICE that are greater than 500 HP, located at area sources of HAP, and operated 24 hours or less per calendar year.

4.3.3 Management Practices

EPA proposed management practices for several subcategories of engines located at area sources. EPA explained that the proposed management practices would be expected to ensure that emission control systems are working properly and would help minimize HAP emissions from the engines. EPA proposed specific maintenance practices and asked for comments on the need and appropriateness for those procedures. Based on feedback received during the public comment period, which included information submitted in comment letters and additional information EPA received following the close of the comment period from different industry groups, EPA is finalizing management practices for existing stationary 2SLB non-emergency SI engines located at area sources of HAP, existing stationary 4SLB and 4SRB non-emergency SI engines less than or equal to 500 HP located at area sources of HAP; existing stationary landfill and digester gas non-emergency engines located at area sources of HAP; and all existing emergency stationary SI engines located at area sources of HAP.

Based on the comments on the proposal and additional information received from stakeholders, EPA made changes to the intervals for the management practices from the proposal. EPA is also adding an option for sources to use an oil change analysis program to extend the oil change frequencies specified above. The analysis program must at a minimum analyze the following three parameters: Total Acid Number, viscosity, and percent water content. If the condemning limits for these parameters are not exceeded, the engine owner or operator is not required to change the oil. If any of the limits are exceeded, the engine owner or operator must change the oil within two days of receiving the results of the analysis; if the engine is not in operation when the results of the analysis are received, the engine owner or operator must change the oil within two days or before commencing operation, whichever is later. Owners and operators of all engines subject to management practices also have the option to work with State permitting authorities pursuant to EPA's regulations at 40 CFR subpart E for alternative management practices to be used instead of the specific management practices promulgated in the final rule. The management practices must be at least as stringent as those specified in the final rule.

4.3.4 Startup, Shutdown, and Malfunction

EPA proposed formaldehyde and CO emission standards for existing stationary engines at major sources to apply during periods of startup and malfunction. EPA also proposed certain standards for existing stationary engines at area sources that would apply during startup and malfunction. EPA did not propose distinct standards for periods of shutdown. EPA proposed that engines would be subject to the same standards during shutdown as are applicable during other periods of operation.

Based on various comments and concerns with the proposed emission standards for periods of startup, EPA has determined that it is not feasible to finalize numerical emission standards that would apply during startup because the application of measurement methodology to this operation is not practicable due to technological and economic limitations. This issue is discussed in detail in the final rule published on March 3, 2010 (75 FR 9674), and as discussed in the Response to Comments for this rule, the analysis is the same for the engines regulated in this final rule.

As a result, EPA is extending the operational standards during startup it promulgated in the March 3, 2010, final rule (75 FR 9674), which specify that owners and operators must limit the engine startup time to no more than 30 minutes and must minimize the engine's time spent at idle during startup, to the engines newly subject to regulation in this rule.

With respect to malfunctions, EPA proposed two options for subcategories where the proposed emission standard was based on the use of catalytic controls. The first proposed option was to have the same standards apply during normal operation and malfunctions. The second proposed option was that standards during malfunctions be based on emissions expected from the best controlled sources prior to the full warm-up of the catalytic control. For subcategories where the proposed emission standard was not based on the use of catalytic controls, we proposed the same emission limitations apply during malfunctions and periods of normal operations. EPA is finalizing the first option described above, which is that the same standards apply during normal operation and malfunctions. In the proposed rule, EPA expressed the view that there are different modes of operation for any stationary source, and that these modes generally include startup, normal operations, shutdown, and malfunctions. However, as discussed in detail in the final rule published on March 3, 2010 (75 FR 9674), and as discussed in the Response to Comments for this rule, after considering the issue of malfunctions more carefully, EPA has determined that malfunctions should not be viewed as a distinct operating mode and, therefore, any emissions that occur at such times do not need to be factored into development of CAA section 112(d) standards, which, once promulgated, apply at all times. In addition, as discussed in detail in the final rule published on March 3, 2010 (75 FR 9674), and as discussed in the Response to Comments for this rule, EPA believes that malfunctions will not cause stationary engines to violate the standard that applies during normal operations. Therefore, the standards that apply during normal operation also apply during malfunction.

4.3.5 Method 323

EPA proposed to remove Method 323 as an option for determining compliance with formaldehyde emission limitations in 40 CFR part 63, subpart ZZZZ. EPA Method 323 was first proposed as part of the NESHAP for Stationary Combustion Turbines published January 14, 2003, (68 FR 1888) for measuring formaldehyde emissions from natural gas-fired sources.

However, the method was not included in the final Stationary Combustion Turbines NESHAP due to reliability concerns and EPA never promulgated EPA Method 323 as a final standard in 40 CFR part 63, appendix A. Due to unresolved technical issues with the method affecting engine test results, EPA found it appropriate to propose to remove the method from 40 CFR part 63, subpart ZZZZ. As discussed in greater detail in section V.D. of the preamble, after EPA proposed to remove Method 323 as a compliance test Method, the Agency received test data comparing Method 323 to EPA Method 320. The results of this comparison testing showed good agreement between the two methods and there was no evidence of bias in the results from Method 323. Therefore, EPA has determined that it is appropriate to promulgate Method 323 and to allow it as an option for measuring formaldehyde in 40 CFR part 63 subpart ZZZZ.

4.4 Cost Impacts

4.4.1 Introduction

EPA has determined that oxidation catalysts for two-stroke lean burn (2SLB) and four-stroke lean burn (4SLB) engines, and non-selective catalytic reduction (NSCR) for four-stroke rich burn (4SRB) engines are applicable controls for HAP reduction from existing stationary SI RICE. To determine the capital and annual costs for these control technologies, equipment cost information was obtained from industry groups[2] and vendors and manufacturers of SI engine control technology. In some cases, the industry groups provided a breakdown of the capital and annual cost components for each of the retrofit options. Using this cost data, annualized cost and capital cost equations for oxidation catalysts and NSCR were developed.

4.4.2 Control Cost Methodology

The following sections describe the methodology used to derive the total capital and total annual costs for each of the control technology options. These methodologies were used to calculate total capital and total annual costs when only purchased equipment costs were available (e.g., vendor equipment costs). The methodologies were not used for cost data provided by industry groups because they included a breakdown of the actual total capital and total annual costs. A summary of the methodologies, equations, and assumptions used to estimate the total capital and total annual costs for some of the cost data are described in the following sections.

[2] Reciprocating Internal Combustion Engine National Emission Standards for Hazardous Air Pollutants (RICE NESHAP) Proposed Revisions – Emission Control Costs Analysis Background for “Above the Floor” Emission Controls for Natural Gas-Fired RICE, Innovative Environmental Solutions Inc., October 2009. (EPA-HQ-OAR-2008-0708-0279).

4.4.2.1 Total Capital Costs

The total capital cost includes the direct and indirect costs of purchasing and installing the control equipment. The direct cost includes the cost of purchasing the equipment and instrumentation, cost of shipping, and the cost of installing the control equipment. The indirect cost includes the costs for engineering, contractor fees, testing costs, and also includes costs for contingencies, such as additional modifications, or delays in startup. The total capital cost equation can be summarized as follows:

Total Capital Cost (TCC) = Direct Costs (DC) + Indirect Costs (IC)

The direct costs include the costs of purchasing and installing the control equipment and can be summarized using the following equation;

DC = Purchased Equipment Cost (PEC) + Direct Installation Costs (DIC).

A summary of the cost assumptions for PEC includes the following:

- Control Device and Auxiliary Equipment (EC);
- Instrumentation (10% of EC);
- Sales Tax (3% of EC);
- Freight (5% of EC);

and can be summarized as:

PEC = 118% EC.

A summary of the cost assumptions for DIC includes the following:

- Foundations and Supports (8% of PEC);
- Handling and Erection (14% of PEC);
- Electrical (4% of PEC);
- Piping (2% of PEC);
- Insulation for Ductwork (1% of PEC);
- Painting (1% of PEC);

and can be summarized as:

$$DIC = 30\% \text{ PEC} = 0.3 \text{ PEC}.$$

Therefore, the direct costs can be simplified using the following equation:

$$DC = PEC + 0.3 \text{ PEC} = 1.3 \text{ PEC}.$$

The indirect costs include the costs of engineering and contractor fees and contingencies and can be summarized using the following equation:

$$IC = \text{Indirect Installation Costs (ICC)} + \text{Contingencies (C)}.$$

A summary of the cost assumptions for ICC includes the following:

- Engineering (10% of PEC);
- Construction and Field Expenses (5% of PEC);
- Contractor Fees (10% of PEC);
- Startup (2% of PEC);
- Performance Test (1% of PEC);

and can be summarized as:

$$IIC = 28\% \text{ PEC} = 0.28 \text{ PEC}.$$

A summary of the cost assumptions for C includes the following:

- Equipment Redesign and Modifications;
- Cost Escalations;
- Delays in Startup;

and is assumed to be:

$$C = 3\% \text{ PEC} = 0.03 \text{ PEC}.$$

Therefore, the IC can be summarized using the following equation:

$$IC = 0.28 \text{ PEC} + 0.03 \text{ PEC} = 0.31 \text{ PEC},$$

and the simplified TCC equation can be expressed as:

$$TCC = 1.3\ PEC + 0.31\ PEC = 1.61\ PEC = 1.61\ (1.18\ EC) = 1.9\ EC$$

4.4.2.2 Total Annual Costs

The total annual cost includes the direct and indirect annual costs of operating and maintaining the control equipment. The direct annual cost includes the cost of the utilities, operating labor, and control device cleaning and maintenance. The indirect annual cost includes the overhead costs such as spare parts for the control equipment, administrative charges, and the capital recovery of the control technology. The total annual cost equation can be summarized as follows:

Total Annual Cost (TAC) = Direct Annual Costs (DAC) + Indirect Annual Costs (IAC).

The DAC includes the following parameters:

- Utilities;
- Operating Labor;
- Maintenance;
- Annual Compliance Test;
- Catalyst Cleaning;
- Catalyst Replacement;
- Catalyst Disposal.

The IAC includes the following parameters:

- Overhead;
- Fuel Penalty;
- Property Tax;
- Insurance;
- Administrative Charges;
- Capital Recovery = $\{I(1+I)^n/((1+I)^n-1)*TCC\}$ where I is the interest rate, and n is the equipment life.

To calculate DAC, the costs were broken up into three separate costs: operation and maintenance materials cost, operation and maintenance labor cost, and the cost for annual performance testing or downtime or allowance for catalyst washing. Actual annual cost data from the industry groups were used to estimate the DAC for each of the control technologies. The IAC was broken up into three separate costs: administrative, fuel penalty, and capital recovery. Again, cost data from the industry groups was used to estimate these costs for each of the control technologies. No fuel penalty was estimated for the oxidation catalyst control technologies, because this control technology does not increase the fuel usage of the SI engine.

4.4.3 Control Cost Equations

Control cost equations were developed for 2SLB oxidation catalyst, 4SLB oxidation catalyst, and a NSCR for 4SRB engines using the total capital cost and total annual cost data for each control technology. Control cost equations for 2SLB and 4SLB oxidation catalysts were developed separately because the 2SLB oxidation catalyst requires a premium catalyst to reduce the HAP compounds because of the low exhaust temperature of 2SLB engines.

4.4.3.1 2SLB Oxidation Catalyst

The 2SLB oxidation catalyst is an effective control technology that reduces HAP emissions from a 2SLB SI engine by oxidizing organic compounds using a catalyst. The oxidation catalyst unit contains a honeycomb-like structure or substrate with a large surface area that is coated with a premium active catalyst layer such as platinum or palladium. The oxidation catalyst works by oxidizing carbon monoxide (CO) and gaseous hydrocarbons (HAP) in the exhaust gas to carbon dioxide (CO_2) and water. The reduction of CO and HAP varies depending on the type of catalyst used and the exhaust temperature of the pollutant stream.

The cost of retrofitting an oxidation catalyst to an existing 2SLB engine was estimated using cost data obtained from vendors and industry groups covering engines ranging from 58 horsepower (HP) to 4,670 HP. An equipment life of 10 years and an interest rate of 7 percent were used to estimate the capital recovery of the control technology and the fuel penalty was assumed to be negligible. The cost equations are presented in 2009 dollars.

The total annualized cost equation for retrofitting an oxidation catalyst on a 2SLB engine was estimated to be:

$$\text{2SLB Oxidation Catalyst Total Annual Cost} = \$11.4 \times \text{HP} + \$13{,}928$$

where

HP = engine size in HP.

The linear equation has a correlation coefficient of 0.8046, which shows the data fits the equation closely. Therefore, this equation was used to estimate annualized cost for an oxidation catalyst on a 2SLB engine.

The total capital cost equation for retrofitting an oxidation catalyst on a 2SLB engine was estimated to be:

2SLB Oxidation Catalyst Total Capital Cost = \$47.1 x HP + \$41,603

where

HP = engine size in HP.

4.4.3.2 4SLB Oxidation Catalyst

The 4SLB oxidation catalyst is an effective control technology that reduces HAP emissions from a 4SLB SI engine by oxidizing organic compounds using a catalyst. The oxidation catalyst unit contains a honeycomb-like structure or substrate with a large surface area that is coated with a premium active catalyst layer such as platinum or palladium. The oxidation catalyst works by oxidizing CO and gaseous hydrocarbons (HAP) in the exhaust gas to CO_2 and water. The reductions of CO and HAP vary depending on the type of catalyst used and the exhaust temperature of the pollutant stream.

The cost of retrofitting an oxidation catalyst to an existing 4SLB engine was estimated using cost data obtained from vendors and industry groups covering engines ranging from 400 HP to 8,000 HP. Again, an equipment life of 10 years and an interest rate of 7 percent were used to estimate the capital recovery of the control technology and the fuel penalty was assumed to be negligible. The cost equations are presented in 2009 dollars.

The total annualized cost equation for retrofitting an oxidation catalyst on a 4SLB engine was estimated to be:

4SLB Oxidation Catalyst Total Annual Cost = \$1.81 x HP + \$3,442

where

HP = engine size in HP.

The linear equation has a correlation coefficient of 0.9779, which shows the data fits the equation very closely. Therefore, this equation was used to estimate annualized cost for an oxidation catalyst on a 4SLB engine.

The total capital cost equation for retrofitting an oxidation catalyst on a 4SLB SI engine was estimated to be:

$$\text{4SLB Oxidation Catalyst Total Capital Cost} = \$12.8 \times HP + \$3{,}069$$

where

HP = engine size in HP.

A summary of the cost calculations, regression analyses, and graphical representations of the annual and capital cost data are presented in Appendix A of the cost memo that is the basis for the cost data presented in this RIA.[3]

4.4.3.3 Non-Selective Catalytic Reduction

The NSCR or three-way catalyst is used to control HAP emissions from 4SRB engines. In addition to HAP reductions, NSCR also reduces the emissions of nitrogen oxides (NOx), CO, and other hydrocarbons (HC). The reduction of HAP and CO takes place through an oxidation reaction that converts HAP to CO_2 and water and converts CO to CO_2. The conversion of NOx takes place through a reduction of the NOx to nitrogen gas and oxygen.

The cost of retrofitting an NSCR on an existing 4SRB engine was estimated based on cost data received from vendors and industry groups. A linear regression analysis was done on the data set and the linear equation for annualized cost was;

$$\text{NSCR Annual Cost} = \$4.77 \times HP + \$5{,}679$$

where

HP = engine size in HP.

The linear equation has a correlation coefficient of 0.7987, which shows an acceptable representation of the cost data. Therefore, this equation was used to estimate annualized cost for retrofitting the NSCR control technology on 4SRB engines.

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[3] Memorandum from Bradley Nelson, EC/R to Melanie King, EPA. OAQPS/SPPD/ESG. Impacts Associated with NESHAP for Existing Stationary SI RICE. June 29, 2010.

The capital cost equation for retrofitting an air-to-fuel ratio (AFR) controller and NSCR on a 4SRB engine was estimated to be:

NSCR Capital Cost = $24.9 x HP + $13,118

where

HP = engine size in HP.

4.4.4 Summary

Table 4-3 presents a summary of the annual and capital control costs as a function of engine size for the control technologies applicable to existing stationary SI engines, as discussed in this memorandum.

Table 4-3. Summary of Annual and Capital Costs Equations for Existing Stationary SI Engines

HAP Control Device	Annual Cost ($2009)	Capital Cost ($2009)
2SLB Oxidation Catalyst	$11.4 x HP + $13,928	$47.1 x HP + $41,603
4SLB Oxidation Catalyst	$1.81 x HP + $3,442	$12.8 x HP + $3,069
NSCR	$4.77 x HP + $5,679	$24.9 x HP + $13,118

A summary of the annual and capital costs associated with the rule and obtained using the methodology described above are presented in Tables 4-4 to 4-7 below.[4] These costs are used in the economic impact as well as the small entity analysis.

[4] Memorandum from Bradley Nelson, EC/R to Melanie King, EPA. OAQPS/SPPD/ESG. Impacts Associated with NESHAP for Existing Stationary SI RICE. June 29, 2010.

Table 4-4. Summary of Major Source and Area Source Costs for the SI RICE NESHAP[a,b]

Size Range (HP)	Capital Control Cost	Annual Control Cost	Initial Test	Record-keeping	Reporting	Monitoring—Capital Cost	Monitoring—Annual Cost	Total Annual Costs	Total Capital Costs
Major Sources									
25–50	$0	$0	$0	$4,060,795	$0	$0	$0	$4,060,795	$0
50–100	$0	$0	$0	$1,087,540	$0	$0	$0	$1,087,540	$0
100–175	$48,502,361	$37,071,061	$15,971,384	$1,721,899	$5,725,314	$0	$0	$60,489,657	$48,502,361
175–300	$13,225,919	$8,382,568	$3,442,648	$371,157	$1,234,097	$0	$0	$13,430,470	$13,225,919
300–500	$10,934,795	$5,562,872	$2,123,326	$228,919	$761,155	$0	$0	$8,676,262	$10,934,795
500–600	$0	$0	$0	$0	$0	$0	$0	$0	$0
600–750	$0	$0	$0	$0	$0	$0	$0	$0	$0
>750	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$72,663,076**	**$51,016,500**	**$21,537,358**	**$7,470,310**	**$7,720,566**	**$0**	**$0**	**$87,744,734**	**$72,663,076**
Area Sources									
25–50	$0	$0	$0	$6,668,944	$0	$0	$0	$6,668,944	$0
50–100	$0	$0	$0	$2,868,511	$0	$0	$0	$2,868,511	$0
100–175	$0	$0	$0	$3,529,711	$0	$0	$0	$3,529,711	$0
175–300	$0	$0	$0	$1,264,799	$0	$0	$0	$1,264,799	$0
300–500	$0	$0	$0	$908,913	$0	$0	$0	$908,913	$0
500–600	$75,474,331	$26,628,053	$3,655,719	$454,493	$1,264,260	$2,821,013	$13,003,822	$45,006,347	$78,295,345
600–750	$15,222,363	$5,052,207	$652,400	$77,882	$225,620	$503,438	$2,320,662	$8,328,771	$15,725,801
>750	$210,754,181	$62,143,967	$6,951,011	$829,795	$2,403,874	$5,363,896	$24,725,562	$97,054,209	$216,118,077
Total	**$301,450,875**	**$93,824,227**	**$11,259,129**	**$16,603,048**	**$3,893,754**	**$8,688,347**	**$40,050,046**	**$165,630,205**	**$310,139,222**
Grand Total									
Total	**$374,113,951**	**$144,840,727**	**$32,796,487**	**$24,073,358**	**$11,614,321**	**$8,688,347**	**$40,050,046**	**$253,374,939**	**$382,802,298**

[a] Costs are presented in 2009 dollars.

[b] For some HP ranges, the annual compliance cost is greater than the capital compliance cost because not all of the engines in those HP ranges are expected to incur capital costs for controls, but all of the engines in those HP ranges are expected to incur annual costs of testing, monitoring, recordkeeping, and reporting.

Table 4-5. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP[a,b]

NAICS		Major Source		Area Source		Total (Major + Area)	
		Capital Cost	Annual Cost	Capital Cost	Annual Cost	Capital Cost	Annual Cost
2211	Electric Power Generation	$52,905,258	$63,062,494	$120,301,416	$65,334,028	$173,206,675	$128,396,522
48621	Natural Gas Transmission	$1,484,494	$1,462,530	$140,977,276	$67,467,484	$142,461,771	$68,930,015
211111	Crude Petroleum & NG Production	$4,561,236	$6,138,383	$732,943	$1,258,072	$5,294,179	$7,396,454
211112	Natural Gas Liquid Producers	$4,561,236	$6,138,383	$732,943	$1,258,072	$5,294,179	$7,396,454
92811	National Security	$5,878,362	$7,006,944	$13,366,824	$7,259,336	$19,245,186	$14,266,280
335312	Hydro Power Units	$0	$25,248	$0	$37,872	$0	$63,120
335312	Irrigation Sets	$3,025,050	$3,230,856	$34,027,819	$22,445,211	$37,052,869	$25,676,067
333992	Welders	$247,440	$679,896	$0	$570,130	$247,440	$1,250,027
	Total	$72,663,076	$87,744,734	$310,139,222	$165,630,205	**$382,802,298**	**$253,374,939**

[a] Costs are presented in 2009 dollars.

[b] For some HP ranges, the annual compliance cost is greater than the capital compliance cost because not all of the engines in those HP ranges are expected to incur capital costs for controls, but all of the engines in those HP ranges are expected to incur annual costs of testing, monitoring, recordkeeping, and reporting.

Table 4-6. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Size[a,b]

	Major Source		Area Source		Total (Major + Area)	
NAICS	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**
Electric Power Generation (2211)						
25–50 hp	$0	$2,758,459	$0	$4,137,688	$0	$6,896,147
50–100 hp	$0	$606,144	$0	$909,215	$0	$1,515,359
100–175 hp	$33,868,173	$42,238,648	$0	$1,803,548	$33,868,173	$44,042,196
175–300 hp	$10,603,849	$10,767,847	$0	$446,361	$10,603,849	$11,214,209
300–500 hp	$8,433,236	$6,691,397	$0	$264,820	$8,433,236	$6,956,217
500–600 hp	$0	$0	$26,390,293	$15,169,876	$26,390,293	$15,169,876
600–750 hp	$0	$0	$5,325,628	$2,820,584	$5,325,628	$2,820,584
>750 hp	$0	$0	$88,585,495	$39,781,934	$88,585,495	$39,781,934
Total Electric Power Generation 2211	$52,905,258	$63,062,494	$120,301,416	$65,334,028	$173,206,675	$128,396,522
Natural Gas Transmission (48621)						
25–50 hp	$0	$102	$0	$1,934	$0	$2,036
50–100 hp	$0	$4,872	$0	$92,571	$0	$97,443
100–175 hp	$301,721	$376,291	$0	$203,518	$301,721	$579,809
175–300 hp	$643,157	$653,104	$0	$342,928	$643,157	$996,032
300–500 hp	$539,617	$428,162	$0	$214,637	$539,617	$642,799
500–600 hp	$0	$0	$19,975,323	$11,482,372	$19,975,323	$11,482,372
600–750 hp	$0	$0	$9,808,436	$5,194,789	$9,808,436	$5,194,789
>750 hp	$0	$0	$111,193,518	$49,934,735	$111,193,518	$49,934,735
Total Natural Gas Transmission (48621)	$1,484,494	$1,462,530	$140,977,276	$67,467,484	$142,461,771	$68,930,015
Crude Petroleum & NG Production (211111)						
25–50 hp	$0	$388,115	$0	$582,173	$0	$970,288
50–100 hp	$0	$66,698	$0	$100,047	$0	$166,744
100–175 hp	$4,549,775	$5,674,246	$0	$242,285	$4,549,775	$5,916,531

(continued)

Table 4-6. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Size[a,b] (continued)

	Major Source		Area Source		Total (Major + Area)	
NAICS	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**
175–300 hp	$1,037	$1,053	$0	$44	$1,037	$1,096
300–500 hp	$10,424	$8,271	$0	$327	$10,424	$8,598
500–600 hp	$0	$0	$32,184	$18,500	$32,184	$18,500
600–750 hp	$0	$0	$0	$0	$0	$0
>750 hp	$0	$0	$700,760	$314,697	$700,760	$314,697
Total Crude Petroleum & NG Production (211111)	$4,561,236	$6,138,383	$732,943	$1,258,072	$5,294,179	$7,396,454
Natural Gas Liquid Producers (211112)						
25–50 hp	$0	$388,115	$0	$582,173	$0	$970,288
50–100 hp	$0	$66,698	$0	$100,047	$0	$166,744
100–175 hp	$4,549,775	$5,674,246	$0	$242,285	$4,549,775	$5,916,531
175–300 hp	$1,037	$1,053	$0	$44	$1,037	$1,096
300–500 hp	$10,424	$8,271	$0	$327	$10,424	$8,598
500–600 hp	$0	$0	$32,184	$18,500	$32,184	$18,500
600–750 hp	$0	$0	$0	$0	$0	$0
>750 hp	$0	$0	$700,760	$314,697	$700,760	$314,697
Total Natural Gas Liquid Producers (211112)	$4,561,236	$6,138,383	$732,943	$1,258,072	$5,294,179	$7,396,454
National Security (92811)						
25–50 hp	$0	$306,495	$0	$459,743	$0	$766,239
50–100 hp	$0	$67,349	$0	$101,024	$0	$168,373
100–175 hp	$3,763,130	$4,693,183	$0	$200,394	$3,763,130	$4,893,577
175–300 hp	$1,178,205	$1,196,427	$0	$49,596	$1,178,205	$1,246,023
300–500 hp	$937,026	$743,489	$0	$29,424	$937,026	$772,913
500–600 hp	$0	$0	$2,932,255	$1,685,542	$2,932,255	$1,685,542

(continued)

Table 4-6. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Size[a,b] (continued)

	Major Source		Area Source		Total (Major + Area)	
NAICS	Capital Cost	Annual Cost	Capital Cost	Annual Cost	Capital Cost	Annual Cost
600–750 hp	$0	$0	$591,736	$313,398	$591,736	$313,398
>750 hp	$0	$0	$9,842,833	$4,420,215	$9,842,833	$4,420,215
Total Natural Gas Liquid Producers (211112)	$5,878,362	$7,006,944	$13,366,824	$7,259,336	$19,245,186	$14,266,280
Hydro Power Units (335312)						
25–50 hp	$0	$22,688	$0	$34,032	$0	$56,721
50–100 hp	$0	$2,560	$0	$3,840	$0	$6,399
100–175 hp	$0	$0	$0	$0	$0	$0
175–300 hp	$0	$0	$0	$0	$0	$0
300–500 hp	$0	$0	$0	$0	$0	$0
500–600 hp	$0	$0	$0	$0	$0	$0
600–750 hp	$0	$0	$0	$0	$0	$0
>750 hp	$0	$0	$0	$0	$0	$0
Total Hydro Power Units (335312)	$0	$25,248	$0	$37,872	$0	$63,120
Irrigation Sets (335312)						
25–50 hp	$0	$32,913	$0	$625,338	$0	$658,251
50–100 hp	$0	$65,825	$0	$1,250,677	$0	$1,316,502
100–175 hp	$1,222,348	$1,524,449	$0	$824,505	$1,222,348	$2,348,954
175–300 hp	$798,634	$810,986	$0	$425,827	$798,634	$1,236,813
300–500 hp	$1,004,068	$796,683	$0	$399,376	$1,004,068	$1,196,060
500–600 hp	$0	$0	$28,933,107	$16,631,556	$28,933,107	$16,631,556
600–750 hp	$0	$0	$0	$0	$0	$0
>750 hp	$0	$0	$5,094,712	$2,287,931	$5,094,712	$2,287,931
Total Irrigation Sets (335312)	$3,025,050	$3,230,856	$34,027,819	$22,445,211	$37,052,869	$25,676,067

(continued)

Table 4-6. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Size[a,b] (continued)

	Major Source		Area Source		Total (Major + Area)	
NAICS	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**	**Capital Cost**	**Annual Cost**
Welders (333992)						
25–50 hp	$0	$163,908	$0	$245,862	$0	$409,771
50–100 hp	$0	$207,394	$0	$311,091	$0	$518,485
100–175 hp	$247,440	$308,594	$0	$13,177	$247,440	$321,771
175–300 hp	$0	$0	$0	$0	$0	$0
300–500 hp	$0	$0	$0	$0	$0	$0
500–600 hp	$0	$0	$0	$0	$0	$0
600–750 hp	$0	$0	$0	$0	$0	$0
>750 hp	$0	$0	$0	$0	$0	$0
Total Welders (333992)	$247,440	$679,896	$0	$570,130	$247,440	$1,250,027
Total	$72,663,076	$87,744,734	$310,139,222	$165,630,205	$382,802,298	$253,374,939

[a] Costs are presented in 2009 dollars.

[b] For some HP ranges, the annual compliance cost is greater than the capital compliance cost because not all of the engines in those HP ranges are expected to incur capital costs for controls, but all of the engines in those HP ranges are expected to incur annual costs of testing, monitoring, recordkeeping, and reporting.

Table 4-7. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Number of Engines[a,b]

	Number of Engines			Total (Major + Area)	
NAICS	**Major**	**Area**	**Total**	**Capital Cost**	**Annual Cost**
Electric Power Generation (2211)					
25–50 hp	37,933	56,900	94,833	$0	$6,896,147
50–100 hp	8,336	12,503	20,839	$0	$1,515,359
100–175 hp	16,534	24,802	41,336	$33,868,173	$44,042,196
175–300 hp	4,092	6,138	10,230	$10,603,849	$11,214,209
300–500 hp	2,428	3,642	6,070	$8,433,236	$6,956,217
500–600 hp	0	2,107	2,107	$26,390,293	$15,169,876
600–750 hp	0	363	363	$5,325,628	$2,820,584
>750 hp	0	4,677	4,677	$88,585,495	$39,781,934
Total Electric Power Generation 2211	69,323	111,132	180,455	$173,206,675	$128,396,522
Natural Gas Transmission (48621)					
25–50 hp	1	27	28	$0	$2,036
50–100 hp	67	1,273	1,340	$0	$97,443
100–175 hp	147	2,799	2,946	$301,721	$579,809
175–300 hp	248	4,716	4,964	$643,157	$996,032
300–500 hp	155	2,952	3,107	$539,617	$642,799
500–600 hp	0	1,595	1,595	$19,975,323	$11,482,372
600–750 hp	0	668	668	$9,808,436	$5,194,789
>750 hp	0	5,871	5,871	$111,193,518	$49,934,735
Total Natural Gas Transmission (48621)	619	19,899	20,519	$142,461,771	$68,930,015
Crude Petroleum & NG Production (211111)					
25–50 hp	5,337	8,006	13,343	$0	$970,288
50–100 hp	917	1,376	2,293	$0	$166,744
100–175 hp	2,221	3,332	5,553	$4,549,775	$5,916,531

(continued)

Table 4-7. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Number of Engines[a] (continued)

	Number of Engines			Total (Major + Area)	
NAICS	Major	Area	Total	Capital Cost	Annual Cost
175–300 hp	0	1	1	$1,037	$1,096
300–500 hp	3	5	8	$10,424	$8,598
500–600 hp	0	3	3	$32,184	$18,500
600–750 hp	0	0	0	$0	$0
>750 hp	0	37	37	$700,760	$314,697
Total Crude Petroleum & NG Production (211111)	8,479	12,758	21,237	$5,294,179	$7,396,454
Natural Gas Liquid Producers (211112)					
25–50 hp	5,337	8,006	13,343	$0	$970,288
50–100 hp	917	1,376	2,293	$0	$166,744
100–175 hp	2,221	3,332	5,553	$4,549,775	$5,916,531
175–300 hp	0	1	1	$1,037	$1,096
300–500 hp	3	5	8	$10,424	$8,598
500–600 hp	0	3	3	$32,184	$18,500
600–750 hp	0	0	0	$0	$0
>750 hp	0	37	37	$700,760	$314,697
Total Natural Gas Liquid Producers (211112)	8,479	12,758	21,237	$5,294,179	$7,396,454
National Security (92811)					
25–50 hp	4,215	6,322	10,537	$0	$766,239
50–100 hp	926	1,389	2,315	$0	$168,373
100–175 hp	1,837	2,756	4,593	$3,763,130	$4,893,577
175–300 hp	455	682	1,137	$1,178,205	$1,246,023
300–500 hp	270	404	674	$937,026	$772,913
500–600 hp	0	234	234	$2,932,255	$1,685,542

(continued)

Table 4-7. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Number of Engines[a] (continued)

NAICS	Number of Engines			Total (Major + Area)	
	Major	Area	Total	Capital Cost	Annual Cost
600–750 hp	0	40	40	$591,736	$313,398
>750 hp	0	520	520	$9,842,833	$4,420,215
Total Natural Gas Liquid Producers (211112)	7,702	12,347	20,050	$19,245,186	$14,266,280
Hydro Power Units (335312)					
25–50 hp	312	468	780	$0	$56,721
50–100 hp	35	53	88	$0	$6,399
100–175 hp	0	0	0	$0	$0
175–300 hp	0	0	0	$0	$0
300–500 hp	0	0	0	$0	$0
500–600 hp	0	0	0	$0	$0
600–750 hp	0	0	0	$0	$0
>750 hp	0	0	0	$0	$0
Total Hydro Power Units (335312)	347	521	868	$0	$63,120
Irrigation Sets (335312)					
25–50 hp	453	8,599	9,052	$0	$658,251
50–100 hp	905	17,199	18,104	$0	$1,316,502
100–175 hp	597	11,338	11,935	$1,222,348	$2,348,954
175–300 hp	308	5,856	6,164	$798,634	$1,236,813
300–500 hp	289	5,492	5,781	$1,004,068	$1,196,060
500–600 hp	0	2,310	2,310	$28,933,107	$16,631,556
600–750 hp	0	0	0	$0	$0
>750 hp	0	269	269	$5,094,712	$2,287,931
Total Irrigation Sets (335312)	2,552	51,063	53,615	$37,052,869	$25,676,067

(continued)

Table 4-7. Summary of Major Source and Area Source NAICS Costs for the SI RICE NESHAP, by Number of Engines[a] (continued)

	Number of Engines			Total (Major + Area)	
NAICS	**Major**	**Area**	**Total**	**Capital Cost**	**Annual Cost**
Welders (333992)					
25–50 hp	2,254	3,381	5,635	$0	$409,771
50–100 hp	2,852	4,278	7,130	$0	$518,485
100–175 hp	121	181	302	$247,440	$321,771
175–300 hp	0	0	0	$0	$0
300–500 hp	0	0	0	$0	$0
500–600 hp	0	0	0	$0	$0
600–750 hp	0	0	0	$0	$0
>750 hp	0	0	0	$0	$0
Total Welders (333992)	5,227	7,840	13,067	$247,440	$1,250,027
Total	102,729	228,319	331,047	$382,802,298	$253,374,939

[a] Costs are presented in 2009 dollars.

[b] For some HP ranges, the annual compliance cost is greater than the capital compliance cost because not all of the engines in those HP ranges are expected to incur capital costs for controls, but all of the engines in those HP ranges are expected to incur annual costs of testing, monitoring, recordkeeping, and reporting.

4.4.5 Caveats and Uncertainties in the Cost Estimates

* Current knowledge about NOx control techniques and costs is applied in this study. Advances such as alternative catalyst formulations may occur between now and when sources comply with this rulemaking that may lower costs. Scale economies can also lower per unit production costs as the market for these NOx control techniques expands.

* The alternative control techniques and corresponding emission reductions and costs may not apply to every unit within the source category. Many factors influence the performance and cost of any control technique. Because control technology references typically evaluate average retrofit situations, costs may be underestimated for the fraction of the source population with difficult to retrofit conditions. Difficult to retrofit conditions may be less of an issue for RICEs than for other point sources, however.

* NOx control efficiency and cost estimates associated with source category-control strategy combinations are represented as point estimates. In practice, control effectiveness and costs will vary by engine.

4.5 Emissions and Emission Reductions

The baseline emissions, emissions factors and emissions reductions associated with the final rule are provided in the tables below. Emissions are in tons per year.

Table 4-8. Summary of Major Source and Area Source Baseline Emissions for the SI RICE NESHAP

Size Range (HP)	Baseline Emissions (TPY)			
	HAP	CO	NOx	VOC
Major Sources				
25–50 hp	1,107	28,557	41,751	5,696
50–100 hp	593	15,296	22,363	3,051
100–175 hp	1,721	44,399	64,913	8,855
175–300 hp	641	16,530	24,168	3,297
300–500 hp	666	17,171	25,105	3,425
500–600 hp	0	0	0	0
600–750 hp	0	0	0	0
>750 hp	0	0	0	0
Total	**4,728**	**121,953**	**178,301**	**24,323**
Area Sources				
25–50 hp	1,818	46,898	68,566	9,354
50–100 hp	1,564	40,344	58,985	8,047
100–175 hp	3,529	91,013	133,065	18,153
175–300 hp	2,184	56,331	82,359	11,235
300–500 hp	2,643	68,178	99,679	13,598
500–600 hp	1,830	47,273	69,094	9,415
600–750 hp	383	9,876	14,438	1,969
>750 hp	6,041	155,890	227,890	31,076
Total	**19,993**	**515,803**	**754,077**	**102,846**
Major + Area Total	**24,721**	**637,756**	**932,378**	**127,169**

Table 4-9. Emissions Factors

Engine	HAP (lb/hp-hr)	CO (lb/hp-hr)	NOx (lb/hp-hr)	VOC (lb/hp-hr)	Formaldehyde (lb/hp-hr)
2SLB	5.96×10^{-4}	1.06×10^{-2}	4.18×10^{-2}	3.07×10^{-3}	4.29×10^{-4}
4SLB	5.41×10^{-4}	3.92×10^{-3}	1.15×10^{-2}	2.78×10^{-3}	3.96×10^{-4}
4SRB	2.43×10^{-4}	1.93×10^{-2}	1.47×10^{-2}	1.25×10^{-3}	1.75×10^{-4}

Table 4-10. Summary of Major Source and Area Source Emissions Reductions for the SI RICE NESHAP

Size Range (HP)	Emission Reductions (TPY) HAP	CO	NOx	VOC
Major Sources				
25–50 hp	0	0	0	0
50–100 hp	0	0	0	0
100–175 hp	744	7,124	0	3,826
175–300 hp	277	2,653	0	1,424
300–500 hp	288	2,755	0	1,480
500–600 hp	0	0	0	0
600–750 hp	0	0	0	0
>750 hp	0	0	0	0
Total	**1,308**	**12,532**	**0**	**6,730**
Area Sources				
25–50 hp	0	0	0	0
50–100 hp	0	0	0	0
100–175 hp	0	0	0	0
175–300 hp	0	0	0	0
300–500 hp	0	0	0	0
500–600 hp	1,005	20,698	20,632	5,170
600–750 hp	220	4,533	4,519	1,132
>750 hp	3,475	71,557	71,328	17,874,
Total	**4,700**	**96,789**	**96,479**	**24,177**
Major + Area Total	**6,008**	**109,321**	**96,479**	**30,907**

SECTION 5
ECONOMIC IMPACT ANALYSIS, ENERGY IMPACTS, AND SOCIAL COSTS

The EIA provides decision makers with social cost estimates and enhances understanding of how the costs may be distributed across stakeholders (EPA, 2000). Although several economic frameworks can be used to estimate social costs for regulations of this size and sector scope, OAQPS has typically used partial equilibrium market models. However, the current data do not provide sufficient details to develop a market model; the data that are available have little or no sector/firm detail and are reported at the national level. In addition, some sectors have unique market characteristics that make developing partial equilibrium models difficult. Given these constraints, we used the direct compliance costs as a measure of total social costs. In addition, we also provide a qualitative analysis of the final rule's impact on stakeholder decisions, a qualitative discussion on if unfunded mandates occur as a result of this final rule, and the potential distribution of social costs between consumers and producers.

5.1 Compliance Costs of the Final Rule

EPA's engineering cost analysis estimates the total annualized costs of the final rule are $253 million (in 2009 dollars) (Nelson, 2010).

As shown in Figure 5-1, the majority of the costs fall on the electric power sector (51%), followed by natural gas transmission (27%). The remaining industries each account for less than 15% of the total annualized cost. The industrial classification for each engine is taken from the Power Systems Research (PSR) database, which is the major source of data for the engines affected by the final rule. The PSR database used as a basis for the analyses in this RIA contains information on both mobile and stationary engines, among other data, and does so not only for the U.S. but worldwide. PSR has collected such data for more than 30 years. The Office of Transportation and Air Quality (OTAQ) uses this database frequently in the development of their mobile source rules.

The annualized compliance costs per engine vary by the engine size (see Figure 5-2). For 500 hp engines or less, the annualized per-engine costs are below $1,200 per engine. Per-engine costs for higher horsepower (hp) engines range between $7,200 and $8,500.

The final rule will affect approximately 331,000 existing stationary SI engines. As shown in Figure 5-3, most of the affected engines fall within the 25 to 50 hp category (45%). The next highest categories are 100 to 175 hp (22%) and 50 to 100 hp (16%).

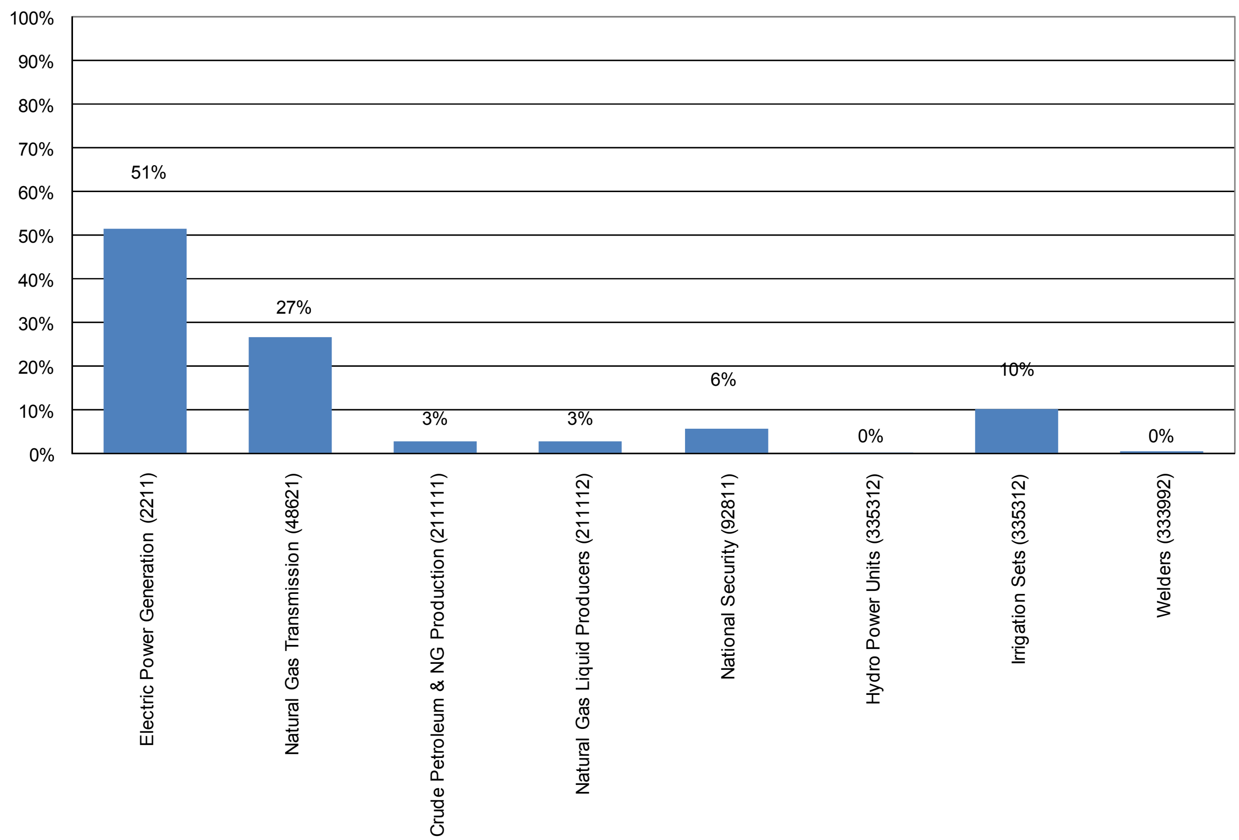


Figure 5-1. Distribution of Annualized Direct Compliance Costs by Industry

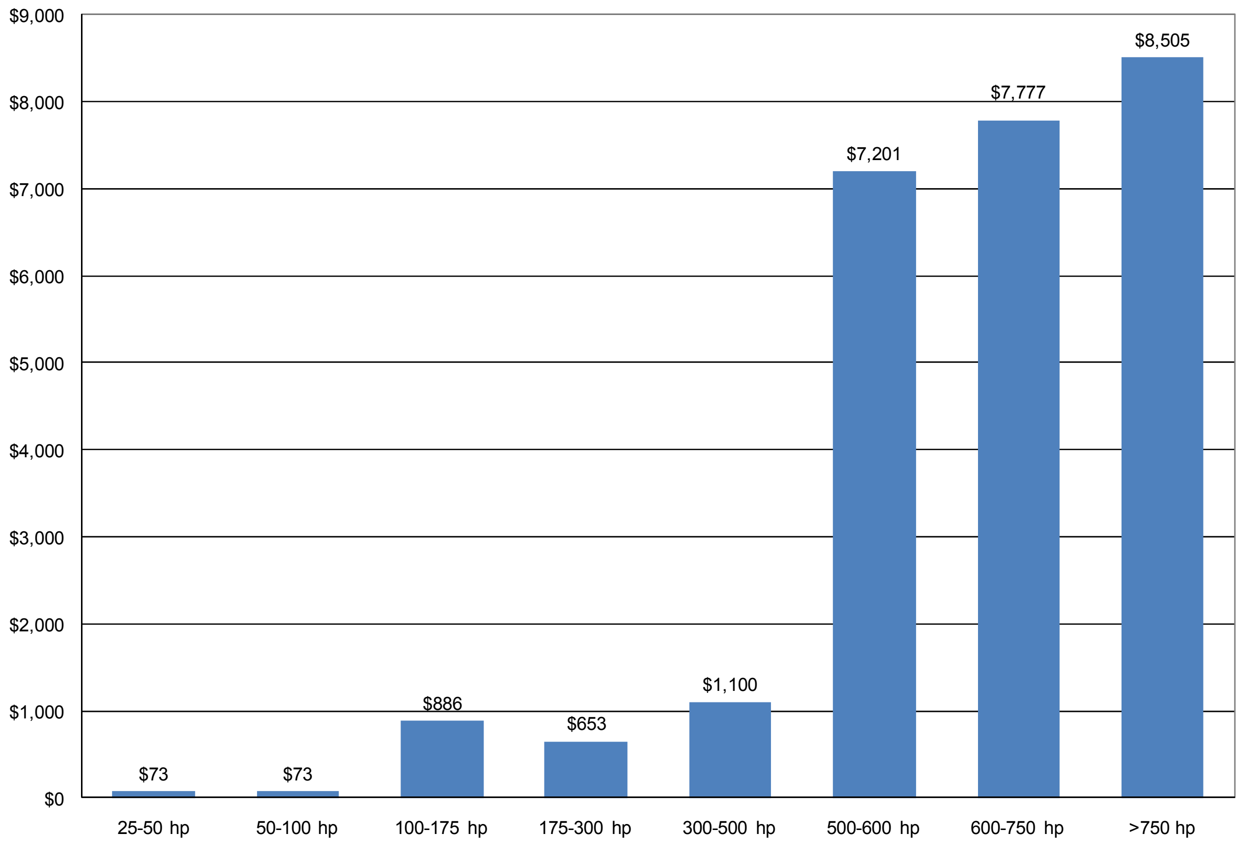


Figure 5-2. Average Annualized Cost per Engine by Horsepower Group ($2009)

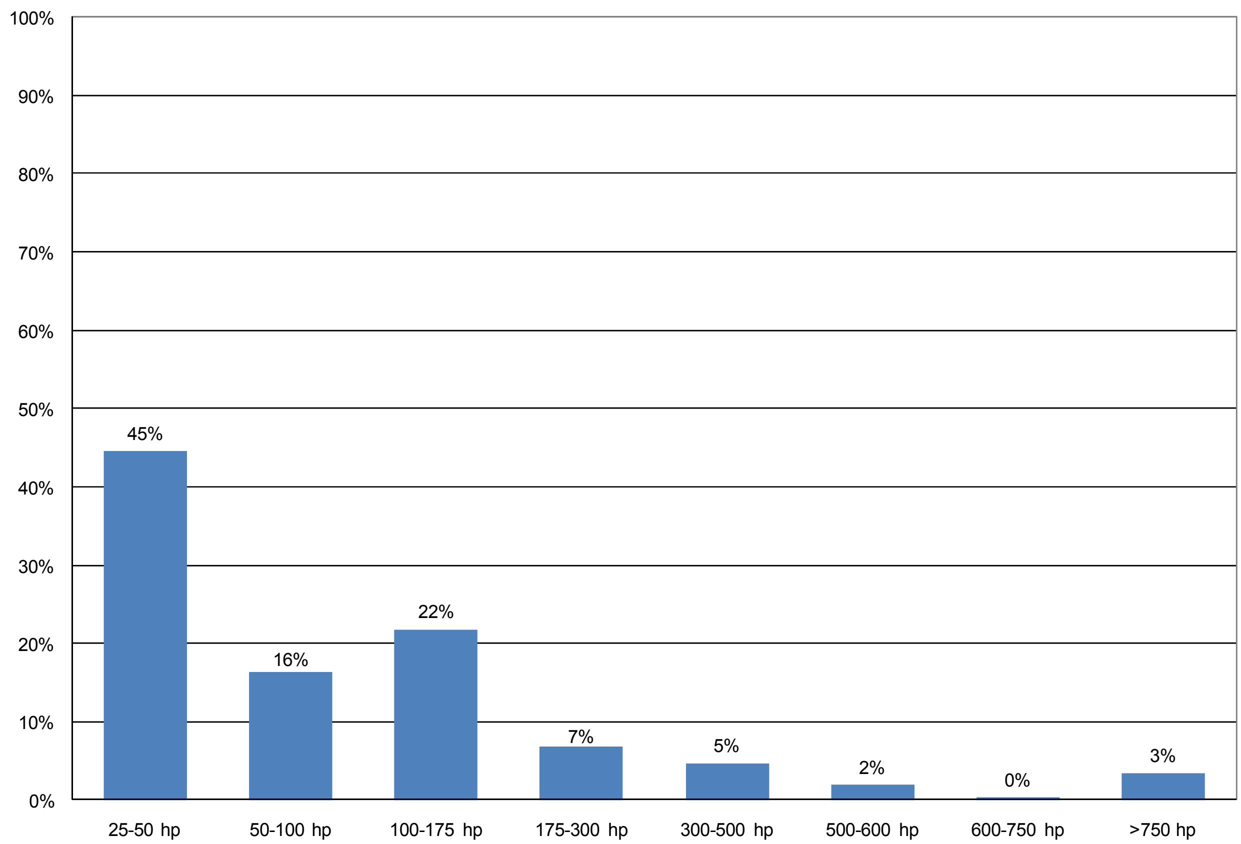


Figure 5-3. Distribution of Engine Population by Horsepower Group

To assess the size of the compliance relative to the value of the goods and services for industries using affected engines, we collected Census data for selected industries. At the industry level, the annualized costs represent a very small fraction of revenue (less than 1%), for all affected industries. Results for affected industries can be found in Table 5-1. These industry level cost-to-sales ratios can be interpreted as an average impact on potentially affected firms in these industries. Based on the cost-to-sales ratios, we can conclude that the annualized cost of this rule should be no higher than 1% of the sales on average for a firm in each of these industries, excluding natural gas transmission and natural gas liquid producers, which face slightly higher costs to sales ratios.

5.2 How Might People and Firms Respond? A Partial Equilibrium Analysis

Markets are composed of people as consumers and producers trying to do the best they can given their economic circumstances. One way economists illustrate behavioral responses to pollution control costs is by using market supply and demand diagrams. The market supply curve describes how much of a good or service firms are willing and able to sell to people at a

Table 5-1. Selected Industry-Level Annualized Compliance Costs as a Fraction of Total Industry Revenue: 2009

Industry (NAICS)	Industry Name	Total Annualized Costs ($ million)[a]	Sales, Shipments, Receipt, or Revenue ($ Billion) ($2007)	($2009)	Cost-to-Sales Ratio
2211	Electric Power Generation	$128.4	$440.4	$453.7	0.004%
48621	Natural Gas Transmission	$68.9	$16.4	$16.9	0.41%
211111	Crude Petroleum & NG Production	$7.4	$214.2	$220.5	0.001%
211112	Natural Gas Liquid Producers	$7.4	$42.4	$43.6	0.005%
92811	National Security	$14.3	#N/A	#N/A	#N/A
333992	Welders	$1.3	$5.2	$5.5	0.025%
111 and 112	Agriculture using irrigation systems[a]	$25.7	$27.9	$28.8	0.09%

[a] Irrigation engine costs assumed to be passed on to agricultural sectors that use irrigation systems.

N/A: receipts are Not Available for National Security

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007" <http://factfinder.census.gov>; (July 7th , 2010).

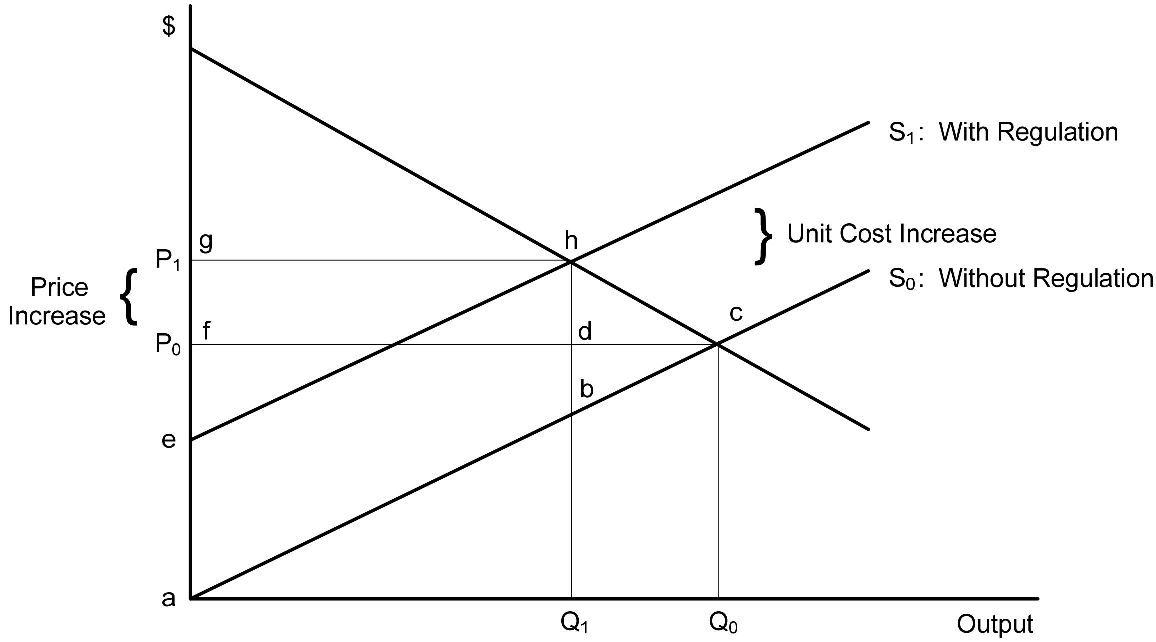
U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS). 2009. "2008 Farm and Ranch Irrigation Survey." Washington, DC: USDA-NASS.

Costs from Existing SI RICE NESHAP Impacts 6-24-2010.xls received from EPA 6/24/10

particular price; we often draw this curve as upward sloping because some production resources are fixed. As a result, the cost of producing an additional unit typically rises as more units are made. The market demand curve describes how much of a good or service consumers are willing and able to buy at some price. Holding other factors constant, the quantity demand is assumed to fall when prices rise. In a perfectly competitive market, equilibrium price (P_0) and quantity (Q_0) is determined by the intersection of the supply and demand curves (see Figure 5-4).

5.2.1 Changes in Market Prices and Quantities

To qualitatively assess how the regulation may influence the equilibrium price and quantity in the affected markets, we assumed the market supply function shifts up by the additional cost of producing the good or service; the unit cost increase is typically calculated by dividing the annual compliance cost estimate by the baseline quantity (Q_0) (see Figure 5-4). As shown, this model makes two predictions: the price of the affected goods and services are likely to rise and the consumption/production levels are likely to fall.



consumer surplus = –[fghd + dhc]

producer surplus = [fghd – aehb] – bdc

total surplus = consumer surplus + producer surplus = –[aehb + dhc + bdc]

Figure 5-4. Market Demand and Supply Model: With and Without Regulation

The size of these changes depends on two factors: the size of the unit cost increase (supply shift) and differences in how each side of the market (supply and demand) responds to changes in price. Economists measure responses using the concept of price elasticity, which represents the percentage change in quantity divided by the percentage change in price. This dependence has been expressed in the following formula:[1]

$$\textit{Share of per-unit } \textbf{cost} = \frac{\text{Price Elasticity of Supply}}{(\text{Price Elasticity of Supply - Price Elasticity of Demand})}$$

As a general rule, a higher share of the per-unit cost increases will be passed on to consumers in markets where

- goods and services are necessities and people do not have good substitutes that they can switch to easily (demand is inelastic) and

[1]For examples of similar mathematical models in the public finance literature, see Nicholson (1998), pages 444–447, or Fullerton and Metcalf (2002).

- suppliers have excess capacity and can easily adjust production levels at minimal costs, or the time period of analysis is long enough that suppliers can change their fixed resources; supply is more elastic over longer periods.

Short-run demand elasticities for energy goods (electricity and natural gas), agricultural products, and construction are often inelastic. Specific estimates of short-run demand elasticities for these products can be obtained from existing literature. For the short-run demand of energy products, the National Energy Modeling System (NEMS) buildings module uses values between 0.1 and 0.3; a 1% increase in price leads to a 0.1 to 0.3% decrease in energy demand (Wade, 2003). For the short-run demand of agriculture and construction, the EPA has estimated elasticities to be 0.2 for agriculture and approximately 1 for construction (U.S. EPA, 2004). As a result, a 1% increase in the prices of agriculture products would lead to a 0.2% decrease in demand for those products, while a 1% increase in construction prices would lead to approximately a 1% decrease in demand for construction. Given these demand elasticity scenarios (shaded in gray), approximately a 1% increase unit costs would result in a price increase of 0.1 to 1% (Table 5-2). As a result, 10 to 100% of the unit cost increase could be passed on to consumers in the form of higher goods/services prices. This price increase would correspond to a 0.1 to 0.8% decline in consumption in these markets (Table 5-3).

Table 5-2. Hypothetical Price Increases for a 1% Increase in Unit Costs

Market Demand Elasticity	Market Supply Elasticity						
	0.1	**0.3**	**0.5**	**0.7**	**1**	**1.5**	**3**
−0.1	**0.5%**	0.8%	0.8%	0.9%	0.9%	0.9%	1.0%
−0.3	0.3%	**0.5%**	0.6%	0.7%	0.8%	0.8%	0.9%
−0.5	0.2%	0.4%	**0.5%**	0.6%	0.7%	0.8%	0.9%
−0.7	0.1%	0.3%	0.4%	**0.5%**	0.6%	0.7%	0.8%
−1.0	0.1%	0.2%	0.3%	0.4%	**0.5%**	0.6%	0.8%
−1.5	0.1%	0.2%	0.3%	0.3%	0.4%	**0.5%**	0.7%
−3.0	0.0%	0.1%	0.1%	0.2%	0.3%	0.3%	**0.5%**

5.2.2 Regulated Markets: The Electric Power Generation, Transmission, and Distribution Sector

Given that the electric power sector bears majority of the estimated compliance costs (Figure 5-1) and the industry is also among the last major regulated energy industries in the United States (EIA, 2000), the competitive model is not necessarily applicable for this industry.

Table 5-3. Hypothetical Consumption Decreases for a 1% Increase in Unit Costs

Market Demand Elasticity	Market Supply Elasticity						
	0.1	**0.3**	**0.5**	**0.7**	**1**	**1.5**	**3**
−0.1	**−0.1%**	−0.1%	−0.1%	−0.1%	−0.1%	−0.1%	−0.1%
−0.3	−0.1%	**−0.2%**	−0.2%	−0.2%	−0.2%	−0.3%	−0.3%
−0.5	−0.1%	−0.2%	**−0.3%**	−0.3%	−0.3%	−0.4%	−0.4%
−0.7	−0.1%	−0.2%	−0.3%	**−0.4%**	−0.4%	−0.5%	−0.6%
−1.0	−0.1%	−0.2%	−0.3%	−0.4%	**−0.5%**	−0.6%	−0.8%
−1.5	−0.1%	−0.3%	−0.4%	−0.5%	−0.6%	**−0.8%**	−1.0%
−3.0	−0.1%	−0.3%	−0.4%	−0.6%	−0.8%	−1.0%	**−1.5%**

Although the electricity industry continues to go through a process of restructuring, whereby the industry is moving toward a more competitive framework (see Figure 5-5 for the status of restructuring by state),[2] in many states, electricity prices continue to be fully regulated by Public Service Commissions. As a result, the rules and processes outlined by these agencies would ultimately determine how these additional regulatory costs would be recovered by affected entities.

5.2.3 Partial Equilibrium Measures of Social Cost: Changes Consumer and Producer Surplus

In partial equilibrium analysis, the social costs are estimated by measuring the changes in consumer and producer surplus, and these values can be determined using the market supply and demand model (Figure 5-4). The change in consumer surplus is measured as follows:

$$\Delta CS = -[\Delta Q_1 \times \Delta p] + [0.5 \times \Delta Q \times \Delta p]. \qquad (5.1)$$

Higher market prices and lower quantities lead to consumer welfare losses. Similarly, the change in producer surplus is measured as follows:

$$\Delta PS = [\Delta Q_1 \times \Delta p] - [\Delta Q_1 \times \mathrm{t}] - [0.5 \times \Delta Q \times (\Delta p - t)]. \qquad (5.2)$$

Higher unit costs and lower production level reduce producer surplus because the net price change ($\Delta p - t$) is negative. However, these losses are mitigated because market prices tend to rise.

[2] http://tonto.eia.doe.gov/energy_in_brief/print_pages/electricity.pdf.

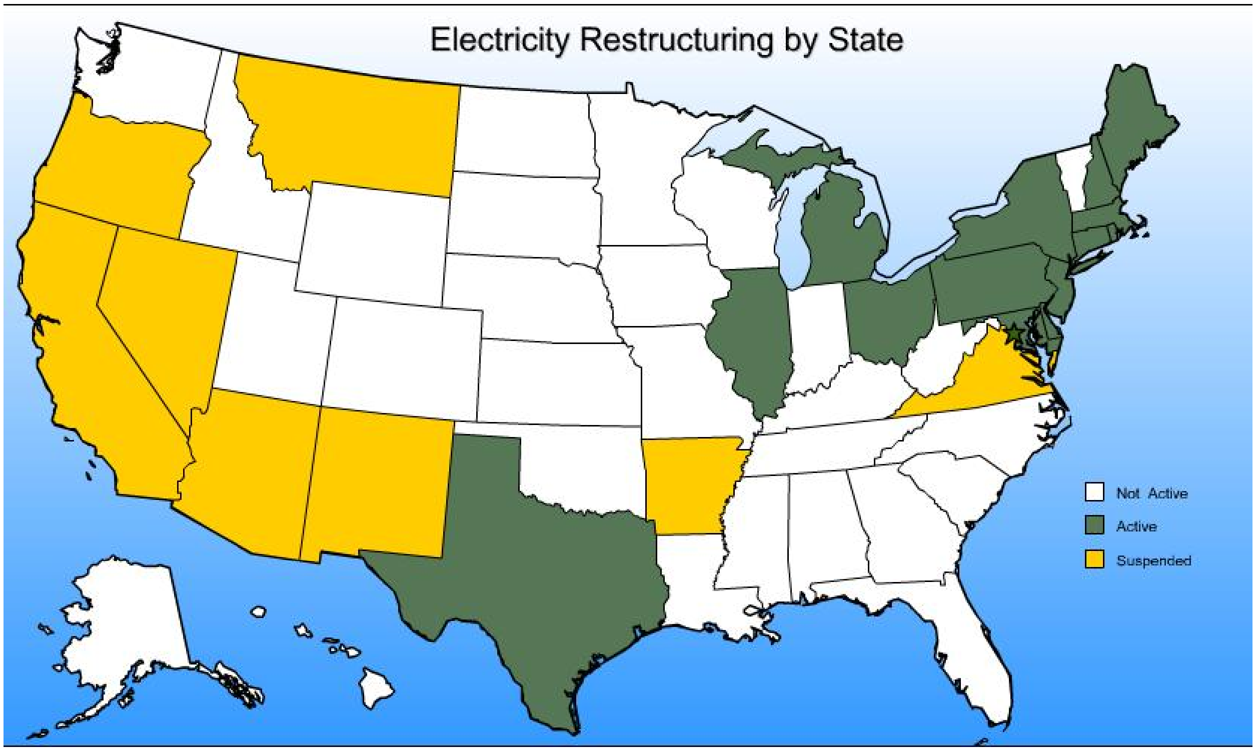


Figure 5-5. Electricity Restructuring by State

Source. U.S. Energy Information Administration. 2008a. <http://www.eia.doe.gov/cneaf/electricity/page/restructuring/restructure_elect.html>. Last updated September 2008.

5.3 Social Cost Estimate

As shown in Table 5-1 the compliance costs are only a small fraction of the affected product value; this suggests that shift of the supply curve may also be small and result in small changes in market prices and consumption. EPA believes the national annualized compliance cost estimates provide a reasonable approximation of the social cost of this final rule. EPA believes this approximation is better for industries whose markets are well characterized as perfectly competitive. This approximation is less well understood for industries where the characterization of markets is not always perfectly competitive such as electric power generation whose legal incidence of this rule is approximately 50 percent of the annualized compliance cost. However, given the data limitation noted earlier, EPA believes the accounting for compliance cost is a reasonable approximation to inform policy discussion in this rulemaking. To shed more light on this issue, EPA ran hypothetical analyses and the results are in Tables 5-2 and 5-3.

5.4 Energy Impacts

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

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

With respect to energy supply and prices, the analysis in Table 5-1 suggests at the industry level, the annualized costs represent a very small fraction of revenue (all industries are impacted under 1%). As a result, we can conclude supply and price impacts should be small.

To enhance understanding regarding the regulation's influence on energy consumption, we examined publicly available data describing energy consumption for the electric power sector that will be affected by this rule. The Annual Energy Outlook 2010 (EIA, 2009) provides energy consumption data. As shown in Table 5-4, this industry account for less than 0.5% of the U.S. total liquid fuels and less than 5.2% of natural gas. As a result, any energy consumption changes attributable to the regulatory program should not significantly influence the supply, distribution, or use of energy.

Table 5-4. U.S. Electric Power[a] Sector Energy Consumption (Quadrillion BTUs): 2013

	Quantity	Share of Total Energy Use
Distillate fuel oil	0.12	0.1%
Residual fuel oil	0.34	0.3%
Liquid fuels subtotal	0.45	0.5%
Natural gas	5.17	5.1%

Steam coal	20.69	20.6%
Nuclear power	8.59	8.5%
Renewable energy[b]	6.06	6.0%
Electricity Imports	0.09	0.1%
Total Electric Power Energy Consumption[c]	41.18	40.9%
Delivered Energy Use	72.41	72.0%
Total Energy Use	100.59	100.0%

[a]Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

[b]Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes net electricity imports.

[c]Includes non-biogenic municipal waste not included above.

Source: U.S. Energy Information Administration. 2009a. Supplemental Tables to the Annual Energy Outlook 2010. Table 2. Available at: <http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html>.

5.5 Unfunded Mandates

The UMRA requires that we estimate, where accurate estimation is reasonably feasible, future compliance costs imposed by the rule and any disproportionate budgetary effects. Our estimates of the future compliance costs of the final rule are discussed previously in Chapter 4 of this RIA. We do not believe that there will be any disproportionate budgetary effects of the final rule on any particular areas of the country, State or local governments, types of communities (e.g., urban, rural), or particular industry segments.

5.5.1 Future and Disproportionate Costs

The UMRA requires that we estimate, where accurate estimation is reasonably feasible, future compliance costs imposed by the rule and any disproportionate budgetary effects. Our estimates of the future compliance costs of the final rule are discussed previously in Chapter 4 of this RIA. We do not believe that there will be any disproportionate budgetary effects of the final rule on any particular areas of the country, State or local governments, types of communities (e.g., urban, rural), or particular industry segments.

5.5.2 Effects on the National Economy

The UMRA requires that we estimate the effect of the final rule on the national economy. To the extent feasible, we must estimate the effect on productivity, economic growth, full employment, creation of productive jobs, and international competitiveness of the U.S. goods and services if we determine that accurate estimates are reasonably feasible and that such effect is relevant and material. The nationwide economic impact of the final rule is presented earlier in this RIA chapter. This analysis provides estimates of the effect of the final rule on most of the categories mentioned above, and these estimates are presented earlier in this RIA chapter. In addition, we have determined that the final rule contains no regulatory requirements that might significantly or uniquely affect small governments. Therefore, today's rule is not subject to the requirements of section 203 of the UMRA.

SECTION 6
SMALL ENTITY SCREENING ANALYSIS

The Regulatory Flexibility Act as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) 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. Small entities include small businesses, small governmental jurisdictions, and small not-for-profit enterprises.

After considering the economic impact of the final rule on small entities, the screening analysis indicates that this final rule will not have a significant economic impact on a substantial number of small entities (or "SISNOSE"). Under the analyses EPA considered, sales and revenue tests for establishments owned by model small entities are less than 1% except electric power generation (NAICS 2211 with receipts less than $100,000 per year) and crop and animal production (NAICS 111 and 112 with receipts less than $25,000 per year).

6.1 Small Entity Data Set

The industry sectors covered by the final rule were identified during the development of the cost analysis (Nelson, 2010). The SUSB provides national information on the distribution of economic variables by industry and enterprise size (U.S. Census, 2006a, b).[1] The Census Bureau and the Office of Advocacy of the SBA supported and developed these files for use in a broad range of economic analyses.[2] Statistics include the total number of establishments and receipts for all entities in an industry; however, many of these entities may not necessarily be covered by the final rule. SUSB also provides statistics by enterprise employment and receipt size.

The Census Bureau's definitions used in the SUSB are as follows:

- *Establishmen*t: An establishment is a single physical location where business is conducted or where services or industrial operations are performed.
- *Receipts*: Receipts (net of taxes) are defined as the revenue for goods produced, distributed, or services provided, including revenue earned from premiums, commissions and fees, rents, interest, dividends, and royalties. Receipts exclude all revenue collected for local, state, and federal taxes.

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[1]The SUSB data do not provide establishment information for the national security NAICS code (92811) or irrigated farms. Since most national security installations are owned by the federal government (e.g., military bases), EPA assumes these entities would not be considered small. For irrigated farms, we relied on receipt data provided in the 2008 Farm and Irrigation Survey (USDA, 2009).

[2]See http://www.census.gov/csd/susb/ and http://www.sba.gov/advo/research/data.html for additional details.

- *Enterprise*: An enterprise is a business organization consisting of one or more domestic establishments that were specified under common ownership or control. The enterprise and the establishment are the same for single-establishment firms. Each multiestablishment company forms one enterprise—the enterprise employment and annual payroll are summed from the associated establishments. Enterprise size designations are determined by the summed employment of all associated establishments.

Because the SBA's business size definitions (SBA, 2008) apply to an establishment's "ultimate parent company," we assumed in this analysis that the "enterprise" definition above is consistent with the concept of ultimate parent company that is typically used for SBREFA screening analyses and the terms are used interchangeably.

6.2 Small Entity Economic Impact Measures

The analysis generated a set of establishment sales tests (represented as cost-to-receipt ratios)[3] for NAICS codes associated with sectors listed in Table 6-1. Although the appropriate SBA size definition should be applied at the parent company (enterprise) level, we can only compute and compare ratios for a model establishment owned by an enterprise within an SUSB size range (employment or receipts). Using the SUSB size range helps us account for receipt differences between establishments owned by large and small enterprises and also allows us to consider the variation in small business definitions across affected industries. Using establishment receipts is also a conservative approach, because an establishment's parent company (the "enterprise") may have other economic resources that could be used to cover the costs of the final rule.

6.2.1 Model Establishment Receipts and Annual Compliance Costs

The sales test compares a representative establishment's total annual engine costs to the average establishment receipts for enterprises in several size categories.[4] For industries with SBA employment size standards, we calculated average establishment receipts for each enterprise employment range (Table 6-2).[5] For industries with SBA receipt size standards, we calculated

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[3]The following metrics for other small entity economic impact measures (if applicable) would potentially include

- small governments (if applicable): "revenue" test; annualized compliance cost as a percentage of annual government revenues and
- small nonprofits (if applicable): "expenditure" test; annualized compliance cost as a percentage of annual operating expenses,

[4]For the 1 to 20 employee category, we excluded SUSB data for enterprises with zero employees. These enterprises did not operate the entire year.

[5]We use 2002 Economic Census data in estimating number of establishments by industry instead of using 2007 Economic Census since this data was not available in time for use in our analysis. The release schedules for different types of 2007 Economic Census data are at http://www.census.gov/econ/census07/pdf/EconCensusScheduleByDate.pdf.

Table 6-1. SI NESHAP for Existing Stationary Reciprocating Internal Combustion Engines (RICE): Affected Sectors and SBA Small Business Size Standards

Industry Description	Corresponding NAICS	SBA Size Standard for Businesses (August 22nd, 2008)	Type of Small Entity
Electric Power Generation	2211	[a]	Business and government
Natural Gas Transmission	48621	$7.0 million in annual receipts	Business
Crude Petroleum & NG Production	211111	500 employees	Business
Natural Gas Liquid Producers	211112	500 employees	Business
National Security	92811	NA	Government
Hydro Power Units	See NAICS 2211	1,000 employees	Business and government
Irrigation Sets	Affects NAICS 111 and 112	Generally $750,000 or less in annual receipts	Business
Welders	Affects industries that use heavy equipment such as construction, mining, farming	Varies by 6-digit NAICS code; Example industry: NAICS 238 = $14 million in annual receipts	Business

[a]NAICS codes 221111, 221112, 221113, 221119, 221121, 221122: A firm is small if, including its affiliates, it is primarily engaged in the generation, transmission, and/or distribution of electric energy for sale and its total electric output for the preceding fiscal year did not exceed 4 million megawatt hours.

average establishment receipts for each enterprise receipt range (Table 6-3). We included the utility sector in the second group, although the SBA size standard for this industry is defined in terms of physical units (megawatt hours) versus receipts. Crop and animal production (NAICS 111 and 112) also have an SBA receipt size standard that defines a small business as receiving $750,000 or less in receipts per year. However, SUSB data were not available for these industries. Therefore, we conducted the sales test using the following range of establishment receipts: farms with annual receipts of $25,000 or less, farms with annual receipts of $100,000 or less, farms with annual receipts of $500,000 or less, and farms with annual receipts of $750,000 or less.

Table 6-2. Average Receipts for Affected Industry by Enterprise: 2002 ($2009 Million/Establishment)

NAICS	NAICS Description	SBA Size Standard for Businesses (effective August 22, 2008)	All Enterprises	Owned By Enterprises with Employee Range: 1-20 employees	20 to 99 employees	100 to 499 employees	500 to 749 employees	750 to 999 employees	1,000 to 1,499 employees
211111	Crude Petroleum & NG Production	500 employees	$14.76	$0.54	$6.79	$9.63	NA	NA	NA
211112	Natural Gas Liquid Producers	500 employees	$174.86	$0.31	NA	$12.03	NA	NA	NA
335312	Motor & generator mfg	1,000 employees	$18.80	$1.38	$6.22	$16.15	$29.82	NA	NA
333992	Welding & soldering equipment mfg	500 employees	$18.73	$1.58	$6.67	$33.64	NA	NA	$115.91

NA = Not available.

Table 6-3. Average Receipts for Affected Industry by Enterprise Receipt Range: 2002 ($2009/Establishment)

NAICS	NAICS Description	SBA Size Standard for Businesses (effective August 22nd, 2008)	All Enterprises	Owned By Enterprises with Receipt Range: 0-99K Receipts	100–499.9K Receipts	500–999.9K Receipts	1,000–4,999.9K Receipts	5,000,000–9,999,999K Receipts	<10,000 K Receipts	10,000–49,999K Receipts	50,000–99,999K Receipts	100,000K + Receipts
2211	Electric Power Generation	[a]	$40.23	$0.1	$0.3	$0.8	$3.1	$6.7	$2.7	$14.8	$22.5	$49.8
48621	Natural Gas Transmission	$7.0 million in annual receipts	$22.09	$0.08	$0.32	$0.89	$2.51	$6.97	$1.57	$10.69	$45.99	$23.06
92811	National Security	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] NAICS codes 221111, 221112, 221113, 221119, 221121, 221122 – A firm is small if, including its affiliates, it is primarily engaged in the generation, transmission, and/or distribution of electric energy for sale and its total electric output for the preceding fiscal year did not exceed 4 million megawatt hours.

NA = Not available. SUSB did not report this data disclosure or other reasons.

Annual entity compliance costs vary depending on the size of the SI engines used at the affected establishment. Absent facility-specific information, we computed per-entity compliance costs based for three different cases based on representative establishments—Cases 1, 2, and 3 (see Table 6-4). Each representative establishment differs based on the size and number of SI engines being used. Compliance costs are calculated by summing the total annualized compliance costs for the relevant engine categories, dividing the sum by the total existing population of those engines, and multiplying the average engine cost by the number of engines assumed to be at the establishment. Since NAICS 2211 and 48621 are fundamentally different than other industries considered in this analysis due to the number of engines affected and amount of cost incurred resulting from this final rule, we used different assumptions about what constitutes the representative establishment and report these assumptions separately.

- Case 1: The representative establishment for all industries uses three 750+ hp engines with an average compliance cost of $8,500 per engine, resulting in a total annualized compliance cost of approximately $25,500 for this representative establishment.
- Case 2: The representative establishment in NACIS 2211 and 48621 uses two 25 to 750+ hp engines with an average compliance cost of $1,013 per engine, resulting in a total annualized compliance cost of $2,026 for this representative establishment. For all other industries, the representative establishment uses two 25 to 300 hp engines with an average compliance cost of $245 per engine, resulting in a total compliance cost of $490 for this representative establishment.
- Case 3: The representative establishment for all industries uses two 50 to 100 hp engines with an average compliance cost of $73 per engine, resulting in a total compliance cost of $145 for this representative establishment.

EPA believes that small entities are most likely to face costs similar to Case 2 (columns shaded in gray in Table 6-4) because most of the engines to be affected by this final rule in NAICS 335312, 333992, 211111, and 211112 are under 300 hp capacity, and most small entities in these industries will own engines of this size or smaller. This is corroborated by Figure 6-1 and 6-2 which shows the distribution of engine population and compliance costs by engine size for all industries. However, it is difficult to make a similar claim for NAICS 2211 and 48621 based on the existing distribution of engines in these industries.[6]

[6]This claim also cannot be made for NAICS 92811: National Security. However, since most national security installations are owned by the federal government (e.g., military bases), EPA assumes these entities would not be considered small.

For the sales test, we divided the representative establishment compliance costs reported in Table 6-4 by the representative establishment receipts reported in Tables 6-2 and 6-3. This is known as the cost-to-receipt (i.e., sales) ratio, or the "sales test." The "sales test" is the impact

Table 6-4. Representative Establishment Costs Used for Small Entity Analysis ($2009)

	Case 1		Case 2		Case 3	
	NAICS 2211, 48621 (+750 hp only)	**All Other NAICS (+750 hp only)**	**NAICS 2211,48621 (25-750+ hp)**	**All Other NAICS (25–300 hp)**	**NAICS 2211, 48621 (25–100 hp only)**	**All Other NAICS (25–100 hp only)**
Total Annualized Costs ($)	$89,716,669	$7,337,540	$203,582,405	$28,057,197	$8,510,985	$6,174,805
Engine Population	10,548	863	200,974	114,517	117,040	84,913
Average Engine Cost ($/engine)	$8,506	$8,502	$1,013	$245	$73	$73
Assumed Engines Per Establishment	3	3	2	2	2	2
Total Annualized Costs per Establishment	$25,517	$25,507	$2,026	$490	$145	$145

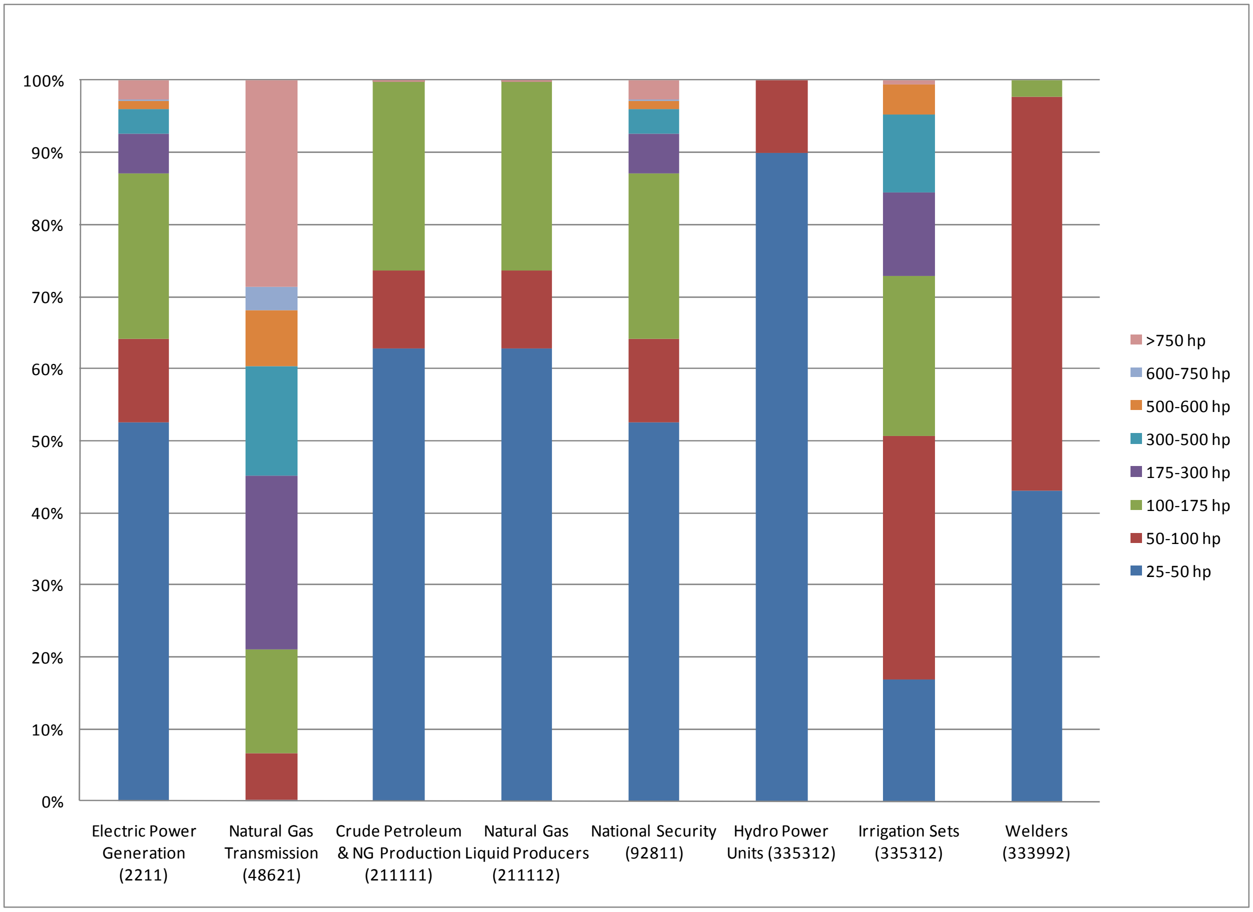

Figure 6-1. Distribution of Engine Population by Size for All Industries

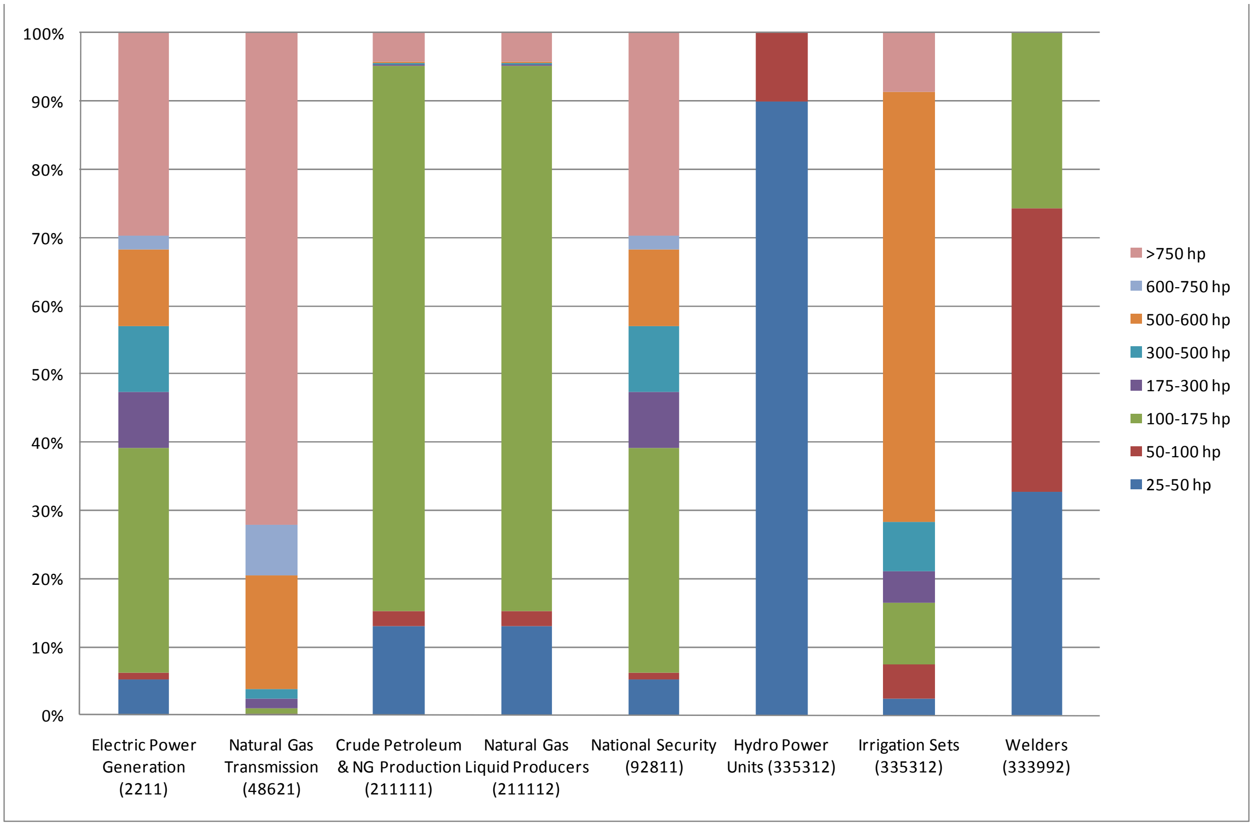

Figure 6-2. Distribution of Compliance Costs by Engine Size for All Industries

methodology EPA employs in analyzing small entity impacts as opposed to a "profits test," in which annualized compliance costs are calculated as a share of profits.

This is because revenues or sales data are commonly available data for entities normally impacted by EPA regulations and profits data normally made available are often not the true profit earned by firms because of accounting and tax considerations. Revenues as typically published are usually correct figures and are more reliably reported when compared to profit data. The use of a "sales test" for estimating small business impacts for a rulemaking such as this one is consistent with guidance offered by EPA on compliance with SBREFA[7] and is consistent with guidance published by the U.S. SBA's Office of Advocacy that suggests that cost as a percentage of total revenues is a metric for evaluating cost increases on small entities in relation to increases on large entities.[8]

[7]The SBREFA compliance guidance to EPA rulewriters regarding the types of small business analysis that should be considered can be found at http://www.epa.gov/sbrefa/documents/rfafinalguidance06.pdf, pp. 24-25.

[8]U.S. SBA, Office of Advocacy. A Guide for Government Agencies, How to Comply with the Regulatory Flexibility Act, Implementing the President's Small Business Agenda and Executive Order 13272, May 2003.

If the cost-to-receipt ratio is less than 1%, then we consider the final rule to not have a significant impact on the establishment company in question. We summarize the industries with cost-to-receipt ratios exceeding 1% below:

Primary Analysis:

- *Case 2*: NAICS 2211 with receipts less than $100,000 per year and NAICS 111 and 112 with receipts less than $25,000 per year
- *Case 3*: No industries

Sensitivity Analysis (unlikely):

- *Case 1*: NAICS 2211 with receipts less than $100,000 per year

In the Case 2 primary analysis, only establishments in NAICS 2211 with receipts less than $100,000 per year (less than 5 percent of the total), and establishments in NAICS 111 and 112 with receipts less than $25,000 per year (around 30 percent of the total) have cost-to-receipt ratios above 1%. However, establishments earning this level of receipts are likely to be using smaller engines than those assumed in Case 2, such as 25 to 300 hp engines. The results of our Case 3 analysis demonstrate that these establishments are not significantly impacted when taking this engine size into account.

After considering the economic impacts of this final rule on small entities, we certify that this action will not have a significant economic impact on a substantial number of small entities. This certification is based on the economic impact of this final action to all affected small entities across all industries affected. We estimate that all small entities will have annualized costs of less than 1 percent of their sales in all industries except NAICS 2211 (electric power generation, transmission, and distribution) and NAICS 111 and 112 (Crop and Animal Production). The number of small entities in NAICS 2211 having annualized costs of greater than 1 percent of their sales is less than 5 percent, and the number of small entities in NAICS 111 and 112 having annualized costs of greater than 1 percent of their sales (but less than 2 percent of sales) is 30 percent. We thus conclude that there is no significant economic impact on a substantial number of small entities (SISNOSE) for this rule.

Although the final rule would not have a significant economic impact on a substantial number of small entities, EPA nonetheless tried to reduce the impact of the final rule on small entities. When developing the revised standards, EPA took special steps to ensure that the burdens imposed on small entities were minimal. EPA conducted several meetings with industry trade associations to discuss regulatory options and the corresponding burden on industry, such as recordkeeping and reporting. In this rule, we are applying the minimum level of control (i.e., the MACT floor) to small non-emergency engines (below 300 HP) and emergency engines located at major HAP sources and the minimum level of testing, monitoring, recordkeeping, and reporting to affected RICE sources, both major and area, allowed by the CAA. Other alternatives considered that provided more than the minimum level of control were deemed as not technically feasible or cost-effective for EPA to implement for small non-emergency engines and emergency engines as explained earlier.

6.3 Small Government Entities

The rule also covers sectors that include entities owned by small and large governments. However, given the uncertainty and data limitations associated with identifying and appropriately classifying these entities, we computed a "revenue" test for a model small government, where the annualized compliance cost is a percentage of annual government revenues (U.S. Census, 2005a, b). The use of a "revenue test" for estimating impacts to small governments for a rulemaking such as this one is consistent with guidance offered by EPA on compliance with SBREFA,[9] and is consistent with guidance published by the US SBA's Office of Advocacy.[10] For example, from the 2002 Census (in 2008 dollars), the average revenue for small governments (counties and municipalities) with populations fewer than 10,000 is $3 million per entity, and the average revenue for local governments with populations fewer than 50,000 is $8 million per entity (U.S. Census Bureau, 2005a; U.S. Census Bureau, 2005b). For the smallest group of local governments (<10,000 people), the cost-to-revenue ratio would be 0.2% or less under each case. For the larger group of governments (<50,000 people), the cost-to-revenue ratio is 0.1% or less under all cases.

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[9]The SBREFA compliance guidance to EPA rule writers regarding the types of small business analysis that should be considered can be found at http://www.epa.gov/sbrefa/documents/rfafinalguidance06.pdf, pp. 24-25.

[10]U.S. SBA, Office of Advocacy. A Guide for Government Agencies, How to Comply with the Regulatory Flexibility Act, Implementing the President's Small Business Agenda and Executive Order 13272, May 2003.

SECTION 7
HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

7.1 Synopsis

In this section, we provide an estimate of the monetized co-benefits associated with reducing particulate matter (PM) for the final NESHAP for spark ignition reciprocating internal combustion engines (SI RICE). Specifically, we calculated the co-benefits of this rule in terms of the co-benefits associated with reducing PM rather than calculating the co-benefits associated with reducing hazardous air pollutants (HAPs). These PM reductions are a consequence of the technologies installed to reduce HAP emissions from SI RICE. These estimates reflect the monetized human health co-benefits of reducing cases of morbidity and premature mortality among populations exposed to the $PM_{2.5}$ precursors reduced by this rulemaking. Using a 3% discount rate, we estimate the total monetized co-benefits of the final NESHAP to be $510 million to $1.2 billion in the implementation year (2013). Using a 7% discount rate, we estimate the total monetized co-benefits of the final NESHAP to be $460 million to $1.1 billion in the implementation year. All estimates are in 2009$.

These estimates reflect EPA's most current interpretation of the scientific literature. Higher or lower estimates of benefits are possible using other assumptions; examples of this are provided in Figure 7-2. Data, resource, and methodological limitations prevented EPA from monetizing the benefits from several important benefit categories, including benefits from reducing hazardous air pollutants, ecosystem effects, and visibility impairment. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 109,000 tons of carbon monoxide and 6,000 tons of HAPs each year.

7.2 Calculation of $PM_{2.5}$ Human Health Co-Benefits

This rulemaking would reduce emissions of NOx and VOCs. Because NOx and VOCs are precursors to $PM_{2.5,}$ reducing these emissions would also reduce $PM_{2.5}$ formation, human exposure, and the incidence of $PM_{2.5}$-related health effects. These PM reductions are a consequence of the technologies installed to reduce HAP emissions from SI RICE. Due to analytical limitations, it was not possible to provide a comprehensive estimate of $PM_{2.5}$-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). The key assumptions are described in detail below. 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 NO_2 NAAQS RIA (U.S. EPA, 2010b). Table 7-1 shows the quantified and unquantified co-benefits captured in those benefit-per-ton estimates.

Table 7-1. 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 $\mu g/m^3$ 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 $\mu g/m^3$ 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).[1] 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).[2] 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 7-2). 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., NOx emitted from electric generating units; NO_2 emitted from mobile sources). Our estimate of $PM_{2.5}$ control co-benefits is therefore based on the total NOx and VOC emissions controlled by sector and multiplied by this per-ton value.

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. NOx and VOCs

[1] These two studies specify multi-pollutant models that control for NOx, among other pollutants.
[2] 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.

are the primary $PM_{2.5}$ precursors affected by this rule. Even though we assume that all fine particles have equivalent health effects, the benefit-per-ton estimates vary between precursors because each ton of precursor reduced has a different propensity to form $PM_{2.5}$. For example, NO_X has a lower benefit-per-ton estimate than direct $PM_{2.5}$ because it does not form as much $PM_{2.5}$, thus the exposure would be lower, and the monetized health co-benefits would be lower.

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 (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.[3] 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

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

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), which is provided as an appendix to this RIA.

Consistent with this recent scientific advice, we are replacing the previous threshold sensitivity analysis with 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 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. 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), which is provided as an appendix to this RIA. The results of this analysis are provided in Section 7.4.

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 $5.5 million (2000$)[4] 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)[5] 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 $6.3 million (2000$).[6] 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.

4. After adjusting the VSL for a different currency year (2009$) and to account for income growth to 2015 to the $5.5 million value, the VSL is $7.9 million.

5 In the (draft) update of the Economic Guidelines (U.S. EPA, 2008), 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.

6 In this analysis, we adjust the VSL to account for a different currency year (2009$) 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 7-1 illustrates the relative breakdown of the monetized $PM_{2.5}$ health co-benefits by health endpoint.

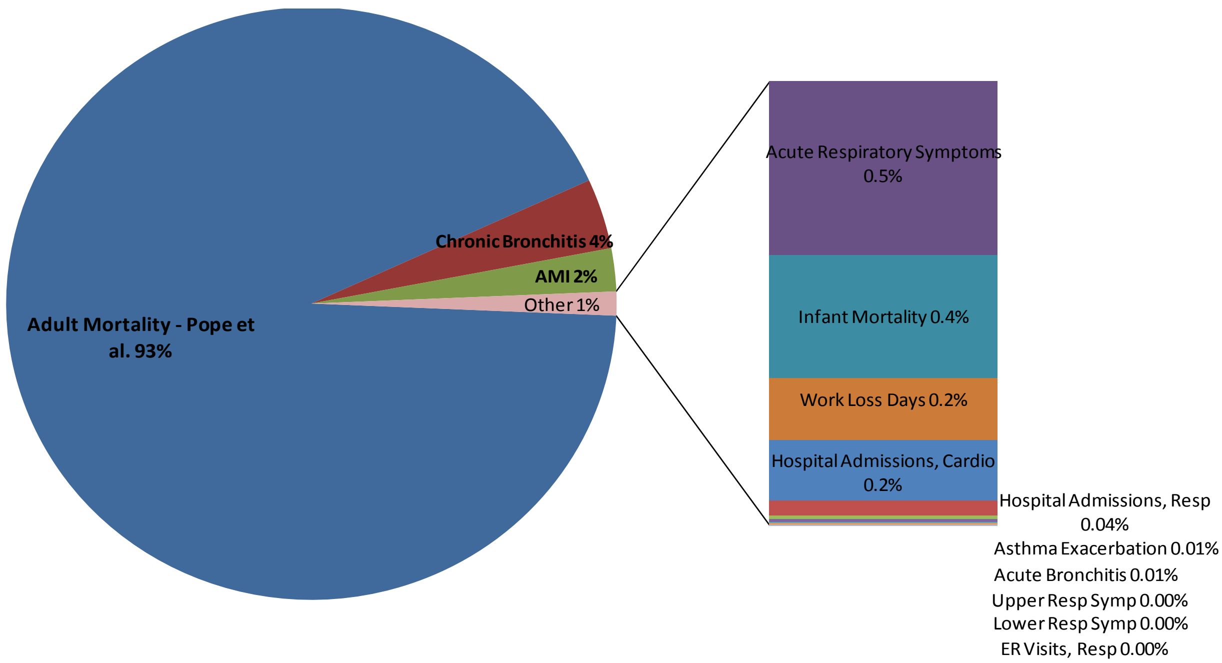

Figure 7-1. Breakdown of Monetized $PM_{2.5}$ Health Co-Benefits using Mortality Function from Pope et al. (2002)[a]

[a] This 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 7-2 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%.[7] Table 7-3 provides a summary of the reductions in health incidences anticipated as a result of the pollution reductions. In Table 7-4, 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.

[7] 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.

Figures 7-2 and 7-3 provide a visual representation of the range of monetized co-benefits estimates and the pollutant breakdown of the monetized co-benefits of the proposed option. The final NESHAP is the MACT floor level of control for all major SI RICE sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the required level of control is above the MACT floor, and the GACT level of control for area SI RICE sources. We also show results for an alternative in which only the MACT level of control is applied to all SI RICE major sources.

Table 7-2. Summary of Monetized Co-Benefits Estimates for the Final Spark Ignition NESHAP in 2013 (2009$)[a]

	Pollutant	Emissions Reductions (tons)	Benefit per ton (Pope, 3%)	Benefit per ton (Laden, 3%)	Benefit per ton (Pope, 7%)	Benefit per ton (Laden, 7%)	Total Monetized Benefits (millions 2008$ at 3%)	Total Monetized Benefits (millions 2008$ at 7%)
Final NESHAP: Major[b]	$PM_{2.5}$ Precursors							
	VOC	6,730	$1,200	$3,000	$1,100	$2,700	$8.2 to $20	$7.4 to $18
	NO_X	0	$4,900	$12,000	$4,400	$11,000	$0	$0
						Total	**$12 to $30**	**$11 to $27**
Alternative 1: Major	$PM_{2.5}$ Precursors							
	VOC	7,265	$1,200	$3,000	$1,100	$2,700	$8.8 to $22	$8.0 to $20
	NO_X	8,040	$4,900	$12,000	$4,400	$11,000	$39 to $95	$35 to $86
						Total	**$48 to $120**	**$43 to $110**
Final: Area Source only[c]	$PM_{2.5}$ Precursors							
	VOC	24,177	$1,200	$3,000	$1,100	$2,700	$29 to $72	$27 to $65
	NO_X	96,479	$4,900	$12,000	$4,400	$11,000	$470 to $1,100	$420 to $1,000
						Total	**$500 to $1,200**	**$450 to $1,100**
Final: Major and Area Total	$PM_{2.5}$ Precursors							
	VOC	30,907	$1,200	$3,000	$1,100	$2,700	$38 to $92	$34 to $83
	NO_X	96,479	$4,900	$12,000	$4,400	$11,000	$470 to $1,100	$420 to $1,000
						Total	**$510 to $1,200**	**$460 to $1,100**

[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.

[b] The final NESHAP is the MACT floor level of control for all major SI RICE sources, and the GACT level of control for area SI RICE sources. We also show results for an alternative (referred to as Alternative 2) in which the MACT level of control is applied to all SI RICE major sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the required level of control is above the MACT floor and the GACT level of control is applied to all SI RICE area sources.

[c] All of the benefits for area sources are attributable to reductions expected from 4SLB and 4SRB non-emergency engines above 500 HP.

Table 7-3. Summary of Reductions in Health Incidences from $PM_{2.5}$ Co-Benefits for Final SI RICE NESHAP in 2013[a]

	Final NESHAP: Major[b]	Alternative 2: Major	Final: Area Source only[c]	Final: Major and Area Sources TOTAL
Avoided Premature Mortality				
Pope et al.	1	2	16	17
Laden et al.	2	5	42	44
Avoided Morbidity				
Chronic Bronchitis	1	2	12	12
Acute Myocardial Infarction	2	4	31	33
Hospital Admissions, Respiratory	0	1	4	4
Hospital Admissions, Cardiovascular	0	1	8	9
Emergency Room Visits, Respiratory	1	2	12	13
Acute Bronchitis	2	3	27	29
Work Loss Days	130	280	2,200	2,400
Asthma Exacerbation	16	37	300	310
Minor Restricted Activity Days	740	1,700	13,000	14,000
Lower Respiratory Symptoms	18	41	320	340
Upper Respiratory Symptoms	14	31	240	260

[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.

[b] The final NESHAP is the MACT floor level of control for all major SI RICE sources and the GACT level of control for area SI RICE sources. We also show results for an alternative (referred to as Alternative 2) in which the MACT level of control is applied to all SI RICE major sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the level of control is above the MACT floor, and the GACT level of control is applied to all area SI RICE sources.

[c] All of the benefits for area sources are attributable to reductions expected from 4SLB and 4SRB non-emergency engines above 500 HP.

Table 7-4. All Monetized $PM_{2.5}$ Co-Benefits Estimates for the Final SI RICE NESHAP at discount rates of 3% and 7% in 2013 (in millions of 2009$)[a]

	Final NESHAP: Major[b]		Alternative 2: Major		Final: Area Source only[c]		Final: Major and Area Sources Total	
	3%	7%	3%	7%	3%	7%	3%	7%
Benefit-per-ton Coefficients derived from Epidemiology Literature								
Pope et al.	$8.2	$7.4	$48	$43	$500	$450	$510	$460
Laden et al.	$20	$18	$120	$110	$1,200	$1,100	$1,200	$1,100
Benefit-per-ton Coefficients Derived from Expert Elicitation								
Expert A	$21	$19	$124	$112	$1,300	$1,160	$1,300	$1,200
Expert B	$16	$15	$95	$86	$1,000	$900	$1,000	$910
Expert C	$16	$15	$95	$85	$1,000	$900	$1,000	$900
Expert D	$11	$10	$67	$61	$700	$600	$710	$640
Expert E	$26	$24	$153	$139	$1,600	$1,400	$1,600	$1,500
Expert F	$15	$13	$86	$78	$900	$800	$910	$820
Expert G	$10	$9	$57	$51	$590	$530	$600	$540
Expert H	$12	$11	$71	$65	$700	$700	$750	$680
Expert I	$16	$14	$94	$85	$1,000	$900	$990	$890
Expert J	$13	$12	$76	$69	$800	$700	$810	$730
Expert K	$3.3	$3.0	$19	$18	$200	$190	$210	$190
Expert L	$12	$11	$70	$63	$700	$700	$740	$670

[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.

[b] The final NESHAP is the MACT floor level of control for all major SI RICE and the GACT level of control for area SI RICE sources. We also show results for an alternative (referred to as Alternative 2) in which the MACT level of control is applied to all SI RICE major sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the required level of control is above the MACT floor, and the GACT level of controls is applied to all area SI RICE sources.

[c] All of the benefits for area sources are attributable to reductions expected from 4SLB and 4SRB non-emergency engines above 500 HP.

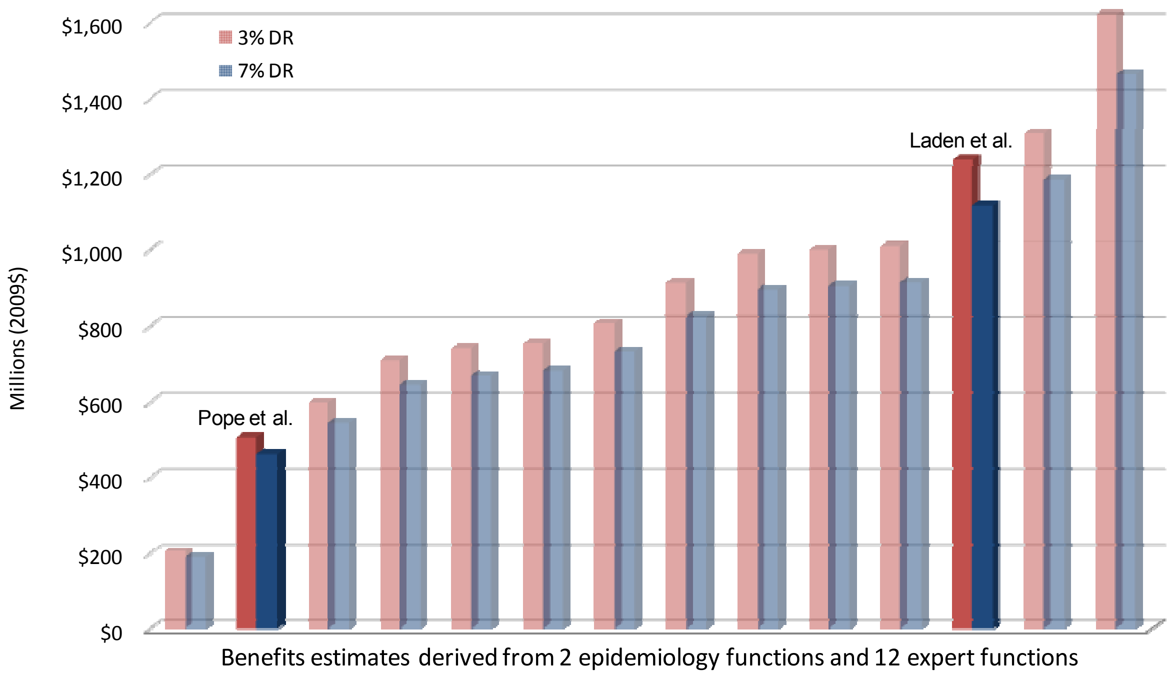

Figure 7-2. Total Monetized $PM_{2.5}$ Co-Benefits for the Final SI RICE NESHAP in 2013

[a] This 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.

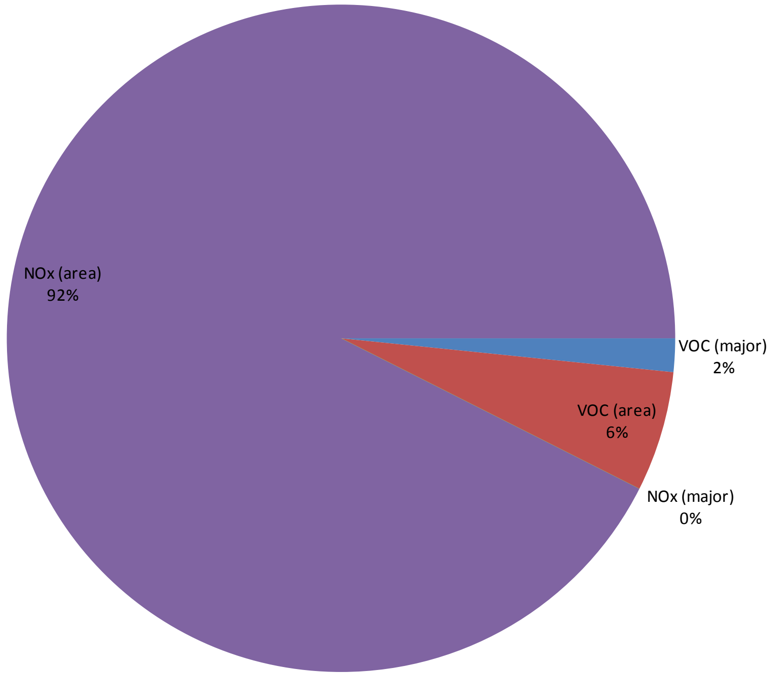

Figure 7-3. Breakdown of Monetized Co-Benefits for the Final SI RICE NESHAP by $PM_{2.5}$ Precursor Pollutant and Source

7.3 Unquantified Benefits

The monetized co-benefits estimated in this RIA only reflect the portion of co-benefits attributable to the health effect reductions associated with ambient fine particles. Data, resource, and methodological limitations prevented EPA from quantifying or monetizing the benefits from several important benefit categories, including benefits from reducing toxic emissions, ecosystem effects, and visibility impairment. The health co-benefits from reducing hazardous air pollutants (HAPs) and carbon monoxide each year have not been monetized in this analysis. In addition to being a $PM_{2.5}$ precursor, NOx emissions also contribute to adverse effects from acidic deposition in aquatic and terrestrial ecosystems, increase mercury methylation, as well as visibility impairment.

7.3.1 Carbon Monoxide Benefits

Carbon monoxide (CO) exposure is associated with a variety of health effects. Without knowing the location of the emission reductions and the resulting ambient concentrations using fine-scale air quality modeling, we were unable to estimate the exposure to CO for nearby populations. Due to data, resource, and methodological limitations, we were unable to estimate the benefits associated with the reductions in CO emissions that would occur as a result of this rule.

Carbon monoxide in ambient air is formed primarily by the incomplete combustion of carbon-containing fuels and photochemical reactions in the atmosphere. The amount of CO emitted from these reactions, relative to carbon dioxide (CO_2), is sensitive to conditions in the combustion zone, such as fuel oxygen content, burn temperature, or mixing time. Upon inhalation, CO diffuses through the respiratory system to the blood, which can cause hypoxia (reduced oxygen availability). Carbon monoxide can elicit a broad range of effects in multiple tissues and organ systems that are dependent upon concentration and duration of exposure.

The Integrated Science Assessment for Carbon Monoxide (U.S. EPA, 2010a) concluded that short-term exposure to CO is "likely to have a causal relationship" with cardiovascular morbidity, particularly in individuals with coronary heart disease. Epidemiologic studies associate short-term CO exposure with increased risk of emergency department visits and hospital admissions. Coronary heart disease includes those who have angina pectoris (cardiac chest pain), as well as those who have experienced a heart attack. Other subpopulations potentially at risk include individuals with diseases such as chronic obstructive pulmonary disease (COPD), anemia, or diabetes, and individuals in very early or late life stages, such as older adults or the developing young. The evidence is suggestive of a causal relationship between short-term exposure to CO and respiratory morbidity and mortality. The evidence is also suggestive of a causal relationship for birth outcomes and developmental effects following long-term exposure to CO, and for central nervous system effects linked to short- and long-term exposure to CO.

7.3.2 Other NOx Benefits

In addition to being a precursor to $PM_{2.5}$, NOx emissions are also associated with a variety of respiratory health effects. Unfortunately, we were unable to estimate the health benefits associated with reduced NOx exposure in this analysis because we do not have air quality modeling data available. Without knowing the location of the emission reductions and the resulting ambient concentrations, we were unable to estimate the exposure to NOx for nearby populations. Therefore, this analysis only quantifies and monetizes the $PM_{2.5}$ co-benefits associated with the reductions in NOx emissions.

Following an extensive evaluation of health evidence from epidemiologic and laboratory studies, the Integrated Science Assessment (ISA) for Nitrogen Dioxide concluded that there is a likely causal relationship between respiratory health effects and short-term exposure to NO_2

(U.S. EPA, 2008a). Persons with preexisting respiratory disease, children, and older adults may be more susceptible to the effects of NO_2 exposure. Based on our review of this information, we identified four short-term morbidity endpoints that the NO_2 ISA identified as a "likely causal relationship": asthma exacerbation, respiratory-related emergency department visits, and respiratory-related hospitalizations. The differing evidence and associated strength of the evidence for these different effects is described in detail in the NO_2 ISA. The NO_2 ISA also concluded that the relationship between short-term NO_2 exposure and premature mortality was "suggestive but not sufficient to infer a causal relationship" because it is difficult to attribute the mortality risk effects to NO_2 alone. Although the NO_2 ISA stated that studies consistently reported a relationship between NO_2 exposure and mortality, the effect was generally smaller than that for other pollutants such as PM.

NOx emissions also contribute to adverse welfare effects from acidic deposition, nutrient enrichment, and visibility impairment. Deposition of nitrogen causes acidification, which can cause a loss of biodiversity of fishes, zooplankton, and macro invertebrates in aquatic ecosystems, as well as a decline in sensitive tree species, such as red spruce (*Picea rubens*) and sugar maple (*Acer saccharum*) in terrestrial ecosystems. In the northeastern United States, the surface waters affected by acidification are a source of food for some recreational and subsistence fishermen and for other consumers and support several cultural services, including aesthetic and educational services and recreational fishing. Biological effects of acidification in terrestrial ecosystems are generally linked to aluminum toxicity, which can cause reduced root growth, which restricts the ability of the plant to take up water and nutrients. These direct effects can, in turn, increase the sensitivity of these plants to stresses, such as droughts, cold temperatures, insect pests, and disease leading to increased mortality of canopy trees. Terrestrial acidification affects several important ecological services, including declines in habitat for threatened and endangered species (cultural), declines in forest aesthetics (cultural), declines in forest productivity (provisioning), and increases in forest soil erosion and reductions in water retention (cultural and regulating). (U.S. EPA, 2008d)

Deposition of is also associated with aquatic and terrestrial nutrient enrichment. In estuarine waters, excess nutrient enrichment can lead to eutrophication. Eutrophication of estuaries can disrupt an important source of food production, particularly fish and shellfish production, and a variety of cultural ecosystem services, including water-based recreational and aesthetic services. Terrestrial nutrient enrichment is associated with changes in the types and number of species and biodiversity in terrestrial systems. Excessive nitrogen deposition upsets the balance between native and nonnative plants, changing the ability of an area to support biodiversity. When the composition of species changes, then fire frequency and intensity can also change, as nonnative grasses fuel more frequent and more intense wildfires. (U.S. EPA, 2008d)

Reducing NO_X emissions and the secondary formation of $PM_{2.5}$ would improve the level of visibility throughout the United States. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). These suspended particles and gases degrade visibility by scattering and absorbing light. Higher visibility impairment levels in the East are due to generally higher concentrations of fine particles, particularly sulfates, and higher average relative humidity levels. Visibility has direct significance to people's enjoyment of daily activities and their overall sense of wellbeing. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities.

7.3.3 Ozone Co-Benefits

In the presence of sunlight, NOx and VOCs can undergo a chemical reaction in the atmosphere to form ozone. Reducing ambient ozone concentrations is associated with significant human health benefits, including mortality and respiratory morbidity (U.S. EPA, 2008). Epidemiological researchers have associated ozone exposure with adverse health effects in numerous toxicological, clinical and epidemiological studies (U.S. EPA, 2006c). These health effects include respiratory morbidity such as fewer asthma attacks, hospital and ER visits, school loss days, as well as premature mortality.

7.3.4 HAP Benefits

Americans are exposed to ambient concentrations of air toxics at levels which have the potential to cause adverse health effects.[8] The levels of air toxics to which people are exposed vary depending on where people live and work and the kinds of activities in which they engage. In order to identify and prioritize air toxics, emission source types and locations which are of greatest potential concern, U.S. EPA conducts the National-Scale Air Toxics Assessment (NATA). The most recent NATA was conducted for calendar year 2002, and was released in June 2009.[9] NATA for 2002 includes four steps:

1) Compiling a national emissions inventory of air toxics emissions from outdoor sources

[8] U.S. EPA. (2009) 2002 National-Scale Air Toxics Assessment. http://www.epa.gov/ttn/atw/nata2002/
[9] U.S. EPA. (2009) 2002 National-Scale Air Toxics Assessment. http://www.epa.gov/ttn/atw/nata2002/

2) Estimating ambient concentrations of air toxics across the United States

3) Estimating population exposures across the United States

4) Characterizing potential public health risk due to inhalation of air toxics including both cancer and noncancer effects

Noncancer health effects can result from chronic,[10] subchronic,[11] or acute[12] inhalation exposures to air toxics, and include neurological, cardiovascular, liver, kidney, and respiratory effects as well as effects on the immune and reproductive systems. According to the 2002 NATA, nearly the entire U.S. population was exposed to an average concentration of air toxics that has the potential for adverse noncancer respiratory health effects.[13] Figures 7-4 and 7-5 depict estimated county-level carcinogenic risk and noncancer respiratory hazard from the assessment. The respiratory hazard is dominated by a single pollutant, acrolein.

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[10] Chronic exposure is defined in the glossary of the Integrated Risk Information (IRIS) database (http://www.epa.gov/iris) as repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).

[11] Defined in the IRIS database as exposure to a substance spanning approximately 10% of the lifetime of an organism.

[12] Defined in the IRIS database as exposure by the oral, dermal, or inhalation route for 24 hours or less.

[13] The NATA modeling framework has a number of limitations which prevent its use as the sole basis for setting regulatory standards. These limitations and uncertainties are discussed on the 2002 NATA website. Even so, this modeling framework is very useful in identifying air toxic pollutants and sources of greatest concern, setting regulatory priorities, and informing the decision making process. U.S. EPA. (2009) 2002 National-Scale Air Toxics Assessment. http://www.epa.gov/ttn/atw/nata2002/

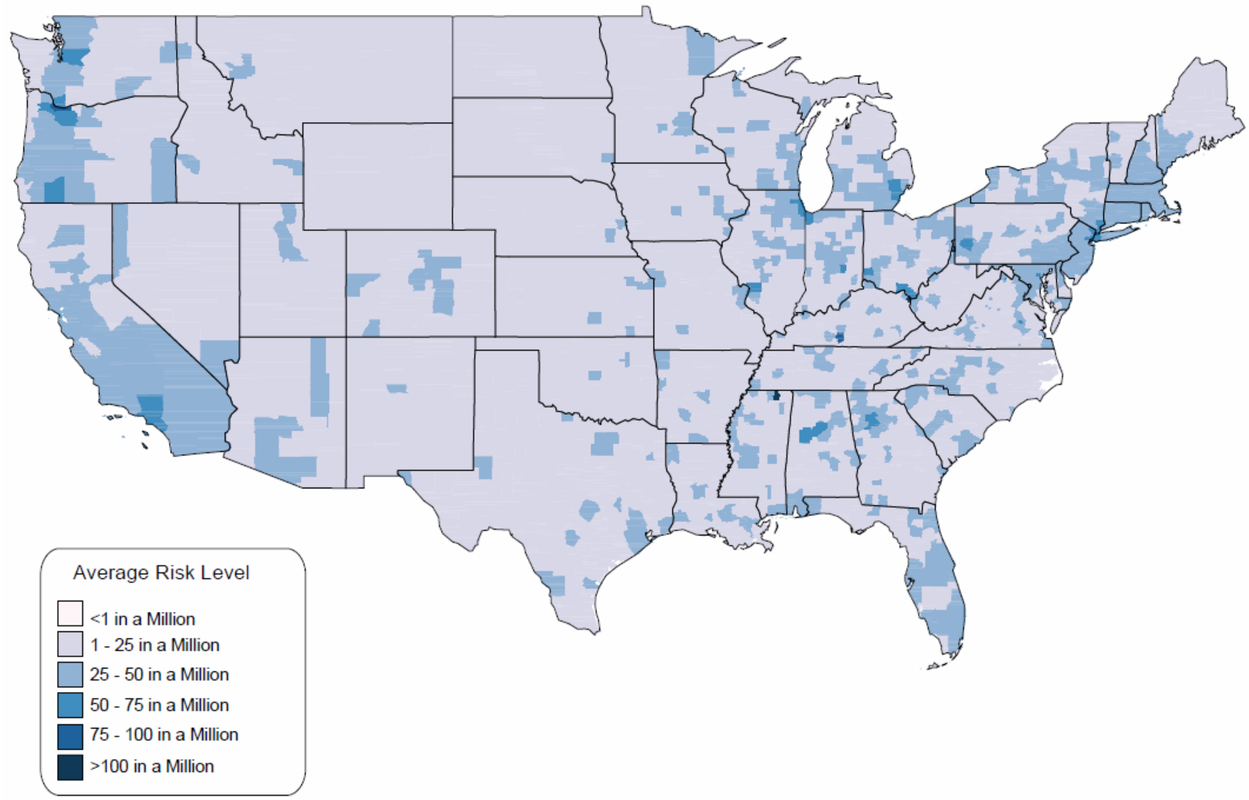

Figure 7-4. Estimated County Level Carcinogenic Risk from HAP exposure from outdoor sources (from 2002 NATA)

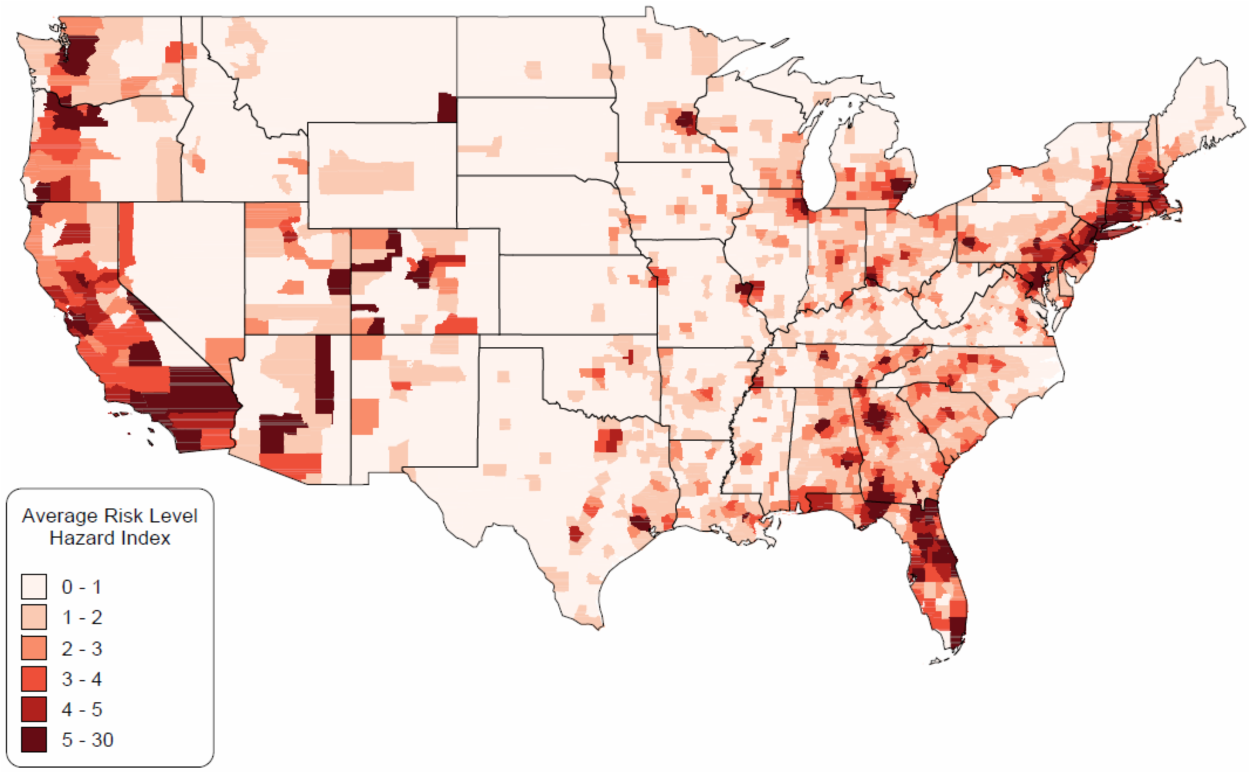

Figure 7-5. Estimated County Level Noncancer (Respiratory) Risk from HAP exposure from outdoor sources (from 2002 NATA)

Due to data, resource, and methodology limitations, we were unable to estimate the benefits associated with the thousands tons of hazardous air pollutants that would be reduced as a result of this rule. Available emissions data show that several different HAPs are emitted from SI RICE, either contained within the fuel burned or formed during the combustion process.

Although numerous HAPs may be emitted from SI RICE, a few HAPs account for over 90% of the total mass of HAPs emissions emitted. These HAPs are formaldehyde (72%), acetaldehyde (8%), acrolein (7%), methanol (3%), and benzene (3%). Although we do not have estimates of emission reductions for each HAP, this rule is anticipated to reduce 6,000 tons of HAPs each year. Below we describe the health effects associated with the top 5 HAPs by mass emitted from SI RICE.

7.3.4.1 Formaldehyde

Since 1987, EPA has classified formaldehyde as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys.[14] EPA is currently reviewing

[14] U.S. EPA. 1987. Assessment of Health Risks to Garment Workers and Certain Home Residents from Exposure to Formaldehyde, Office of Pesticides and Toxic Substances, April 1987.

recently published epidemiological data. For instance, research conducted by the National Cancer Institute (NCI) found an increased risk of nasopharyngeal cancer and lymphohematopoietic malignancies such as leukemia among workers exposed to formaldehyde.[15,16] In an analysis of the lymphohematopoietic cancer mortality from an extended follow-up of these workers, NCI confirmed an association between lymphohematopoietic cancer risk and peak exposures.[17] A recent National Institute of Occupational Safety and Health (NIOSH) study of garment workers also found increased risk of death due to leukemia among workers exposed to formaldehyde.[18] Extended follow-up of a cohort of British chemical workers did not find evidence of an increase in nasopharyngeal or lymphohematopoietic cancers, but a continuing statistically significant excess in lung cancers was reported.[19]

In the past 15 years there has been substantial research on the inhalation dosimetry for formaldehyde in rodents and primates by the CIIT Centers for Health Research (formerly the Chemical Industry Institute of Toxicology), with a focus on use of rodent data for refinement of the quantitative cancer dose-response assessment.[20,21,22] CIIT's risk assessment of formaldehyde incorporated mechanistic and dosimetric information on formaldehyde. However, it should be noted that recent research published by EPA indicates that when two-stage modeling assumptions are varied, resulting dose-response estimates can vary by several orders of magnitude.[23,24,25,26] These findings are not supportive of interpreting the CIIT model results as

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[15] Hauptmann, M.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Blair, A. 2003. Mortality from lymphohematopoetic malignancies among workers in formaldehyde industries. Journal of the National Cancer Institute 95: 1615-1623.
[16] Hauptmann, M.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Blair, A. 2004. Mortality from solid cancers among workers in formaldehyde industries. American Journal of Epidemiology 159: 1117-1130.
[17] Beane Freeman, L. E.; Blair, A.; Lubin, J. H.; Stewart, P. A.; Hayes, R. B.; Hoover, R. N.; Hauptmann, M. 2009. Mortality from lymphohematopoietic malignancies among workers in formaldehyde industries: The National Cancer Institute cohort. J. National Cancer Inst. 101: 751-761.
[18] Pinkerton, L. E. 2004. Mortality among a cohort of garment workers exposed to formaldehyde: an update. Occup. Environ. Med. 61: 193-200.
[19] Coggon, D, EC Harris, J Poole, KT Palmer. 2003. Extended follow-up of a cohort of British chemical workers exposed to formaldehyde. J National Cancer Inst. 95:1608-1615.
[20] Conolly, RB, JS Kimbell, D Janszen, PM Schlosser, D Kalisak, J Preston, and FJ Miller. 2003. Biologically motivated computational modeling of formaldehyde carcinogenicity in the F344 rat. Tox Sci 75: 432-447.
[21] Conolly, RB, JS Kimbell, D Janszen, PM Schlosser, D Kalisak, J Preston, and FJ Miller. 2004. Human respiratory tract cancer risks of inhaled formaldehyde: Dose-response predictions derived from biologically-motivated computational modeling of a combined rodent and human dataset. Tox Sci 82: 279-296.
[22] Chemical Industry Institute of Toxicology (CIIT).1999. Formaldehyde: Hazard characterization and dose-response assessment for carcinogenicity by the route of inhalation. CIIT, September 28, 1999. Research Triangle Park, NC.
[23] U.S. EPA. Analysis of the Sensitivity and Uncertainty in 2-Stage Clonal Growth Models for Formaldehyde with Relevance to Other Biologically-Based Dose Response (BBDR) Models. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-08/103, 2008
[24] Subramaniam, R; Chen, C; Crump, K; .et .al. (2008) Uncertainties in biologically-based modeling of formaldehyde-induced cancer risk: identification of key issues. Risk Anal 28(4):907-923.
[25] Subramaniam, R; Chen, C; Crump, K; .et .al. (2007). Uncertainties in the CIIT 2-stage model for formaldehyde-induced nasal cancer in the F344 rat: a limited sensitivity analysis-I. Risk Anal 27:1237

providing a conservative (health protective) estimate of human risk.[27] EPA research also examined the contribution of the two-stage modeling for formaldehyde towards characterizing the relative weights of key events in the mode-of-action of a carcinogen. For example, the model-based inference in the published CIIT study that formaldehyde's direct mutagenic action is not relevant to the compound's tumorigenicity was found not to hold under variations of modeling assumptions.[28]

Based on the developments of the last decade, in 2004, the working group of the IARC concluded that formaldehyde is carcinogenic to humans (Group 1), on the basis of sufficient evidence in humans and sufficient evidence in experimental animals - a higher classification than previous IARC evaluations. After reviewing the currently available epidemiological evidence, the IARC (2006) characterized the human evidence for formaldehyde carcinogenicity as "sufficient," based upon the data on nasopharyngeal cancers; the epidemiologic evidence on leukemia was characterized as "strong."[29] EPA is reviewing the recent work cited above from the NCI and NIOSH, as well as the analysis by the CIIT Centers for Health Research and other studies, as part of a reassessment of the human hazard and dose-response associated with formaldehyde.

Formaldehyde exposure also causes a range of noncancer health effects, including irritation of the eyes (burning and watering of the eyes), nose and throat. Effects from repeated exposure in humans include respiratory tract irritation, chronic bronchitis and nasal epithelial lesions such as metaplasia and loss of cilia. Animal studies suggest that formaldehyde may also cause airway inflammation – including eosinophil infiltration into the airways. There are several studies that suggest that formaldehyde may increase the risk of asthma – particularly in the young.[30,31]

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[26] Crump, K; Chen, C; Fox, J; .et .al. (2008) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495.

[27] Crump, K; Chen, C; Fox, J; .et .al. (2008) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495.

[28] Subramaniam, R; Chen, C; Crump, K; .et .al. (2007). Uncertainties in the CIIT 2-stage model for formaldehyde-induced nasal cancer in the F344 rat: a limited sensitivity analysis-I. Risk Anal 27:1237

[29] International Agency for Research on Cancer (2006) Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. Monographs Volume 88. World Health Organization, Lyon, France.

[30] Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for Formaldehyde. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. http://www.atsdr.cdc.gov/toxprofiles/tp111.html

[31] WHO (2002) Concise International Chemical Assessment Document 40: Formaldehyde. Published under the joint sponsorship of the United Nations Environment Programme, the International Labour Organization, and the World Health Organization, and produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals. Geneva.

7.3.4.2 Acetaldehyde

Acetaldehyde is classified in EPA's IRIS database as a probable human carcinogen, based on nasal tumors in rats, and is considered toxic by the inhalation, oral, and intravenous routes.[32] Acetaldehyde is reasonably anticipated to be a human carcinogen by the U.S. DHHS in the 11th Report on Carcinogens and is classified as possibly carcinogenic to humans (Group 2B) by the IARC.[33,34] EPA is currently conducting a reassessment of cancer risk from inhalation exposure to acetaldehyde.

The primary noncancer effects of exposure to acetaldehyde vapors include irritation of the eyes, skin, and respiratory tract.[35] In short-term (4 week) rat studies, degeneration of olfactory epithelium was observed at various concentration levels of acetaldehyde exposure.[36, 37] Data from these studies were used by EPA to develop an inhalation reference concentration. Some asthmatics have been shown to be a sensitive subpopulation to decrements in functional expiratory volume (FEV1 test) and bronchoconstriction upon acetaldehyde inhalation.[38] The agency is currently conducting a reassessment of the health hazards from inhalation exposure to acetaldehyde.

7.3.4.3 Acrolein

EPA determined in 2003 that the human carcinogenic potential of acrolein could not be determined because the available data were inadequate. No information was available on the carcinogenic effects of acrolein in humans and the animal data provided inadequate evidence of

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32 U.S. Environmental Protection Agency (U.S. EPA). 1991. Integrated Risk Information System File of Acetaldehyde. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/iris/subst/0290.htm.

33 U.S. Department of Health and Human Services National Toxicology Program 11th Report on Carcinogens available at: http://ntp.niehs.nih.gov/go/16183.

34 International Agency for Research on Cancer (IARC). 1999. Re-evaluation of some organic chemicals, hydrazine, and hydrogen peroxide. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemical to Humans, Vol 71. Lyon, France.

35 U.S. Environmental Protection Agency (U.S. EPA). 1991. Integrated Risk Information System File of Acetaldehyde. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/iris/subst/0290.htm.

36 U.S. Environmental Protection Agency (U.S. EPA). 1991. Integrated Risk Information System File of Acetaldehyde. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/iris/subst/0290.htm.

37 Appleman, L.M., R.A. Woutersen, and V.J. Feron. (1982). Inhalation toxicity of acetaldehyde in rats. I. Acute and subacute studies. Toxicology. 23: 293-297.

38 Myou, S.; Fujimura, M.; Nishi K.; Ohka, T.; and Matsuda, T. (1993) Aerosolized acetaldehyde induces histamine-mediated bronchoconstriction in asthmatics. Am. Rev. Respir.Dis.148(4 Pt 1): 940-943.

carcinogenicity.[39] The IARC determined in 1995 that acrolein was not classifiable as to its carcinogenicity in humans.[40]

Acrolein is extremely acrid and irritating to humans when inhaled, with acute exposure resulting in upper respiratory tract irritation, mucus hypersecretion and congestion. The intense irritancy of this carbonyl has been demonstrated during controlled tests in human subjects, who suffer intolerable eye and nasal mucosal sensory reactions within minutes of exposure.[41] These data and additional studies regarding acute effects of human exposure to acrolein are summarized in EPA's 2003 IRIS Human Health Assessment for acrolein.[42] Evidence available from studies in humans indicate that levels as low as 0.09 ppm (0.21 mg/m^3) for five minutes may elicit subjective complaints of eye irritation with increasing concentrations leading to more extensive eye, nose and respiratory symptoms.[43] Lesions to the lungs and upper respiratory tract of rats, rabbits, and hamsters have been observed after subchronic exposure to acrolein.[44] Acute exposure effects in animal studies report bronchial hyper-responsiveness.[45] In a recent study, the acute respiratory irritant effects of exposure to 1.1 ppm acrolein were more pronounced in mice with allergic airway disease by comparison to non-diseased mice which also showed decreases in respiratory rate.[46] Based on these animal data and demonstration of similar effects in humans (i.e., reduction in respiratory rate), individuals with compromised respiratory function (e.g., emphysema, asthma) are expected to be at increased risk of developing adverse responses to strong respiratory irritants such as acrolein.

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[39] U.S. Environmental Protection Agency (U.S. EPA). 2003. Integrated Risk Information System File of Acrolein. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available at http://www.epa.gov/iris/toxreviews/0364tr.pdf.

[40] International Agency for Research on Cancer (IARC). 1995. Monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 63, Dry cleaning, some chlorinated solvents and other industrial chemicals, World Health Organization, Lyon, France.

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7.3.4.4 Methanol

Exposure of humans to methanol by inhalation or ingestion may result in central nervous system depression and degenerative changes in the brain and visual systems. After inhaled or ingested, methanol is converted to formate, a highly toxic metabolite that within the course of a few hours can cause narcosis, metabolic acidosis, headaches, severe abdominal and leg pain and visual degeneration that can lead to blindness.[47]

Methanol has been demonstrated to cause developmental toxicity in rats and mice, and reproductive and developmental toxicity in monkeys. A number of studies have reported adverse effects in the offspring of rats and mice exposed to methanol by inhalation including reduced weight of brain pituitary gland, thymus, thyroid, reduced overall fetal body weight and increased incidence of extra ribs and cleft palate.[48,49,50] Methanol inhalation studies using rhesus monkeys have reported a decrease in the length of pregnancy, and limited evidence of impaired learning ability in offspring.[51,52,53,54] EPA has not classified methanol with respect to its carcinogenicity.

7.3.4.5 Benzene

The EPA's IRIS database lists benzene as a known human carcinogen (causing leukemia) by all routes of exposure, and concludes that exposure is associated with additional health effects, including genetic changes in both humans and animals and increased proliferation of bone marrow cells in mice.[55,56,57] EPA states in its IRIS database that data indicate a causal

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[52] Burbacher, T; Shen, D; Grant, K; Sheppard, L; Damian, D; Ellis, S; Liberato, N. 1999. Reproductive and offspring developmental effects following maternal inhalation exposure to methanol in nonhuman primates Part I: methanol disposition and reproductive toxicity in adult females. Health Effects Institute. Cambridge, MA.

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[54] Burbacher, TM; Shen, DD; Lalovic, B; Grant, KS; Sheppard, L; Damian, D; Ellis, S; Liberato, N. 2004. Chronic maternal methanol inhalation in nonhuman primates (Macaca fascicularis): exposure and toxicokinetics prior to and during pregnancy. Neurotoxicol Teratol, 26: 201-221.

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relationship between benzene exposure and acute lymphocytic leukemia and suggest a relationship between benzene exposure and chronic non-lymphocytic leukemia and chronic lymphocytic leukemia. The International Agency for Research on Carcinogens (IARC) has determined that benzene is a human carcinogen and the U.S. Department of Health and Human Services (DHHS) has characterized benzene as a known human carcinogen.[58,59]

A number of adverse noncancer health effects including blood disorders, such as preleukemia and aplastic anemia, have also been associated with long-term exposure to benzene.[60,61] The most sensitive noncancer effect observed in humans, based on current data, is the depression of the absolute lymphocyte count in blood.[62,63] In addition, recent work, including studies sponsored by the Health Effects Institute (HEI), provides evidence that biochemical responses are occurring at lower levels of benzene exposure than previously known.[64,65,66,67] EPA's IRIS program has not yet evaluated these new data.

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available electronically at: http://www.epa.gov/iris/subst/0276.htm.

[56] International Agency for Research on Cancer, IARC monographs on the evaluation of carcinogenic risk of chemicals to humans, Volume 29, Some industrial chemicals and dyestuffs, International Agency for Research on Cancer, World Health Organization, Lyon, France, p. 345-389, 1982.

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7.3.4.6 Other Air Toxics

In addition to the compounds described above, other compounds from SI RICE would be affected by this rule. Information regarding the health effects of these compounds can be found in EPA's IRIS database.[68]

7.4 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 final estimate of economic 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.

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

[68] U.S. EPA Integrated Risk Information System (IRIS) database is available at: www.epa.gov/iris

co-benefits- per-ton for emission reductions in specific locations may be very different than the estimates presented here.

Understanding the transport of pollutants is a critical component for estimating exposure and the associated human health benefits from reducing air pollution emissions. The underlying emissions modeling and air quality modeling supporting the $PM_{2.5}$ co-benefits analysis accounts for the current distribution of emissions sources, including both urban and rural sources. In addition, the air quality modeling included 14 vertical layers to simulate the differences between ground-level emissions and higher stack emissions (U.S. EPA, 2006b). The distance that HAPs travel away from the emission source depends on several factors. HAPs such as formaldehyde, acetaldehyde, acrolein, methanol, and benzene are emitted as gases. Regional photochemical model simulations, examining particular scenarios, have shown that gaseous HAPs like formaldehyde and acetaldehyde can be transported hundreds of kilometers from their emissions source in distinct plumes (U.S. EPA, 2010f). Further, these emissions can contribute to regional airmasses with elevated concentrations of gaseous HAPs. These polluted airmasses can be transported thousands of kilometers and affect locations well distant from the original emissions source. For the SI RICE examined in this rule, EPA does not have enough information to determine the extent of transport specific to the HAPs reduced.

$PM_{2.5}$ mortality 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 7-6 and 7-7), increasing our confidence in the PM mortality analysis. Figure 7-6 shows a bar chart of the percentage of the population exposed to various air quality levels in the pre- and post-policy policy. Figure 7-7 shows a cumulative distribution function of the same data. 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 $\mu g/m^3$. Using the Laden et al. (2006) study, 40% of the population is exposed above the LML of 10 $\mu g/m^3$. 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.

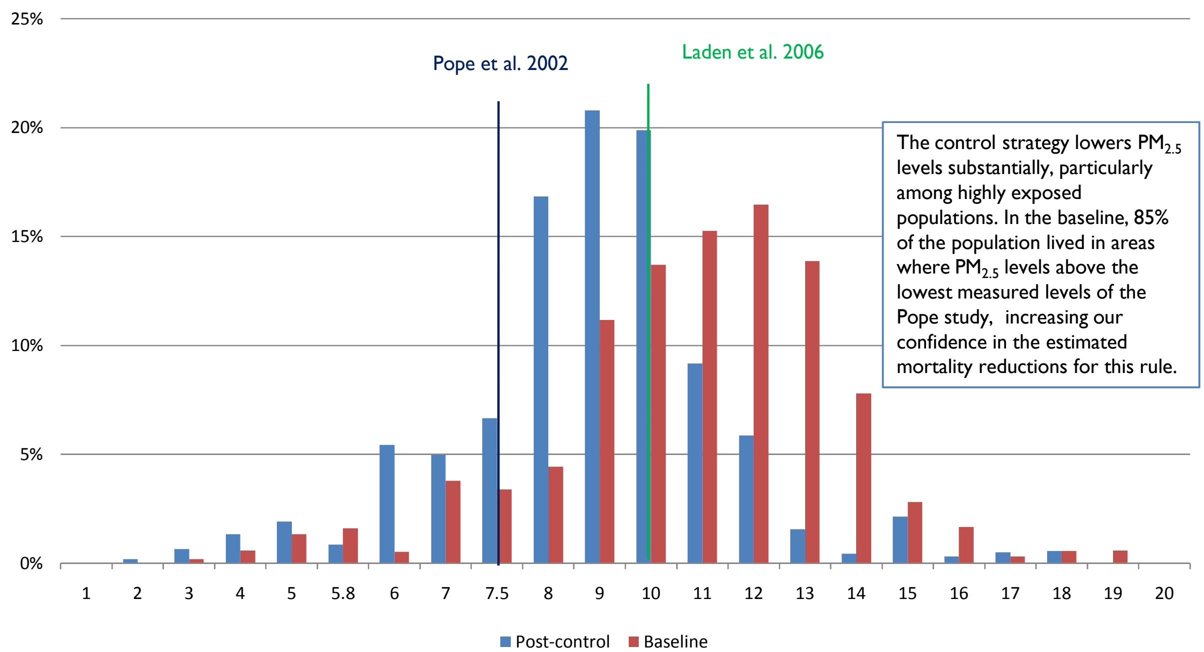

Figure 7-6. Percentage of Adult Population by Annual Mean $PM_{2.5}$ Exposure (pre- and post-policy policy)

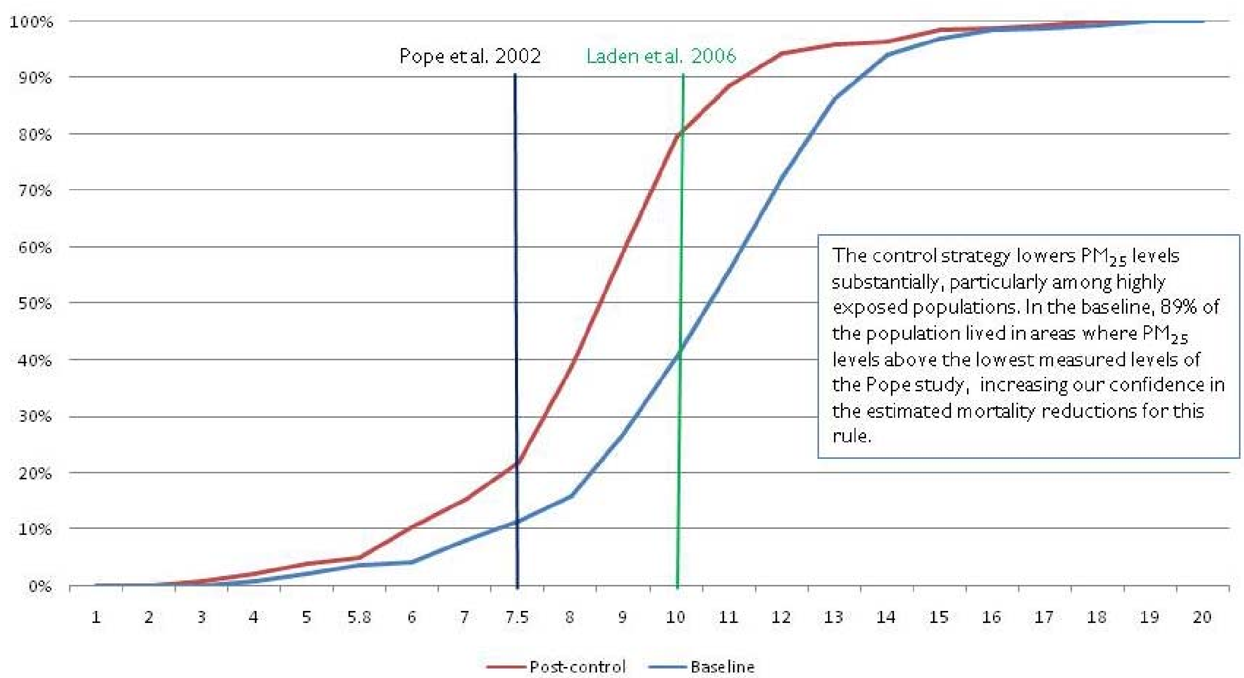

Figure 7-7. Cumulative Distribution of Adult Population at Annual Mean $PM_{2.5}$ levels (pre- and post-policy policy)

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.

7.5 Comparison of Co-Benefits and Costs

Using a 3% discount rate, we estimate the total combined monetized co-benefits of the final SI RICE NESHAP to be $510 million to $1.2 billion in the implementation year (2013). Using a 7% discount rate, we estimate the total monetized co-benefits of the final rule to be $460 million to $1.1 billion. The annualized social costs of the final NESHAP are $253 million at a 7% interest rate.[69] Thus, the net benefits are $250 million to $980 million at a 3% discount rate and $210 million to $860 million at a 7% discount rate. All estimates are in 2009$ for the year 2013.

Table 7-5 shows a summary of the monetized co-benefits, social costs, and net benefits for the final SI RICE NESHAP, respectively. Figures 7-8 and 7-9 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%. In addition, the benefits from reducing 109,000 tons of carbon monoxide and 6,000 tons of HAPs each year from SI RICE have not been included in these estimates. 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. As mentioned earlier in this RIA, the final NESHAP is the MACT floor level of control for all SI RICE major sources and the GACT level of control for all SI RICE area sources. We show results in Table 7-5 for an alternative (referred to as "Alternative 2") which is a more stringent alternative than the final NESHAP for major sources. For this alternative, the MACT floor level of control is applied to all SI RICE major sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the level of control is above the MACT floor, and the GACT level of control is applied to all area SI RICE sources.

[69] For more information on the annualized social costs, please refer to Section 5 of this RIA.

Table 7-5. Summary of the Monetized Co-Benefits, Social Costs, and Net benefits for the Final SI RICE NESHAP in 2013 (millions of 2009$)[1]

	3% Discount Rate	7% Discount Rate
Final NESHAP: Major[4]		
Total Monetized Benefits[2]	\$8.2 to \$20	\$7.4 to \$18
Total Social Costs[3]	\$88	\$88
Net Benefits	-\$80 to -\$68	-\$81 to -\$70
Non-monetized Benefits	12,500 tons of carbon monoxide 2,000 tons of hazardous air pollutants (HAPs) Ecosystem effects Visibility impairment	
Alternative 2: Major		
Total Monetized Benefits[2]	\$48 to \$120	\$43 to \$110
Total Social Costs[3]	\$95	\$95
Net Benefits	-\$47 to \$22	-\$52 to \$11
Non-monetized Benefits	17,800 tons of carbon monoxide 1,400 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	
Final NESHAP: Area[5]		
Total Monetized Benefits[2]	\$500 to \$1,200	\$450 to \$1,100
Total Social Costs[3]	\$166	\$166
Net Benefits	\$330 to \$1,100	\$290 to \$930
Non-monetized Benefits	97,000 tons of carbon monoxide 4,700 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	
Final Major and Area Source NESHAP		
Total Monetized Benefits[2]	\$510 to \$1,200	\$460 to \$1,100
Total Social Costs[3]	\$253	\$253
Net Benefits	\$250 to \$980	\$210 to \$860
Non-monetized Benefits	109,000 tons of carbon monoxide 6,000 tons of hazardous air pollutants (HAPs) Health effects from NO_2 and ozone exposure Ecosystem effects Visibility impairment	

[1]All estimates are for the implementation year (2013), and are rounded to two significant figures.

[2] The total monetized co-benefits reflect the human health co-benefits associated with reducing exposure to $PM_{2.5}$ through reductions of $PM_{2.5}$ precursors such as NOx and VOC. 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.

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

[4]The final NESHAP is the MACT floor level of control for all major SI RICE non-emergency sources. We also show results for Alternative 2, an more stringent alternative than the final NESHAP for major sources. In this alternative, the MACT level of control is applied to all SI RICE major non-emergency sources except for four-stroke rich-burn (4SRB) engines of 300-500 horsepower (HP), where the level of control is above the MACT floor, and the GACT level of control is applied to all area SI RICE sources.

[5] All of the benefits for area sources are attributable to reductions expected from 4SLB and 4SRB non-emergency engines above 500 HP.

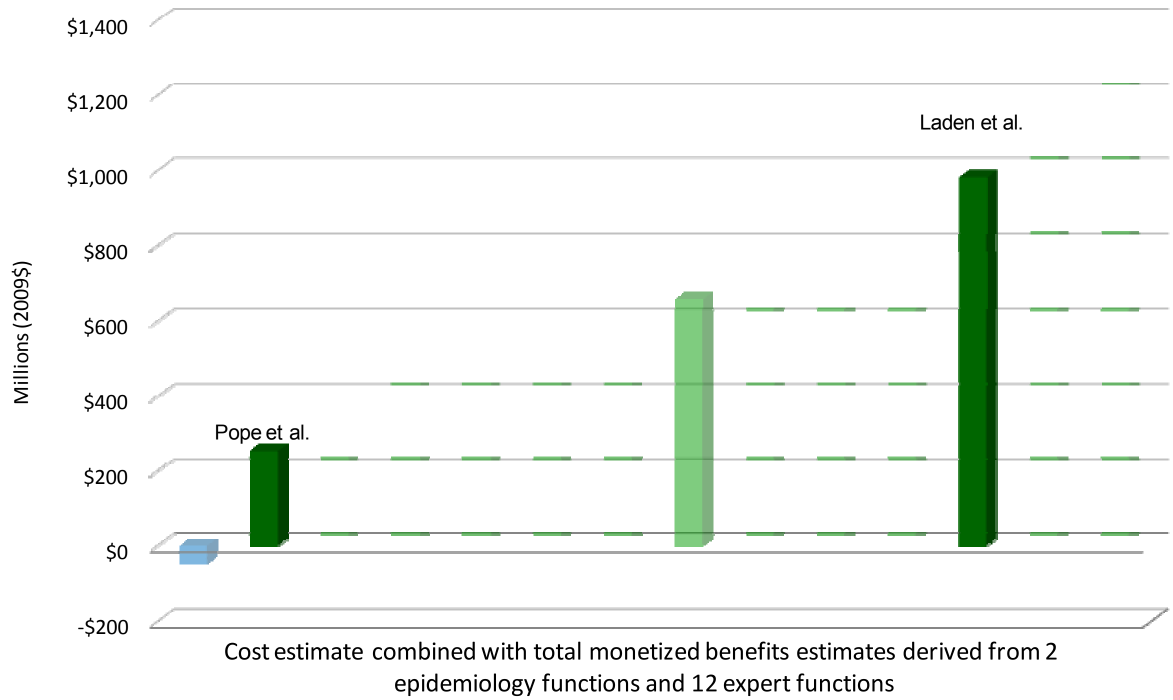

Figure 7-8. Net Benefits for the Final SI RICE NESHAP at 3% Discount Rate [a]

[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.

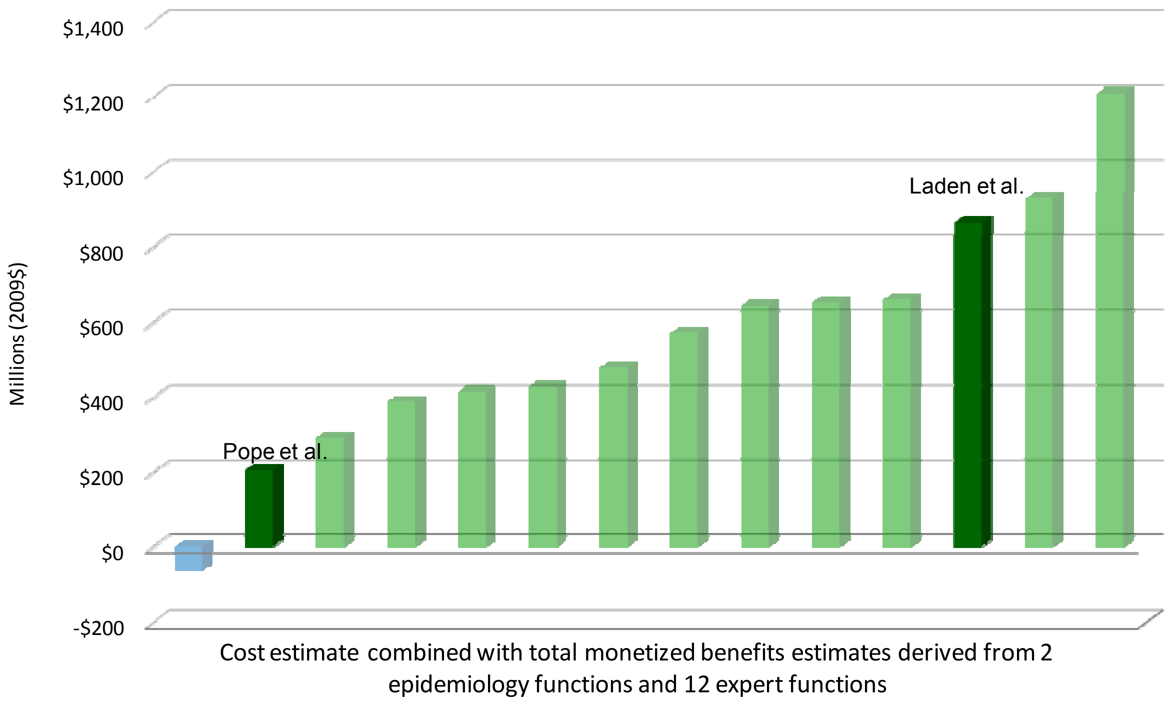

Figure 7-9. Net Benefits for the Final SI RICE NESHAP at 7% Discount Rate [a]

[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.

SECTION 8
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APPENDIX A

SUMMARY OF EXPERT OPINIONS ON THE EXISTENCE OF A THRESHOLD IN THE CONCENTRATION-RESPONSE FUNCTION FOR $PM_{2.5}$-RELATED MORTALITY

Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality

Technical Support Document (TSD)

June 2010

Compiled by:
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Health and Environmental Impact Division
Air Benefit-Cost Group
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Contents:

A. HES Comments on 812 Analysis (2010)

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2010. Review of EPA's DRAFT Health Benefits of the Second Section 812 Prospective Study of the Clean Air Act. EPA-COUNCIL-10-001. June. Available on the Internet at <http://yosemite.epa.gov/sab/sabproduct.nsf/0/72D4EFA39E48CDB28525774500738776/$File/EPA-COUNCIL-10-001-unsigned.pdf>.

Pg 2: "The HES generally agrees with other decisions made by the EPA project team with respect to PM, in particular, the PM mortality effect threshold model, the cessation lag model, the inclusion of infant mortality estimation, and differential toxicity of PM."

Pg 2: "Further, the HES fully supports EPA's use of a no-threshold model to estimate the mortality reductions associated with reduced PM exposure."

Pg 6: "The HES also supports the Agency's choice of a no-threshold model for PM-related effects."

Pg 13: "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."

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B. Scientific Statement from American Heart Association (2010)

Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. (2010). "Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association." ***Circulation*****. 121: 2331-2378.**

Pg 2338: "Finally, there appeared to be no lower-limit threshold below which PM_{10} was not associated with excess mortality across all regions."

Pg 2350: "There also appears to be a monotonic (e.g., linear or log-linear) concentration-response relationship between $PM_{2.5}$ and mortality risk observed in cohort studies that extends below present-day regulations of 15 μg/m^3 for mean annual levels, without a discernable "safe" threshold." (cites Pope 2004, Krewski 2009, and Schwartz 2008)

Pg 2364: "The $PM_{2.5}$ concentration– cardiovascular risk relationships for both short- and long-term exposures appear to be monotonic, extending below 15 μg/m^3 (the 2006 annual NAAQS level) without a discernable "safe" threshold."

Pg 2365: "This updated review by the AHA writing group corroborates and strengthens the conclusions of the initial scientific statement. In this context, we agree with the concept and continue to support measures based on scientific evidence, such as the US EPA NAAQS, that seek to control PM levels to protect the public health. Because the evidence reviewed supports that there is no safe threshold, it appears that public health benefits would accrue from lowering $PM_{2.5}$ concentrations even below present-day annual (15 μg/m^3) and 24-hour (35 μg/m^3) NAAQS, if feasible, to optimally protect the most susceptible populations."

Pg 2366: "Although numerous insights have greatly enhanced our understanding of the PM-cardiovascular relationship since the first AHA statement was published, the following list represents broad strategic avenues for future investigation: ... Determine whether any "safe" PM threshold concentration exists that eliminates both acute and chronic cardiovascular effects in healthy and susceptible individuals and at a population level."

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C. Integrated Science Assessment for Particulate Matter (2009)

U.S. Environmental Protection Agency (U.S. EPA). 2009. Integrated Science Assessment for Particulate Matter (Final Report). EPA-600-R-08-139F. National Center for Environmental Assessment – RTP Division. December. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546>.

Pg 1-22: "An important consideration in characterizing the public health impacts associated with exposure to a pollutant is whether the concentration-response relationship is linear across the full concentration range encountered, or if nonlinear relationships exist along any part of this range. Of particular interest is the shape of the concentration-response curve at and below the level of the current standards. The shape of the concentration-response curve varies, depending on the type of health outcome, underlying biological mechanisms and dose. At the human population level, however, various sources of variability and uncertainty tend to smooth and "linearize" the concentration-response function (such as the low data density in the lower concentration range, possible influence of measurement error, and individual differences in susceptibility to air pollution health effects). In addition, many chemicals and agents may act by perturbing naturally occurring background processes that lead to disease, which also linearizes population concentration-response relationships (Clewell and Crump, 2005, 156359; Crump et al., 1976, 003192; Hoel, 1980, 156555). These attributes of population dose-response may explain why the available human data at ambient concentrations for some environmental pollutants (e.g., PM, O_3, lead [Pb], ETS, radiation) do not exhibit evident thresholds for health effects, even though likely mechanisms include nonlinear processes for some key events. These attributes of human population dose-response relationships have been extensively discussed in the broader epidemiologic literature (Rothman and Greenland, 1998, 086599)."

Pg 2-16: "In addition, cardiovascular hospital admission and mortality studies that examined the PM_{10} concentration-response relationship found evidence of a log-linear no-threshold relationship between PM exposure and cardiovascular-related morbidity (Section 6.2) and mortality (Section 6.5)."

Pg 2-25: "2.4.3. PM Concentration-Response Relationship
An important consideration in characterizing the PM-morbidity and mortality association is whether the concentration-response relationship is linear across the full concentration range that is encountered or if there are concentration ranges where there are departures from linearity (i.e., nonlinearity). In this ISA studies have been identified that attempt to characterize the shape of the concentration-response curve along with possible PM "thresholds" (i.e., levels which PM concentrations must exceed in order to elicit a health response). The epidemiologic studies evaluated that examined the shape of the concentration-response curve and the potential presence of a threshold have focused on cardiovascular hospital admissions and ED visits and mortality associated with short-term exposure to PM_{10} and mortality associated with long-term exposure to $PM_{2.5}$.

"A limited number of studies have been identified that examined the shape of the PM cardiovascular hospital admission and ED visit concentration-response relationship. Of these studies, some conducted an exploratory analysis during model selection to determine if a linear curve most adequately represented the concentration-response relationship; whereas, only one study conducted an extensive analysis to examine the shape of the concentration-response curve at different concentrations (Section 6.2.10.10). Overall, the limited evidence from the studies evaluated supports the use of a no-threshold, log-linear model, which is consistent with the observations made in studies that examined the PM-mortality relationship.

"Although multiple studies have previously examined the PM-mortality concentration-response relationship and whether a threshold exists, more complex statistical analyses continue to be developed to analyze this association. Using a variety of methods and models, most of the studies evaluated support the use of a no-threshold, log-linear model; however, one study did observe heterogeneity in the shape of the concentration-response curve across cities (Section 6.5). Overall, the studies evaluated further support the use of a no-threshold log-linear model, but additional issues such as the influence of heterogeneity in estimates between cities, and the effect of seasonal and regional differences in PM on the concentration-response relationship still require further investigation.

"In addition to examining the concentration-response relationship between short-term exposure to PM and mortality, Schwartz et al. (2008, 156963) conducted an analysis of the shape of the concentration-response relationship associated with long-term exposure to PM. Using a variety of statistical methods, the concentration-response curve was found to be indistinguishable from linear, and, therefore, little evidence was observed to suggest that a threshold exists in the association between long-term exposure to $PM_{2.5}$ and the risk of death (Section 7.6)."

Pg 6-75: "6.2.10.10. Concentration Response
The concentration-response relationship has been extensively analyzed primarily through studies that examined the relationship between PM and mortality. These studies, which have focused on short- and long-term exposures to PM have consistently found no evidence for deviations from linearity or a safe threshold (Daniels et al., 2004, 087343; Samoli et al., 2005, 087436; Schwartz, 2004, 078998; Schwartz et al., 2008, 156963) (Sections 6.5.2.7 and 7.1.4). Although on a more limited basis, studies that have examined PM effects on cardiovascular hospital admissions and ED visits have also analyzed the PM concentration-response relationship, and contributed to the overall body of evidence which suggests a log-linear, no-threshold PM concentration-response relationship.

"The results from the three multicity studies discussed above support no-threshold log-linear models, but issues such as the possible influence of exposure error and heterogeneity of shapes across cities remain to be resolved. Also, given the pattern of seasonal and regional differences in PM risk estimates depicted in recent multicity study results (e.g., Peng et al., 2005, 087463), the very concept of a concentration-response relationship estimated across cities and for all-year data may not be very informative."

Pg 6-197: "6.5.2.7. Investigation of Concentration-Response Relationship
The results from large multicity studies reviewed in the 2004 PM AQCD (U.S. EPA, 2004, 056905) suggested that strong evidence did not exist for a clear threshold for PM mortality effects. However, as discussed in the 2004 PM AQCD (U.S. EPA, 2004, 056905), there are

several challenges in determining and interpreting the shape of PM-mortality concentration-response functions and the presence of a threshold, including: (1) limited range of available concentration levels (i.e., sparse data at the low and high end); (2) heterogeneity of susceptible populations; and (3) investigate the PM-mortality concentration-response relationship.

"Daniels et al. (2004, 087343) evaluated three concentration-response models: (1) log-linear models (i.e., the most commonly used approach, from which the majority of risk estimates are derived); (2) spline models that allow data to fit possibly non-linear relationship; and (3) threshold models, using PM_{10} data in 20 cities from the 1987-1994 NMMAPS data. They reported that the spline model, combined across the cities, showed a linear relation without indicating a threshold for the relative risks of death for all-causes and for cardiovascular-respiratory causes in relation to PM_{10}, but "the other cause" deaths (i.e., all cause minus cardiovascular-respiratory) showed an apparent threshold at around 50 μg/m^3 PM^{10}, as shown in Figure 6-35. For all-cause and cardio-respiratory deaths, based on the Akaike's Information Criterion (AIC), a log-linear model without threshold was preferred to the threshold model and to the spline model.

"The HEI review committee commented that interpretation of these results required caution, because (1) the measurement error could obscure any threshold; (2) the city-specific concentration-response curves exhibited a variety of shapes; and (3) the use of AIC to choose among the models might not be appropriate due to the fact it was not designed to assess scientific theories of etiology. Note, however, that there has been no etiologically credible reason suggested thus far to choose one model over others for aggregate outcomes. Thus, at least statistically, the result of Daniels et al. (2004, 087343) suggests that the log-linear model is appropriate in describing the relationship between PM10 and mortality.

"The Schwartz (2004, 078998) analysis of PM_{10} and mortality in 14 U.S. cities, described in Section 6.5.2.1, also examined the shape of the concentration-response relationship by including indicator variables for days when concentrations were between 15 and 25 μg/m^3, between 25 and 34 μg/m^3, between 35 and 44 μg/m^3, and 45 μg/m^3 and above. In the model, days with concentrations below 15 μg/m^3 served as the reference level. This model was fit using the single stage method, combining strata across all cities in the case-crossover design. Figure 6-36 shows the resulting relationship, which does not provide sufficient evidence to suggest that a threshold exists. The authors did not examine city-to-city variation in the concentration-response relationship in this study.

"PM_{10} and mortality in 22 European cities (and BS in 15 of the cities) participating in the APHEA project. In nine of the 22 cities, PM10 levels were estimated using a regression model relating co-located PM10 to BS or TSP. They used regression spline models with two knots (30 and 50 μg/m^3) and then combined the individual city estimates of the splines across cities. The investigators concluded that the association between PM and mortality in these cities could be adequately estimated using the log-linear model. However, in an ancillary analysis of the concentration-response curves for the largest cities in each of the three distinct geographic areas (western, southern, and eastern European cities): London, England; Athens, Greece; and Cracow, Poland, Samoli et al. (2005, 087436) observed a difference in the shape of the concentration-response curve across cities. Thus, while the combined curves (Figure 6-37) appear to support no-threshold relationships between PM_{10} and mortality, the heterogeneity of the shapes across cities makes it difficult to interpret the biological relevance of the shape of the combined curves.

“The results from the three multicity studies discussed above support no-threshold log-linear models, but issues such as the possible influence of exposure error and heterogeneity of shapes across cities remain to be resolved. Also, given the pattern of seasonal and regional differences in PM risk estimates depicted in recent multicity study results (e.g., Peng et al., 2005, 087463), the very concept of a concentration-response relationship estimated across cities and for all-year data may not be very informative.”

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D. CASAC comments on PM ISA and REA (2009)

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2009. Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008). EPA-COUNCIL-09-008. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf>.

Pg 9: "There is an appropriate discussion of the time-series studies, but this section needs to have an explicit finding that the evidence supports a relationship between PM and mortality that is seen in these studies. This conclusion should be followed by the discussion of statistical methodology and the identification of any threshold that may exist."

U.S. Environmental Protection Agency Science Advisory Board (U.S. EPA-SAB). 2009. Consultation on EPA's Particulate Matter National Ambient Air Quality Standards: Scope and Methods Plan for Health Risk and Exposure Assessment. EPA-COUNCIL-09-009. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/723FE644C5D758DF852575BD00763A32/$File/EPA-CASAC-09-009-unsigned.pdf>.

Pg 6: "On the issue of cut-points raised on 3-18, the authors should be prepared to offer a scientifically cogent reason for selection of a specific cut-point, and not simply try different cut-points to see what effect this has on the analysis. The draft ISA was clear that there is little evidence for a population threshold in the C-R function."

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2009. Review of *Integrated Science Assessment for Particulate Matter (Second External Review Draft, July 2009)*. EPA-CASAC-10-001. November. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/151B1F83B023145585257678006836B9/$File/EPA-CASAC-10-001-unsigned.pdf>.

Pg 2: "The paragraph on lines 22-30 of page 2-37 is not clearly written. Twice in succession it states that the use of a no-threshold log-linear model is supported, but then cites other studies that suggest otherwise. It would be good to revise this paragraph to more clearly state – well, I'm not sure what. Probably that more research is needed."

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E. Krewski et al. (2009)

Krewski, Daniel, Michael Jerrett, Richard T. Burnett, Renjun Ma, Edward Hughes, Yuanli Shi, Michelle C. Turner, C. Arden Pope III, George Thurston, Eugenia E. Calle, and Michael J. Thun with Bernie Beckerman, Pat DeLuca, Norm Finkelstein, Kaz Ito, D.K. Moore, K. Bruce Newbold, Tim Ramsay, Zev Ross, Hwashin Shin, and Barbara Tempalski. (2009). Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. *HEI Research Report*, 140, Health Effects Institute, Boston, MA.

Pg 119: [About Pope et al. (2002)] "Each 10-μg/m^3 increase in long-term average ambient $PM_{2.5}$ concentrations was associated with approximately a 4%, 6%, or 8% increase in risk of death from all causes, cardiopulmonary disease, and lung cancer, respectively. There was no evidence of a threshold exposure level within the range of observed $PM_{2.5}$ concentrations."

Krewski (2009). Letter from Dr. Daniel Krewski to HEI's Dr. Kate Adams (dated July 7, 2009) regarding "EPA queries regarding HEI Report 140". Dr. Adams then forwarded the letter on July 10, 2009 to EPA's Beth Hassett-Sipple. (letter placed in docket #EPA-HQ-OAR-2007-0492).

Pg 4: "6. The Health Review Committee commented that the Updated Analysis completed by Pope et al. 2002 reported "no evidence of a threshold exposure level within the range of observed $PM_{2.5}$ concentrations" (p. 119). In the Extended Follow-Up study, did the analyses provide continued support for a no-threshold response or was there evidence of a threshold?

"Response: As noted above, the HEI Health Review Committee commented on the lack of evidence for a threshold exposure level in Pope et al. (2002) with follow-up through the year 1998. The present report, which included follow-up through the year 2000, also does not appear to demonstrate the existence of a threshold in the exposure-response function within the range of observed $PM_{2.5}$ concentrations."

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F. Schwartz et al. (2008)

Schwartz J, Coull B, Laden F. (2008). The Effect of Dose and Timing of Dose on the Association between Airborne Particles and Survival. *Environmental Health Perspectives*. 116: 64-69.

Pg 67: "A key finding of this study is that there is little evidence for a threshold in the association between exposure to fine particles and the risk of death on follow-up, which continues well below the U.S. EPA standard of 15 $\mu g/m^3$."

Pg 68: "In conclusion, penalized spline smoothing and model averaging represent reasonable, feasible approaches to addressing questions of the shape of the exposure–response curve, and can provide valuable information to decisionmakers. In this example, both approaches are consistent, and suggest that the association of particles with mortality has no threshold down to close to background levels."

G. Expert Elicitation on PM-Mortality (2006, 2008)

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

Pg v: “Each expert was given the option to integrate their judgments about the likelihood of a causal relationship and/or threshold in the C-R function into his distribution or to provide a distribution "conditional on" one or both of these factors.”

Pg vii: “Only one of 12 experts explicitly incorporated a threshold into his C-R function.[3] The rest believed there was a lack of empirical and/or theoretical support for a population threshold. However, three other experts gave differing effect estimate distributions above and below some cut-off concentration. The adjustments these experts made to median estimates and/or uncertainty at lower $PM^{2.5}$ concentrations were modest.”

> “[3] Expert K indicated that he was 50 percent sure that a threshold existed. If there were a threshold, he thought that there was an 80 percent chance that it would be less than or equal to 5 $\mu g/m^3$, and a 20 percent chance that it would fall between 5 and 10 $\mu g/m^3$.”

Pg ix: “Compared to the pilot study, experts in this study were in general more confident in a causal relationship, less likely to incorporate thresholds, and reported higher mortality effect estimates. The differences in results compared with the pilot appear to reflect the influence of new research on the interpretation of the key epidemiological studies that were the focus of both elicitation studies, more than the influence of changes to the structure of the protocol.”

Pg 3-25: “3.1.8 THRESHOLDS
The protocol asked experts for their judgments regarding whether a threshold exists in the $PM_{2.5}$ mortality C-R function. The protocol focused on assessing expert judgments regarding theory and evidential support for a population threshold (i.e., the concentration below which no member of the study population would experience an increased risk of death).[32] If an expert wished to incorporate a threshold in his characterization of the concentration-response relationship, the team then asked the expert to specify the threshold $PM_{2.5}$ concentration probabilistically, incorporating his uncertainty about the true threshold level.

“From a theoretical and conceptual standpoint, all experts generally believed that individuals exhibit thresholds for PM-related mortality. However, 11 of them discounted the idea of a population threshold in the C-R function on a theoretical and/or empirical basis. Seven of these experts noted that theoretically one would be unlikely to observe a population threshold due to the variation in susceptibility at any given time in the study population resulting from combinations of genetic, environmental, and socioeconomic factors.[33] All 11 thought that there was insufficient empirical support for a population threshold in the C-R function. In addition, two experts (E and L) cited analyses of the ACS cohort data in Pope et al. (2002) and another (J) cited Krewski et al. (2000a & b) as supportive of a linear relationship in the study range.

“Seven of the experts favored epidemiological studies as ideally the best means of addressing the population threshold issue, because they are best able to evaluate the full range of susceptible individuals at environmentally relevant exposure levels. However, those who favored epidemiologic studies generally acknowledged that definitive studies addressing thresholds would be difficult or impossible to conduct, because they would need to include a very large and diverse population with wide variation in exposure and a long follow-up period. Furthermore, two experts (B and I) cited studies documenting difficulties in detecting a threshold using epidemiological studies (Cakmak et al. 1999, and Brauer et al., 2002, respectively). The experts generally thought that clinical and toxicological studies are best suited for researching mechanisms and for addressing thresholds in very narrowly defined groups. One expert, B, thought that a better understanding of the detailed biological mechanism is critical to addressing the question of a threshold.

“One expert, K, believed it was possible to make a conceptual argument for a population threshold. He drew an analogy with smoking, indicating that among heavy smokers, only a proportion of them gets lung cancer or demonstrates an accelerated decline in lung function. He thought that the idea that there is no level that is biologically safe is fundamentally at odds with toxicological theory. He did not think that a population threshold was detectable in the currently available epidemiologic studies. He indicated that some of the cohort studies showed greater uncertainty in the shape of the C-R function at lower levels, which could be indicative of a threshold.

“Expert K chose to incorporate a threshold into his C-R function. He indicated that he was 50 percent sure that a threshold existed. If there were a threshold, he thought that there was an 80 percent chance that it would be less than or equal to 5 $\mu g/m^3$, and a 20 percent chance that it would fall between 5 and 10 $\mu g/m^3$.”

Roman, Henry A., Katherine D. Walker, Tyra L. Walsh, Lisa Conner, Harvey M. Richmond, Bryan J. Hubbell, and Patrick L. Kinney. (2008). “Expert Judgment Assessment of the Mortality Impact of Changes in Ambient Fine Particulate Matter in the U.S.” ***Environ. Sci. Technol.*****, 42(7):2268-2274.**

Pg 2271: “Eight experts thought the true C-R function relating mortality to changes in annual average $PM_{2.5}$ was log-linear across the entire study range (ln(mortality)) $\beta \times$ PM). Four experts (B, F, K, and L) specified a “piecewise” log-linear function, with different β coefficients for PM concentrations above and below an expert-specified break point. This approach allowed them to express increased uncertainty in mortality effects seen at lower concentrations in major epidemiological studies. Expert K thought the relationship would be log-linear above a threshold.”

Pg 2271: “Expert K also applied a threshold, T, to his function, which he described probabilistically. He specified $P(T > 0) = 0.5$. Given $T > 0$, he indicated $P(T \leq 5\ \mu g/m^3) = 0.8$ and $P(5\ \mu g/m^3 < T \leq 10\ \mu g/m^3) = 0.2$. Figure 3 does not include the impact of applying expert K’s threshold, as the size of the reduction in benefits will depend on the distribution of baseline PM levels in a benefits analysis.”

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H. CASAC comments on PM Staff Paper (2005)

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2005. EPA's Review of the National Ambient Air Quality Standards for Particulate Matter (Second Draft PM Staff Paper, January 2005). EPA-SAB-CASAC-05-007. June. Available on the Internet at <http://yosemite.epa.gov/sab/sabproduct.nsf/E523DD36175EB5AD8525701B007332AE/$File/SAB-CASAC-05-007_unsigned.pdf>.

Pg 6: "A second concern is with methodological issues. The issue of the selection of concentration-response (C-R) relationships based on locally-derived coefficients needs more discussion. The Panel did not agree with EPA staff in calculating the burden of associated incidence in their risk assessment using either the predicted background or the lowest measured level (LML) in the utilized epidemiological analysis. The available epidemiological database on daily mortality and morbidity does not establish either the presence or absence of threshold concentrations for adverse health effects. Thus, in order to avoid emphasizing an approach that assumes effects that extend to either predicted background concentrations or LML, and to standardize the approach across cities, for the purpose of estimating public health impacts, the Panel favored the primary use of an assumed threshold of 10 $\mu g/m^3$. The original approach of using background or LML, as well as the other postulated thresholds, could still be used in a sensitivity analysis of threshold assumptions.

"The analyses in this chapter highlight the impact of assumptions regarding thresholds, or lack of threshold, on the estimates of risk. The uncertainty associated with threshold or nonlinear models needs more thorough discussion. A major research need is for more work to determine the existence and level of any thresholds that may exist or the shape of nonlinear concentration-response curves at low levels of exposure that may exist, and to reduce uncertainty in estimated risks at the lowest PM concentrations."

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I. HES Comments on 812 Analysis (2004)

U.S. Environmental Protection Agency - Science Advisory Board (U.S. EPA-SAB). 2004. Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act, 1990-2020. Advisory by the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis. EPA-SAB-COUNCIL-ADV-04-002. March. Available on the Internet at <http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/08E1155AD24F871C85256E5400433D5D/$File/council_adv_04002.pdf>.

Pg 20: "The Subcommittee agrees that the whole range of uncertainties, such as the questions of causality, shape of C-R functions and thresholds, relative toxicity, years of life lost, cessation lag structure, cause of death, biologic pathways, or susceptibilities may be viewed differently for acute effects versus long-term effects.

"For the studies of long-term exposure, the HES notes that Krewski et al. (2000) have conducted the most careful work on this issue. They report that the associations between $PM_{2.5}$ and both all-cause and cardiopulmonary mortality were near linear within the relevant ranges, with no apparent threshold. Graphical analyses of these studies (Dockery et al., 1993, Figure 3 and Krewski et al., 2000, page 162) also suggest a continuum of effects down to lower levels. Therefore, it is reasonable for EPA to assume a no threshold model down to, at least, the low end of the concentrations reported in the studies."

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J. NRC – Committee on Estimating the Health Risk Reduction Benefits of Proposed Air Pollution Regulations (2002)

National Research Council (NRC). 2002. Estimating the Public Health Benefits of Proposed Air Pollution Regulations. Washington, DC: The National Academies Press.

Pg 109: "**Linearity and Thresholds**

"The shape of the concentration-response functions may influence the overall estimate of benefits. The shape is particularly important for lower ambient air pollution concentrations to which a large portion of the population is exposed. For this reason, the impact of the existence of a threshold may be considerable.

"In epidemiological studies, air pollution concentrations are usually measured and modeled as continuous variables. Thus, it may be feasible to test linearity and the existence of thresholds, depending on the study design. In time-series studies with the large number of repeated measurements, linearity and thresholds have been formally addressed with reasonable statistical power. For pollutants such as PM_{10} and $PM_{2.5}$, there is no evidence for any departure of linearity in the observed range of exposure, nor any indication of a threshold. For example, examination of the mortality effects of short-term exposure to PM_{10} in 88 cities indicates that the concentration-response functions are not due to the high concentrations and that the slopes of these functions do not appear to increase at higher concentrations (Samet et al. 2000). Many other mortality studies have examined the shape of the concentration-response function and indicated that a linear (nonthreshold) model fit the data well (Pope 2000). Furthermore, studies conducted in cities with very low ambient pollution concentrations have similar effects per unit change in concentration as those studies conducted in cities with higher concentrations. Again, this finding suggests a fairly linear concentration-response function over the observed range of exposures.

"Regarding the studies of long-term exposure, Krewski et al. (2000) found that the assumption of a linear concentration-response function for mortality outcomes was not unreasonable. However, the statistical power to assess the shape of these functions is weakest at the upper and lower end of the observed exposure ranges. Most of the studies examining the effects of long-term exposure on morbidity compare subjects living in a small number of communities (Dockery et al. 1996; Ackermmann-Liebrich 1997; Braun-Fahrländer et al. 1997). Because the number of long-term effects studies are few and the number of communities studied is relatively small (8 to 24), the ability to test formally the absence or existence of a no-effect threshold is not feasible. However, even if thresholds exist, they may not be at the same concentration for all health outcomes.

"A review of the time-series and cohort studies may lead to the conclusion that although a threshold is not apparent at commonly observed concentrations, one may exist at lower levels. An important point to acknowledge regarding thresholds is that for health benefits analysis a key threshold is the population threshold (the lowest of the individual thresholds). However, the population threshold would be very difficult to observe empirically through epidemiology, because epidemiology integrates information from very large groups of people (thousands). Air pollution regulations affect even larger groups of people (millions). It is reasonable to assume that among such large groups susceptibility to air pollution health effects varies considerably across individuals and depends on a large set of underlying factors, including genetic makeup, age, exposure measurement error, preexisting disease, and simultaneous exposures from smoking and occupational hazards. This variation in individual susceptibilities and the resulting distribution of individual thresholds underlies the concentration-response function observed in epidemiology. Thus, until biologically based models of the distribution of individual thresholds are developed, it may be productive to assume that the population concentration-response function is continuous and to focus on finding evidence of changes in its slope as one approaches lower concentrations.

EPA's Use of Thresholds

"In EPA's benefits analyses, threshold issues were discussed and interpreted. For the PM and ozone National Ambient Air Quality Standards (NAAQS), EPA investigated the effects of a potential threshold or reference value below which health consequences were assumed to be zero (EPA 1997). Specifically, the high-end benefits estimate assumed a 12-microgram per cubic meter ($\mu g/m^3$) mean threshold for mortality associated with long-term exposure to $PM_{2.5}$. The low-end benefits estimate assumed a 15-$\mu g/m^3$ threshold for all PM-related health effects. The studies, however, included concentrations as low as 7.5 $\mu g/m^3$. For the Tier 2 rule and the HD engine and diesel-fuel rule, no threshold was assumed (EPA 1999, 2000). EPA in these analyses acknowledged that there was no evidence for a threshold for PM.

"Several points should be noted regarding the threshold assumptions. If a threshold is assumed where one was not apparent in the original study, then the data should be refit and a new curve generated with the assumption of a zero slope over a segment of the concentration-response function that was originally found to be positively sloped. The assumption of a zero slope over a portion of the curve will force the slope in the remaining segment of the positively sloped concentration-response function to be greater than was indicated in the original study. A new concentration-response function was not generated for EPA's benefits analysis for the PM and ozone NAAQS for which threshold assumptions were made. The generation of the steeper slope in the remaining portion of the concentration-response function may fully offset the effect of assuming a threshold. These aspects of assuming a threshold in a benefits analysis where one was not indicated in the original study should be conveyed to the reader. The committee notes that the treatment of thresholds should be evaluated in a consistent and transparent framework by using different explicit assumptions in the formal uncertainty analyses (see Chapter 5)."

Pg 117: "Although the assumption of no thresholds in the most recent EPA benefits analyses was appropriate, EPA should evaluate threshold assumptions in a consistent and transparent framework using several alternative assumptions in the formal uncertainty analysis."

Pg 136: "Two additional illustrative examples are thresholds for adverse effects and lag structures.[2] EPA considers implausible any threshold for mortality in the particulate matter (PM) exposure ranges under consideration (EPA 1999a, p. 3-8). Although the agency conducts sensitivity analyses incorporating thresholds, it provides no judgment as to their relative plausibility. In a probabilistic uncertainty analysis, EPA could assign appropriate weights to various threshold models. For PM-related mortality in the Tier 2 analysis, the committee expects that this approach would have resulted in only a slight widening of the probability distribution for avoided mortality and a slight reduction in the mean of that distribution, thus reflecting EPA's views about the implausibility of thresholds. The committee finds that such formal incorporation of EPA's expert judgments about the plausibility of thresholds into its primary analysis would have been an improvement.

"Uncertainty about thresholds is a special aspect of uncertainty about the shape of concentration-response functions. Typically, EPA and authors of epidemiological studies assume that these functions are linear on some scale. Often, the scale is a logarithmic transformation of the risk or rate of the health outcome, but when a rate or risk is low, a linear function on the logarithmic scale is approximately linear on the scale of the rate or risk itself. Increasingly, epidemiological investigators are employing analytic methods that permit the estimation of nonlinear shapes for concentration-response functions (Greenland et al. 1999). As a consequence, EPA will need to be prepared to incorporate nonlinear concentration-response functions from epidemiological studies into the agency's health benefits analyses. Any source of error or bias that can distort an epidemiological association can also distort the shape of an estimated concentration -response function, as can variation in individual susceptibility (Hattis and Burmaster 1994; Hattis et al. 2001)."

Pg 137: "In principle, many components of the health benefits model need realistic probabilistic models (see Table 5-1 for a listing of such components), in addition to concentration-response thresholds and time lags between exposure and response. For example, additional features of the concentration-response function—such as projection of the results from the study population to the target populations (which may have etiologically relevant characteristics outside the range seen in the study population) and the projection of baseline frequencies of morbidity and mortality into the future—must be characterized probabilistically. Other uncertainties that might affect the probability distributions are the estimations of population exposure (or even concentration) from emissions, estimates of emissions themselves, and the relative toxicity of various classes of particles. Similarly, many aspects of the analysis of the impact of regulation on ambient concentrations and on population exposure involve considerable uncertainty and, therefore, may be beneficially modeled in this way. Depending on the analytic approach used, joint probability distributions will have to be specified to incorporate correlations between model components that are structurally dependent upon each other, or the analysis will have to be conducted in a sequential fashion that follows the model for the data-generating process.

"EPA should explore alternative options for incorporating expert judgment into its probabilistic uncertainty analyses. The agency possesses considerable internal expertise, which should be employed as fully as possible. Outside experts should also be consulted as needed, individually or in panels. In all cases, when expert judgment is used in the construction of a model component, the experts should be identified and the rationales and empirical bases for their judgments should be made available."

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APPENDIX B

LOWEST MEASURED LEVEL (LML) ASSESSMENT FOR RULES WITHOUT POLICY-SPECIFIC AIR QUALITY DATA AVAILABLE: TECHNICAL SUPPORT DOCUMENT (TSD)

Lowest Measured Level (LML) Assessment for Rules without Policy-Specific Air Quality Data Available

Technical Support Document (TSD)

June 2010

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Health and Environmental Impact Division
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Inherent in any complex Regulatory Impact Analysis (RIA) are multiple sources of uncertainty. Health benefits analysis relies on an array of data inputs—including air quality modeling, health impact functions and valuation estimates among others—which are themselves subject to uncertainty and may also in turn contribute to the overall uncertainty in this analysis. There are a variety of methods to characterizing the uncertainty associated with the human health benefits of air pollution, including quantitative and qualitative methods. When evaluated within the context of these uncertainties, the health impact and monetized benefits estimates in an RIA can provide useful information regarding the magnitude of the public health impacts attributable to reducing air pollution.

Reductions in premature mortality typically dominate the size of the overall monetized benefits. Therefore, most of the uncertainty characterization generally focuses on the mortality-related benefits. Typically, EPA employs two primary techniques for quantifying this uncertainty. First, because this characterization of random statistical error may omit important sources of uncertainty, we employ the results of an expert elicitation on the relationship between premature mortality and ambient $PM_{2.5}$ concentration (Roman et al., 2008); this provides additional insight into the likelihood of different outcomes and about the state of knowledge regarding the benefits estimates. Second, when we have air quality modeling specific to the policy we are evaluating and it can be used as an input to the health impact and economic analysis, we use Monte Carlo methods for characterizing random sampling error associated with the concentration response functions from epidemiological studies and economic valuation functions.[81] Both approaches have different strengths and weaknesses, which are fully described in Chapter 5 of the PM NAAQS RIA (U.S. EPA, 2006).

In addition, some RIAs, including the PM NAAQS RIA (2006d) and Ozone NAAQS RIA (2008a), also contain a suite of sensitivity analyses that evaluate the sensitivity of the monetized benefits to the specification of alternate mortality cessation lags and income growth adjustment factors. Cessation lags and income growth adjustments are simply multipliers applied to the valuation function, which generally affect monetized benefits estimates in the same manner. Thus, it is possible for readers to infer the sensitivity of these parameters by referring to those previous analyses.[82] Other RIAs contain unique sensitivity analyses that are specific to the

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[81] Currently, we are unable to characterize the random sampling error from the underlying studies when applying national average benefit-per-ton estimates.

[82] For example, in the PM NAAQS RIA, the use of an alternate lag structure would change the $PM_{2.5}$-related mortality benefits discounted at 3% discounted by between 10.4% and –27%; when discounted at 7%, these

input parameters of that analysis, such as blood lead level (U.S. EPA, 2008b) or rollback method (U.S. EPA, 2010a). Other sources of uncertainty, including the projection of atmospheric conditions and source-level emissions, the projection of baseline morbidity rates, incomes and technological development are typically unquantified in our RIAs. For these sources, we typically provide a qualitative uncertainty characterization associated with these input parameters.

One particular aspect of uncertainty has received extensive quantitative and qualitative attention in recent RIAs: the existence of a threshold in the concentration-response function for $PM_{2.5}$-related mortality. A threshold is a specific type of discontinuity in the concentration-response function where there are no benefits associated with reducing $PM_{2.5}$ levels in areas where the baseline air quality is less than the threshold. Previously, EPA had included a sensitivity analysis with an arbitrary assumed threshold at 10 $\mu g/m^3$ in the PM-mortality health impact function in the RIA to illustrate that the fraction of benefits that occur at lower air pollution concentration levels are inherently more uncertain. A threshold of 10 $\mu g/m^3$ does not necessarily have any stronger technical basis than any other threshold, and we could have instead assumed a threshold at 4, 7.5, or 12 $\mu g/m^3$ for the sensitivity analysis. In addition to identifying the most support for a non-threshold model, the underlying scientific evidence does not support any specific "bright line".

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.[83] 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

benefits change by between 31% and -49%. When applying higher and lower income growth adjustments, the monetary value of $PM_{2.5}$ and ozone-related premature changes between 30% and -10%; the value of chronic endpoints change between 5% and -2% and the value of acute endpoints change between 6% and -7%. (U.S. EPA, 2006)

[83] It is important to note that uncertainty regarding the shape of the concentration-response function is conceptually distinct from an assumed threshold. An assumed threshold (below which there are no health effects) is a discontinuity, which is a specific example of non-linearity.

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." For a summary of these scientific review statements and the panel members 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. While an LML 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. Unlike an assumed threshold, which is a modeling assumption that reduces the magnitude of the estimated health impacts, the LML is a characterization of the fraction of benefits that are more uncertain. It is important to emphasize that 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.

While the LML of each study is important to consider when characterizing and interpreting the overall level PM-related benefits, EPA believes that large cohort-based mortality estimates are suitable for use in air pollution health impact analyses. When estimating PM mortality impacts using risk coefficients drawn from the Harvard Six Cities and the American Cancer Society cohorts there are innumerable other attributes that may affect the size of the reported risk estimates—including differences in population demographics, the size of the cohort, activity patterns and particle composition among others. The LML assessment provides a limited representation of one key difference between the two studies. For the purpose of estimating the benefits associated with reducing $PM_{2.5}$ levels, we utilize the effect coefficients from Pope et al. (2002) for the American Cancer Society cohort and from Laden et al. (2006) for the Harvard Six Cities cohort.

Analyses of these cohorts using data from more recent years, during which time PM concentrations have fallen, continue to report strong associations with mortality. For example, the Krewski et al. (2009) follow-up study of the American Cancer Society cohort had an LML of 5.8 $\mu g/m^3$. As we model mortality impacts among populations exposed to levels of $PM_{2.5}$ that are successively lower than the LML of each study, our confidence in the results diminishes. As air pollution emissions continue to decrease over time, there will be more people in areas where we do not have published epidemiology studies. However, each successive cohort study has shown evidence of effects at successively lower levels of $PM_{2.5}$. As more large cohort studies follow populations over time, we will likely have more studies with lower LML as air quality levels continue to improve. Even in the absence of a definable threshold, we have more confidence in the benefits estimates above the LML of the large cohort studies. To account for the uncertainty in each of the studies that we base our mortality estimates on, we provide the LML for each of the cohort studies. However, the finding of effects at the lowest LML from the recent Krewski et al (2009) study indicates that confidence in $PM_{2.5}$-related mortality effects down to at least 5.8 $\mu g/m^3$ is high.

In the recently proposed Transport Rule RIA (U.S. EPA, 2010b), we included the new LML assessment in which we binned the estimated number of avoided $PM_{2.5}$-related premature mortalities resulting from the implementation of the Transport Rule according to the projected 2014 baseline $PM_{2.5}$ air quality levels. This presentation is consistent with our approach to applying $PM_{2.5}$ mortality risk coefficients that have not been adjusted to incorporate an assumed threshold. A very large proportion of the avoided PM-related impacts occurred among populations initially exposed at or above the LML of each study, which gave us a high level of confidence in the PM mortality estimates. This assessment summarized the distribution of avoided PM mortality impacts according to the baseline $PM_{2.5}$ levels experienced by the population receiving the $PM_{2.5}$ mortality benefit. Approximately 80% of the avoided impacts occurred at or above a baseline annual mean $PM_{2.5}$ level of 10 $\mu g/m^3$ (the LML of the Laden et al. 2006 study); about 97% occur at or above an annual mean $PM_{2.5}$ level of 7.5 $\mu g/m^3$ (the LML of the Pope et al. 2002 study). This assessment confirmed that the great majority of the impacts associated with the Transport Rule occurred at or above each study's LML.

For the Transport Rule, policy-specific air quality modeling data for the year 2014 was available as an input into the benefits analysis. For some rules, especially New Source Performance Standards (NSPS) or National Emissions Standards for Hazardous Air Pollutant (NESHAP) rules, policy-specific air quality data is not available due to time or resource limitations. For these rules, we provide the following LML assessment as a characterization of the baseline exposure to $PM_{2.5}$ levels in the U.S. Many of the upcoming NSPS and NESHAP rules have compliance dates between 2013 and 2016 and represent marginal improvements in air quality levels. Although it the data is not a perfect match, we believe that the air quality data from the Transport Rule is a reasonable approximation of the baseline exposure in the U.S. for upcoming NSPS and NESHAP rules.[84]

For rules without air quality modeling, we generally estimate the monetized benefits and health impacts using benefit-per-ton estimates (Fann, Fulcher and Hubbell, 2009). Using this method, we are unable to estimate the percentage of premature mortality associated with the specific rules' emission reductions at each $PM_{2.5}$ level. However, we believe that it is still important to characterize the uncertainty associated with the distribution of the baseline air quality. As a surrogate measure of mortality impacts, we provide the percentage of baseline exposure at each $PM_{2.5}$ level. If air quality levels in the baseline are above the LML, the marginal changes anticipated from these rules would likely also lead to post-policy air quality levels above the LML. Therefore, we have high confidence that the magnitude of the benefits estimated for these rules, as the marginal changes would also be above the LML.

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 the specific rule. Therefore, caution is warranted when interpreting the following assessment.

A very large proportion of the population is exposed at or above the lowest LML of the cohort studies (Figures 1 and 2), increasing our confidence in the PM mortality analysis. Figure 1 shows a bar chart of the percentage of the population exposed to various air quality levels in the pre- and post-policy policy. Figure 2 shows a cumulative distribution function of the same data. In addition, Figure 2 also demonstrates that policy had a greater impact on reducing exposure to the portion of the population in areas with high $PM_{2.5}$ levels relative to the portion of the population at low $PM_{2.5}$ levels. 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 above the LML. Under baseline conditions, about 96 percent of the population is

[84] Because the Transport Rule is not yet promulgated, the baseline exposure obtained from this modeling data would slightly overestimate the fraction of the population exposed to air quality levels below the LML. As additional rules continue to reduce the ambient $PM_{2.5}$ levels over time, a larger fraction of the population would be exposed to air quality levels below the LML. However, the emission reductions anticipated from the rules without air quality modeling available are comparatively small and represent marginal changes. We intend to update this LML assessment as necessary to correspond with the successively lower baseline air quality levels anticipated as the result of promulgating significant upcoming rules.

exposed to annual mean $PM_{2.5}$ levels of at least 5.8 µg/m^3, which is the lowest air quality level considered in the most recent study of the American Cancer Society cohort by Krewski et al. (2009). Using the Pope et al. (2002) study, the 85% of the population is exposed at or above the LML of 7.5 µg/m^3. Using the Laden et al. (2006) study, 40% of the population is exposed above the LML of 10 µg/m^3. 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, which is 5.8 µg/m^3. 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.

Figure 1: Percentage of Adult Population by Annual Mean $PM_{2.5}$ Exposure (pre- and post-policy)

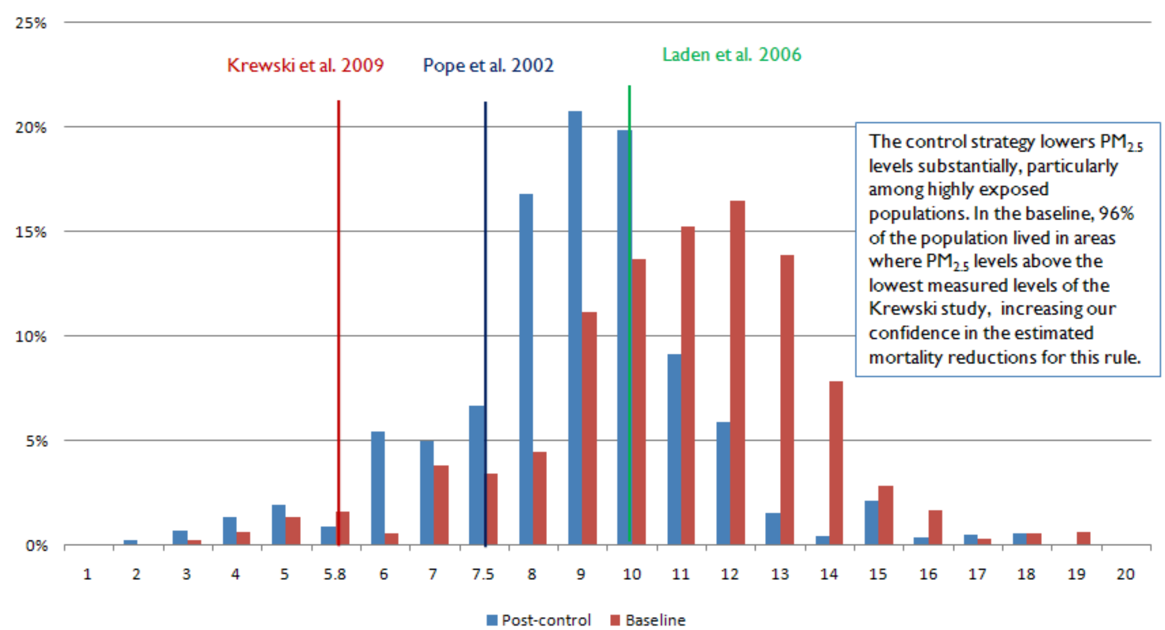

Figure 2: Cumulative Distribution of Adult Population at Annual Mean $PM_{2.5}$ levels (pre- and post-policy)

There are several important differences between the assessment conducted for the Transport Rule and the assessment presented here. If you compare the graphics in the Transport Rule to those provided here, you will notice that these graphs show a larger percentage of the population below the LML. It is imperative to point out that the Transport Rule graphics represented mortality impacts attributable to the Transport Rule, whereas these graphics represent exposure. Mortality impacts are the result of the incremental change in exposure between the baseline and control. However, the baseline population exposure at lower air quality levels is so much larger than the impacts among these same populations. In other words, the population exposed to lower $PM_{2.5}$ levels are not receiving very much of the air quality benefit between the base and the control case.

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