December 19, 2012

MEMORANDUM

SUBJECT: Regulatory Impact Results for the Reconsideration Final Rule for National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters at Major Sources

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The EPA analyzed the economic impacts and benefits of this final reconsideration using the identical methodology as the Regulatory Impact Analysis (RIA) for the boiler rules finalized in February 2011 and included as Attachment A to this memo. Therefore, all changes to the costs, monetized benefits, and economic impacts for this final reconsideration are due to changes in the final reconsideration for major source boilers, which are fully described in the preamble to the final reconsideration. There are no changes to the area source boiler impacts.

Changes Since 2010 Final Rule to Emission Reductions and Engineering Costs

There were two major changes to the March 2011 final rule for major source boilers and process heaters (i.e., Boiler MACT). First, an increase in the inventory of affected units and, second, changes in the provisions (generally less stringent) of the rule. Since the March 2011 final rule, 72 major source facilities were identified that were not previously in the Boiler MACT inventory database. Adding the boilers and process heaters located at these newly identified major source facilities resulted in 73 additional coal-fired units, 32 additional biomass-fired units, 82 additional oil-fired units, and 149 additional gas-fired units. The resulting additional cost impact for these additional existing boilers and process heaters to comply with the final amended rule is $0.6 billion in capital expenditures and $0.21 billion per year in total annual costs, considering fuel savings, with the additional coal-fired units (46%) and the additional oil-fired units (51%) accounting for 97% of the additional capital expenditures and nearly all of the additional total annual costs. The additional emission reductions from the additional coal-fired and oil-fired units alone (excluding the additional emission reductions from biomass and gas-fired units) are 73,400 tons of SO_2 per year and 1,300 tons of $PM_{2.5}$ per year

The second major change to the March 2011 final rule is differences in the rule provisions. The changes in emission reductions and annual engineering costs are due to provision changes in this final reconsideration are mainly the result of revisions made to the emission limits due to new data, corrections to old data, and subcategories changes. For existing subcategories in the final amended rule, for the HCl emission limits, 10 are more stringent, 3 are less stringent and 1 remained the same from the March 21, 2011 final rule; for the mercury emission limits, 3 are more stringent and 11 are less stringent from the March 21, 2011 final rule; for the PM emission limits, 2 are more stringent, 7 are less stringent and 5 are unchanged from the March 21, 2011 final rule; and for the CO emission limits, 4 are more stringent and 10 are less stringent from the March 21, 2011 final rule. Overall, these changes to the emission limits resulted in a decrease in annual engineering costs but the decrease in annual engineering costs is mainly the results of less stringent emission limits for units in the liquid fuel subcategories. For the liquid fuel subcategories, the cost reduction was due to less oil-fired units estimated to install fabric filters since the PM emission limit was revised from 0.0075 lb/MMBtu for all oil-fired units to 0.062 lb/MMBtu for units firing heavy oil. One of the provision changes was splitting the liquid fuel subcategories into two subcategories, heavy liquid subcategory and light liquid subcategory. In addition, less oil-fired units were estimated to install wet scrubbers to comply with the revised HCl emission limit which changed from 0.00033 lb/MMBtu to 0.0011 lb/MMBtu. Also, less oil-fired units were estimated to install oxidation catalysts to comply with the revised CO emission limits which changed from 4 ppm to 130 ppm. These changes to the emission limits for liquid-fired units resulted in a reduction of about 350 million dollars per year in total annual costs. This total annual costs reduction was offset somewhat by the increase in total annual costs due to the more stringent HCl standard for coal-fired units which resulted in higher estimated costs for installing wet scrubbers to comply with the revised HCl emission limit. The additional emission reductions resulting from these provision changes are mainly due to the additional SO_2 reductions resulting from the revised HCl emission limit for coal-fired units.

Table 1 shows the changes in emission reductions of directly emitted $PM_{2.5}$ and SO_2. Table 2 shows an estimate of the changes in monetized benefits associated with the emission reductions and engineering costs in the major source boilers final reconsideration.

Table 1. Changes in Emission Reductions for final Boiler Reconsideration[a]

	Direct $PM_{2.5}$ (tons per year)	**SO_2 (tons per year)**
Major Boiler Final Rule (March 2011)	28,990	439,619
Changes due to increase in scope (addition of 336 units)	+1,314	+74,152
Changes due to provision changes in this final reconsideration	-13,753	+57,956
Net changes since final rule	-12,439	+132,108
Major Boiler Final Reconsideration	16,593	571,727

[a] We provide only the emission changes associated with these 2 pollutants in this table because the other pollutants (e.g., Hg, HCl, CO, D/F, HF, and THC) were not monetized in the RIA.

Table 2. Changes in Benefits and Costs for final Boiler Reconsideration

	Monetized Benefits in 2015[a]		Annual Engineering Costs[b] (considering fuel savings)
	3% discount rate	**7% discount rate**	
Major Boiler Final Rule (March 2011)	$25 to $54 billion	$20 to $49 billion	$1.40 billion
Changes due to increase in scope (addition of 336 units)	+$3.5 to $8.6 billion	+$3.2 to $7.7 billion	+$0.219 to $0.224 billion
Changes due to provision changes in this final reconsideration[c]	+$1.7 to $4.1 billion	+$1.5 to $3.7 billion	-$0.24 to -$0.042 billion
Net changes since final rule	+$5.1 to $13 billion	+$4.7 to $11 billion	-$0.02 to + $0.18 billion
Major Boiler Final Reconsideration	$27 to $67 billion	$25 to $61 billion	+$1.4 to $1.6 billion

[a] These benefits do not include benefits associated with reduced exposure to HAP, direct exposure to SO_2, visibility impairment, or ecosystem effects

[b] Minimum and maximum fuel savings reflect a range of fuel prices for the final reconsideration.

[c] The change in benefits due to provision changes in this final reconsideration is positive because the solid fuel HCl limit is somewhat lower, which resulted in increased SO_2 reductions and increased benefits. The costs are negative because the cost decrease for liquid-fired units is greater than the cost increase for coal-fired units.

The monetized benefits estimates for the final reconsideration are very similar to the monetized benefits for the proposed reconsideration, which are both slightly higher than the monetized benefits for the final Boiler RIA (March 2011). We estimated the total monetized benefits for the final Boiler RIA (March 2011) to be $22 billion to $54 billion at 3 percent discount rate and $20 billion to $49 billion at 7 percent discount rate. For this final reconsideration, we estimate the total monetized benefits to be $27 billion to $67 billion at 3 percent discount rate and $25 billion to $61 billion at 7 percent discount rate. All estimates are in 2008$.

While it may seem hard to understand why changes due to the provision changes result in increased benefits and decreased costs, the fact that some emission limits are more stringent and other limits are less stringent is the key to understanding this. The increase in SO_2 reductions has more benefits associated with it than the decrease in $PM_{2.5}$ reductions. Similarly, the increase in SO_2 reductions has a smaller cost increase associated with it than the cost savings associated with the decrease in $PM_{2.5}$ reductions.

Revised Economic Impacts

The market impact results are very similar to the ones in the final rule in the RIA. The agencies economic model suggests the average national price increases for industrial sectors are less than 0.01 percent, while average annual domestic production may fall by less than 0.01 percent. Because of higher domestic prices, imports slightly rise. Table 3 shows the price, production, import, and export changes for this final reconsideration, which are very close to the estimated changes for the final rule RIA.

Table 3. Price, Production, Import, and Export Changes Resulting from the Boiler MACT Final Reconsideration

Industry Sector	U.S. Prices	U.S. Production	Imports	U.S. Consumption	Exports
Energy	0.033%	-0.019%	0.070%	-0.006%	-0.005%
Coal	0.015%	-0.012%	0.033%	-0.010%	-0.002%
Crude Oil Extraction	0.001%	-0.043%	0.005%	-0.008%	0.000%
Electric generation	0.101%	-0.010%	0.199%	-0.010%	-0.016%
Natural Gas	0.008%	-0.033%	0.098%	-0.008%	-0.002%
Refined Petroleum	0.017%	-0.008%	0.016%	-0.003%	-0.001%
Nonmanufacturing	0.001%	-0.003%	0.001%	-0.003%	0.000%
Manufacturing					
Food, beverages, and textiles	0.012%	-0.013%	0.015%	-0.007%	-0.008%
Lumber, paper, and printing	0.084%	-0.037%	0.086%	-0.023%	-0.058%
Chemicals	0.005%	-0.012%	0.006%	-0.008%	-0.005%
Plastics and Rubber	0.007%	-0.009%	0.008%	-0.006%	-0.007%
Nonmetallic Minerals	0.003%	-0.004%	0.001%	-0.003%	-0.003%
Primary Metals	0.019%	-0.022%	0.018%	-0.011%	-0.018%
Fabricated Metals	0.004%	-0.005%	0.004%	-0.004%	-0.002%
Machinery and Equipment	0.008%	-0.010%	0.007%	-0.004%	-0.013%
Electronic Equipment	-0.001%	-0.002%	0.000%	-0.001%	0.001%
Transportation Equipment	0.003%	-0.006%	0.004%	-0.003%	-0.006%
Other	0.004%	-0.008%	0.006%	-0.002%	-0.003%
Wholesale and Retail Trade	-0.002%	-0.001%	-0.001%	-0.001%	0.001%
Transportation Services	0.000%	-0.003%	-0.001%	-0.003%	0.000%
Other Services	0.000%	-0.001%	0.000%	-0.001%	0.000%

The results for sales tests for small businesses are somewhat lower than those calculated for the final rule. For the sales tests using small companies identified in the Combustion Survey, the mean cost to receipts dropped from 4 percent in the RIA to 3 percent for the final reconsideration and the median was 0.2 percent for in the RIA and also 0.2 percent in the final reconsideration. The number of parent companies with sales tests exceeding 3 percent dropped from 8 in the RIA to 5 for the final reconsideration. There was no change in the results for small public entities. Median cost is still about $1.1 million and representative small major public entities would have cost-to-revenue ratios above 10 percent.

The change in employment estimates between the RIA and the final reconsideration is minimal. The estimated employment changes range between −3,100 to +6,500 employees, with a central estimate of +1,700 employees for the major source NESHAP in the RIA. For the final reconsideration, the estimated employment is a central estimate of +1,400 with the range between −2,600 to +5,400 employees.

Revised Benefits

The health benefits were calculated using the methodology described in the final Boiler RIA (March 2011), using the revised emission reductions estimated for the final reconsideration.

In addition, we fixed an error in the 95th confidence intervals reported in the proposal reconsideration memo for the incidence estimates, and added the 95th percentile confidence intervals for the monetized benefits by mortality estimate. We were unable to estimate the benefits from reducing exposure to HAPs and ozone, ecosystem impairment, and visibility impairment, including reducing 180,000 tons of carbon monoxide, 39,000 tons of HCl, 500 tons of HF, 2,500 tons of other metals, and 3,100 to 5,300 pounds of mercury. Energy disbenefits due to increased CO_2 emissions from increased electricity usage were estimated to be \$5.8 million to \$75 million depending on the discount rate for the final boiler RIA (March 2011), and thus do not affect the rounded monetized benefits and have not been re-estimated here. Please refer to the full description in the final Boiler RIA of the unquantified benefits as well as technical details of the analysis and its limitations and uncertainties. These monetized benefits are approximately 23% higher than the final Boiler MACT due to the increase in SO_2 emission reductions. These benefit-per-ton estimates were calculated for a 2014 analysis year (i.e., using population and income growth for 2014), which slightly underestimates the 2015 benefits. Since the reconsideration proposal, we have made several updates to the approach we use to estimate mortality and morbidity benefits in the PM NAAQS RIAs (U.S. EPA, 2012a,b)[1,2], including updated epidemiology studies, health endpoints, and population data. Although we have not re-estimated the benefits for this rule to apply this new approach, these updates generally offset each other, and we anticipate that the rounded benefits estimated for this rule are unlikely to be different than those provided below. See Tables 4 to 6 and Figures 1 and 2 for the updated benefits results.

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[1] U.S. Environmental Protection Agency (U.S. EPA). 2012a. *Regulatory Impact Analysis for the Proposed Revisions to the National Ambient Air Quality Standards for Particulate Matter*. EPA-452/R-12-003. Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. June. Available at http://www.epa.gov/ttnecas1/regdata/RIAs/PMRIACombinedFile_Bookmarked.pdf.

[2] U.S. Environmental Protection Agency (U.S. EPA). 2012b. *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter*. EPA-452/R-12-003. Office of Air Quality Planning and Standards, Health and Environmental Impacts Division. December. Available at http://www.epa.gov/pm/2012/finalria.pdf.

Table 4: Summary of Monetized Benefits Estimates for the Final Boiler MACT Reconsideration in 2015

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 (billions 2008$ at 3%)	Total Monetized Benefits (billions 2008$ at 7%)
Direct $PM_{2.5}$	16,593	$72,000	$180,000	$65,000	$160,000	$1.2 to $2.9	$1.1 to $2.7
SO_2	571,727	$46,000	$110,000	$42,000	$100,000	$26 to $64	$24 to $58
					Total	**$27 to $67**	**$25 to $61**

*All estimates are for the implementation year (2015), and are rounded to two significant figures so numbers may not sum across columns. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The benefit per ton estimates vary because each ton of precursor reduced has a different propensity to become $PM_{2.5}$. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage, or ozone benefits. These benefits reflect existing boilers and new boilers anticipated to come online by 2015.

Table 5: Summary of Estimated Reductions in Health Incidences from $PM_{2.5}$ for the Final Boiler MACT Reconsideration in 2015 (95th percentile confidence interval)*

	Final Reconsideration
Avoided Premature Mortality	
Pope et al.	3,100 (1,000 -- 5,200)
Laden et al.	7,900 (4,000 -- 12,000)
Woodruff (Infant mortality)	13 (0 -- 37)
Avoided Morbidity	
Chronic Bronchitis	2,000 (220 -- 3,800)
Acute Myocardial Infarction	5,000 (1,500 -- 8,400)
Hospital Admissions, Respiratory	750 (330 -- 1,200)
Hospital Admissions, Cardiovascular	1,600 (1,100 -- 1,900)
Emergency Room Visits, Respiratory	3,000 (1,600 -- 4,300)
Acute Bronchitis	4,600 (0 -- 9,800)
Work Loss Days	390,000 (330,000 -- 440,000)
Asthma Exacerbation	51,000 (3,700 -- 160,000)
Minor Restricted Activity Days	2,300,000 (1,900,000 -- 2,700,000)
Lower Respiratory Symptoms	55,000 (24,000 -- 86,000)
Upper Respiratory Symptoms	41,000 (10,000 -- 72,000)

*All estimates are for the analysis year (2015) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, VOC emissions and ozone exposure, nor energy disbenefits associated with the increased emissions from additional energy usage. These confidence intervals only reflect the standard errors within the epidemiology studies, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and new boilers anticipated to come online by 2015.

Table 6: Summary of Monetized Benefits Estimates from PM2.5 for the Final Boiler MACT Reconsideration in 2015 (95th percentile confidence interval)*

	3%	7%
Based on Epidemiology Literature		
Pope et al.	$27,000 ($2,300 -- $83,000)	$25,000 ($2,000 -- $76,000)
Laden et al.	$67,000 ($6,000 -- $200,000)	$61,000 ($5,300 -- $180,000)
Based on Expert Elicitation		
Expert A	$71,000 ($4,200 -- $230,000)	$64,000 ($3,700 -- $210,000)
Expert B	$54,000 ($2,100 -- $220,000)	$49,000 ($1,800 -- $200,000)
Expert C	$54,000 ($3,200 -- $200,000)	$49,000 ($2,800 -- $190,000)
Expert D	$38,000 ($2,600 -- $120,000)	$35,000 ($2,200 -- $110,000)
Expert E	$88,000 ($7,700 -- $260,000)	$80,000 ($6,800 -- $240,000)
Expert F	$49,000 ($4,800 -- $140,000)	$45,000 ($4,300 -- $130,000)
Expert G	$32,000 ($310 -- $120,000)	$29,000 ($200 -- $110,000)
Expert H	$41,000 ($380 -- $160,000)	$37,000 ($260 -- $140,000)
Expert I	$54,000 ($3,100 -- $180,000)	$49,000 ($2,700 -- $160,000)
Expert J	$44,000 ($3,400 -- $170,000)	$40,000 ($2,900 -- $150,000)
Expert K	$10,000 ($310 -- $67,000)	$9,600 ($200 -- $61,000)
Expert L	$36,000 ($1,500 -- $140,000)	$33,000 ($1,200 -- $130,000)

*All estimates are for the analysis year (2015) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage. These confidence intervals only reflect the standard errors within the epidemiology studies and valuation functions, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and new boilers anticipated to come online by 2015.

Figure 1: Breakdown of Monetized Benefits by Fuel Subcategory

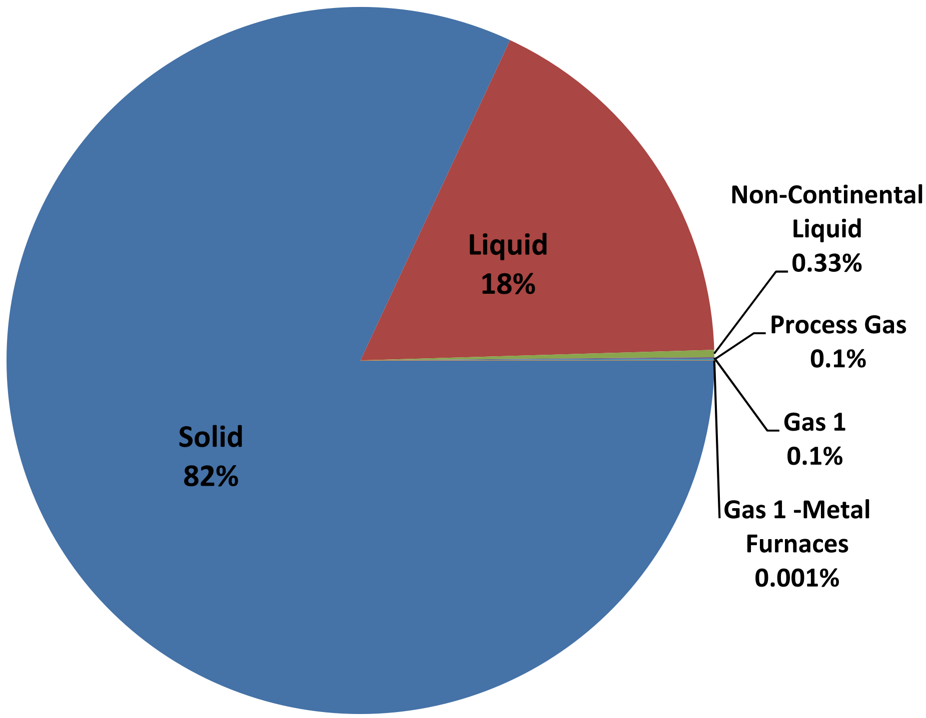
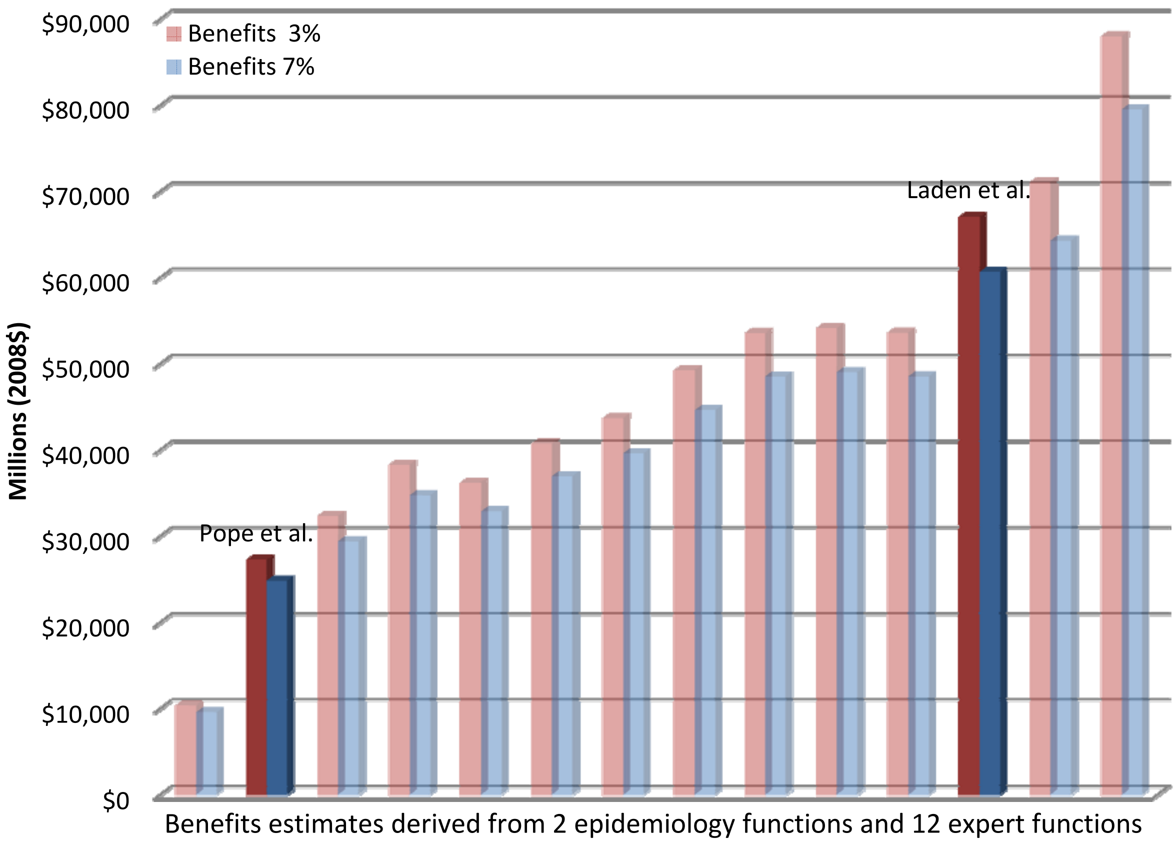


Figure 2: Total Monetized $PM_{2.5}$ Benefits Estimates for the Final Boiler MACT Reconsideration in 2015



Revised Net Benefits

Table 7 shows the estimated costs and benefits for the boiler MACT and the reconsideration proposal. The estimated net benefits are greater than the range for the RIA, which was $18.5 billion to $47.5 billion at a 7 percent discount rate and was $20.5 billion to $52.5 billion at 3 percent.

Table 7. Summary of Estimated Social Costs and Benefits*

Category	Low Estimate	High Estimate	Year Dollar	Discount Rate	Period Covered
Benefits					
Annualized Monetized ($millions/year)	$25,000	$61,000	2008	7%	2015
	$27,000	$67,000	2008	3%	2015
Costs					
Annualized Monetized ($millions/year)	$1,400	$1,600	2008	7%	2015
	$1,400	$1,600	2008	3%	2015
Net Benefits					
Annualized Monetized ($millions/year)	$23,000	$59,000	2008	7%	2015
	$26,000	$65,000	2008	3%	2015

*All estimates are for the analysis year (2015) and are rounded to two significant figures.

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Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards (OAQPS)
Air Economics Group
Risk and Benefits Group
Air Quality Modeling Group
Research Triangle Park, NC 27711

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SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is promulgating two rules for national emission standards for hazardous air pollutants (NESHAP) for new and existing industrial, commercial, and institutional boilers and process heaters.[1] One rule requires all major sources to meet hazardous air pollutant (HAP) emissions standards reflecting the application of the maximum achievable control technology (MACT). In the other rule, EPA is promulgating a NESHAP for two area source categories: industrial boilers and institutional and commercial boilers.[2] The emission standards for controlling mercury and polycyclic organic matter (POM) emissions are based on the MACT. The emission standards for controlling other HAPs are based on EPA's determination as to what constitutes the generally available control technology (GACT) or management practices. As part of the regulatory process, EPA is required to develop a regulatory impact analysis (RIA). The RIA includes an economic impact analysis (EIA) and a small entity impacts analysis and documents the RIA methods and results.

1.1 Executive Summary

The key results of the RIA are as follows:

- **Engineering Cost Analysis:** EPA estimates the major source NESHAP's total annualized costs will be $1.4 billion (2008$). For the area source NESHAP, EPA estimates the total annualized costs will be $0.5 billion.
- **Market Analysis:** Under the major source NESHAP, the Agency's economic model suggests the average national prices for industrial sectors could be small (less than 0.01% higher). Average annual domestic production may also fall by less than 0.01%. Because of higher domestic prices, imports rise by less than 0.01% per year. Market-level effects for the area source NESHAP are smaller when compared to the major source rule; average price, production, and import changes are less than 0.01%.
- **Social Cost Analysis:** The estimated social cost of the major source rule is just under $1.5 billion (2008$). The Agency's economic model suggests that industries are able to pass approximately $0.5 billion of the rule's costs to consumers (e.g., higher market prices). Domestic industries' surplus falls by $1.4 billion, while other countries on net benefit from higher prices (a net increase in rest-of-the world [ROW] surplus of less than $0.1 billion). Additional costs and fuel savings for new and existing major sources that are not included in the

[1] On June 19, 2007, the U.S. Court of Appeals for the District of Columbia Circuit (DC Circuit) vacated the NESHAP for industrial/commercial/institutional boilers and process heaters. This action provides EPA's rule in response to the court's vacatur.

[2] Gas-fired boilers are not part of the area source categories of industrial boilers and institutional/commercial boilers.

economic model represent a net benefit of \$0.4 billion.[1] The estimated social cost of the area source rule is approximately \$0.5 billion (2008\$). The Agency's economic model suggests that industries are able to pass approximately \$0.2 billion of the rule's costs to consumers. Domestic industries' surplus falls by \$0.3 billion and the net increase in ROW surplus is less than \$0.1 billion. Additional costs and fuel savings for unknown, existing, and new area sources not included in the economic model results represent a net benefit of less than \$0.1 billion.

- **Employment Changes**: The estimated employment changes range between −3100 to 6,500 employees, with a central estimate of +1,700 employees for the major source NESHAP. The estimated employment changes range between −1,000 to 2,000 employees, with a central estimate of +500 employees for the area source NESHAP.

- **Small Entity Analyses: EPA performed a scre**ening analysis for impacts on small entities by comparing compliance costs to sales/revenues (e.g., sales and revenue tests). EPA's analysis found the tests were typically higher than 3% for small entities included in the screening analysis. Pursuant to section 603 of the RFA, EPA prepared an initial regulatory flexibility analysis (IRFA) for the proposed rule and convened a Small Business Advocacy Review Panel to obtain advice and recommendations of representatives of the regulated small entities. A detailed discussion of the Panel's advice and recommendations is found in the final Panel Report (Docket ID No. EPA-HQ-OAR-2002-0058-0797). A summary of the Panel's recommendations is also presented in the preamble to the proposed rule at 75 FR 32044-32045 (June 4, 2010). In the proposed rule, EPA included provisions consistent with four of the Panel's recommendations. As required by section 604 of the RFA, we also prepared a final regulatory flexibility analysis (FRFA) the final rule (see Section 5).

- **Benefits Analysis:**

– The benefits from reducing some air pollutants have not been monetized in this analysis, including reducing a combined 113,000 tons of carbon monoxide, 30,000 tons of HCl, 830 tons of HF, 2,900 pounds of mercury, 3,000 tons of other metals, and 23 grams of dioxins/furans (TEQ) each year. We assess the benefits of these emission reductions qualitatively in this analysis.

– We have monetized the benefits from reducing PM (as a surrogate for metal HAP), as well as the co-benefits that result from the HAP emissions reductions (e.g., the pollution control equipment for HCl also reduces sulfur dioxide, a precursor to $PM_{2.5}$). Thus all monetized benefits reported reflect improvements in ambient $PM_{2.5}$ and ozone concentrations. As such, although the monetized benefits likely underestimate the total benefits, the extent of the underestimate is unclear.

– Using a 3% discount rate, we estimate the total monetized benefits of the Boiler MACT to be \$22 billion to \$54 billion in the implementation year (2014). Using a 7% discount rate, we estimate the total monetized benefits of the Boiler MACT to

[1] See additional details in Chapter 3 and Cost Appendices.

be \$20 billion to \$49 billion in the implementation year. 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.

– Using a 3% discount rate, we estimate the total monetized benefits of the Boiler Area Source Rule to be \$210 million to \$520 million in the implementation year (2014). Using a 7% discount rate, we estimate the total monetized of the Boiler Area Source Rule to be \$190 million to \$470 million in the implementation year.

– Using a 3% discount rate, we estimate the total monetized benefits of the combined Boiler MACT and Boiler Area Source Rule to be \$22 billion to \$58 billion in the implementation year (2014). Using a 7% discount rate, we estimate the total monetized benefits of the combined Boiler MACT and Boiler Area Source Rule to be \$20 billion to \$50 billion in the implementation year. All estimates are in 2008\$.

- **Net Benefits:** For the Boiler MACT, the net benefits are \$21 billion to \$53 billion at a 3% discount rate for the benefits and \$19 million to \$48 billion at a 7% discount rate. For the Boiler Area Source Rule, the net benefits are −\$280 million to \$30 million at a 3% discount rate for the benefits and −\$300 million to −\$20 million at a 7% discount rate. These results are shown in Tables 1-1 and 1-2.

1.2 Organization of this Report

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

- Section 2 presents the affected industry profiles.
- Section 3 describes the engineering cost analysis.
- Section 4 describes the economic impact analysis.
- Section 5 describes the small entity analyses.
- Section 6 describes the air quality modeling performed by EPA.
- Section 7 presents the benefits estimates.
- Section 8 presents the net benefits.
- Appendix A describes the multimarket model used in the economic analysis.
- Appendix B provides additional economic model result tables by sector.

Table 1-1. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the Boiler MACT (Major Sources) in 2014 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Selected						
Total Monetized Benefits[b]	$22,000	to	$54,000	$20,000	to	$49,000
Total Social Costs[3]		$1,500			1,500	
Net Benefits	$20,500	to	$52,500	$18,500	to	$47,500
Non-monetized Benefits	112,000 tons of carbon monoxide					
	30,000 tons of HCl					
	820 tons of HF					
	2,800 pounds of mercury					
	2,700 tons of other metals					
	23 grams of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					
Alternative						
Total Monetized Benefits[b]	$18,000	to	$43,000	$16,000	to	$39,000
Total Social Costs[b]		$1,900			$1,900	
Net Benefits	$16,100	to	$41,100	$14,100	to	$37,100
Non-monetized Benefits	112,000 tons of carbon monoxide					
	22,000 tons of HCl					
	620 tons of HF					
	2,400 pounds of mercury					
	2,600 tons of other metals					
	23 grams of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures. These results include units anticipated to come online and the lowest cost disposal assumption.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors such as SO_2, as well as reducing exposure to ozone through reductions of VOCs. 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 the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates include energy disbenefits associated with the increased emissions from additional energy usage valued at $22 million for the selected option and $37 million for the alternative option. Ozone benefits are valued at $3.6 to $15 million for both options.

[c] The methodology used to estimate social costs for one year in the multimarket model using surplus changes results in the same social costs for both discount rates.

Table 1-2. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the Boiler Area Source Rule in 2014 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Final MACT/GACT Approach: Selected						
Total Monetized Benefits[b]	$210	to	$520	$190	to	$470
Total Social Costs[c]		$490			$490	
Net Benefits	−$280	to	$30	−$300	to	−$20
Non-monetized Benefits	1,100 tons of carbon monoxide					
	340 tons of HCl					
	8 tons of HF					
	90 pounds of mercury					
	320 tons of other metals					
	<1 gram of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					
Proposed MACT Approach: Alternative						
Total Monetized Benefits[b]	$200	to	$490	$180	to	$440
Total Social Costs[c]		$850			$850	
Net Benefits	−$650	to	−$360	−$670	to	−$410
Non-monetized Benefits	1,100 tons of carbon monoxide					
	340 tons of HCl					
	8 tons of HF					
	90 pounds of mercury					
	320 tons of other metals					
	<1 gram of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures. These results include units anticipated to come online and the lowest cost disposal assumption.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors such as SO_2. 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 the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates include energy disbenefits associated with the increased emissions from additional energy usage valued at less than $1 million.

[c] The methodology used to estimate social costs for one year in the multimarket model using surplus changes results in the same social costs for both discount rates.

1.3 Section 1 References

Laden, F., J. Schwartz, F.E. Speizer, and D.W. Dockery. 2006. “Reduction in Fine Particulate Air Pollution and Mortality.” *American Journal of Respiratory and Critical Care Medicine* 173:667-672.

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. “Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution.” *Journal of the American Medical Association* 287:1132-1141.

SECTION 2
INDUSTRY PROFILES

In this section, we provide an introduction selected industries that are affected by the rules. The industries were selected based on high facility population counts within 3-digit NAICs industries reported in the combustion facility survey. The purpose is to give the reader a general understanding of economic aspects and industry trends to provide additional context for the economic impact analysis.

2.1 Food Manufacturing

2.1.1 Introduction

Food manufacturing involves the transformation of raw agricultural and livestock products into processed food. Between 1997 and 2002, shipment values stagnated, falling 0.38%, while the number of employees and payroll increased 2.71% and 7.76%, respectively (Table 2-1). This trend reversed between 2002 and 2006, as shipment values rose 4.77 % and number of employees and payroll fell 5.94% and 3.28% respectively (Table 2-1). Shipments, payroll, and employment continued to increase between 2006 and 2007, but there was a notable drop in the number of establishments between 2002 and 2007 (Table 2-1). As Table 2-2 shows, payroll per employee grew 4.91% from 1997 to 2002 and continued to increase, albeit at a slower rate of 2.83%, from 2002 to 2006. Between 2006 and 2007, the payroll per employee declined as the growth in employees outpaced the increase in the annual payroll (Table 2-2).

The food manufacturing industry consists of nine different industry groups, each distinguished by the livestock or agricultural products used as raw materials for the processed food products as follows:

- Animal Food Manufacturing (North American Industry Classification System [NAICS] 3111)
- Grain and Oilseed Milling (NAICS 3112)
- Sugar and Confectionery Product Manufacturing (NAICS 3113)
- Fruit and Vegetable Preserving and Specialty Food Manufacturing (NAICS 3114)
- Dairy Product Manufacturing (NAICS 3115)
- Animal Slaughtering and Processing (NAICS 3116)
- Seafood Product Preparation and Packaging (3117)
- Bakeries and Tortilla Manufacturing (NAICS 3118)

Table 2-1. Key Statistics: Food Manufacturing (North American Industry Classification System [NAICS] 311)

	1997	2002	2006	2007
Shipments ($2007, millions)	$528,928	$526,939	$552,075	$589,550
Payroll ($2007, millions)	$48,118	$51,852	$50,151	$50,467
Employees	1,466,956	1,506,781	1,417,274	1,466,683
Establishments	26,302	27,899	NA	22,055

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005.” <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 00: All sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997.” <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 00: All sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (2007 NAICS Basis): 2002 and 2007.” <http://factfinder.census.gov>; (January 4, 2010).

Table 2-2. Industry Data: Food Manufacturing (NAICS 311)

Industry Data	1997	2002	2006	2007
Total shipments ($2007, millions)	$528,928	$526,939	$552,075	589,550
Shipments per establishment ($2007, thousands)	$20,110	$18,887	NA	$26,731
Average Shipments per employee ($2007)	$360,561	$349,712	$389,533	$401,961
Average Shipments per $ of payroll ($2007)	$10.99	$10.16	$11.01	$11.68
Average Annual payroll per employee ($2007)	$32,800.97	$34,412.12	$35,385.46	$34,409.00
Average Employees per establishment	56	54	NA	67

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005.” <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 00: All sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997.” <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; “Sector 00: All sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (2007 NAICS Basis): 2002 and 2007.” <http://factfinder.census.gov>; (January 4, 2010).

In 2006, Animal Slaughtering and Processing made up the largest share of both employment (33%) and the value of shipments (27%) in food manufacturing (Figures 2-1 and 2-2).

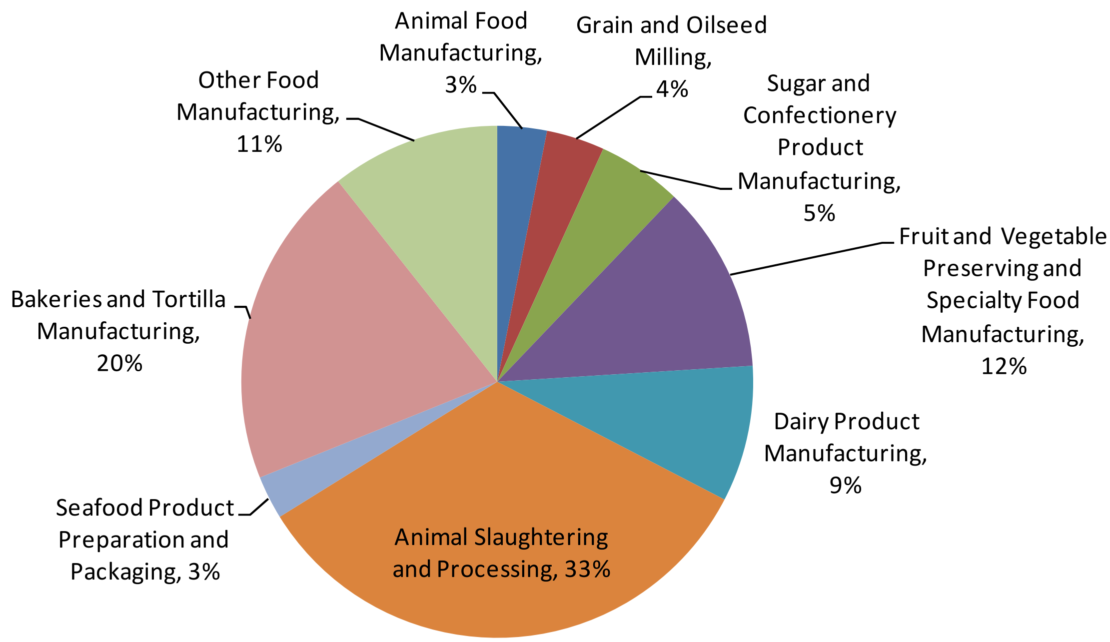

Figure 2-1. Distribution of Employment within Food Manufacturing (NAICS 311): 2006

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

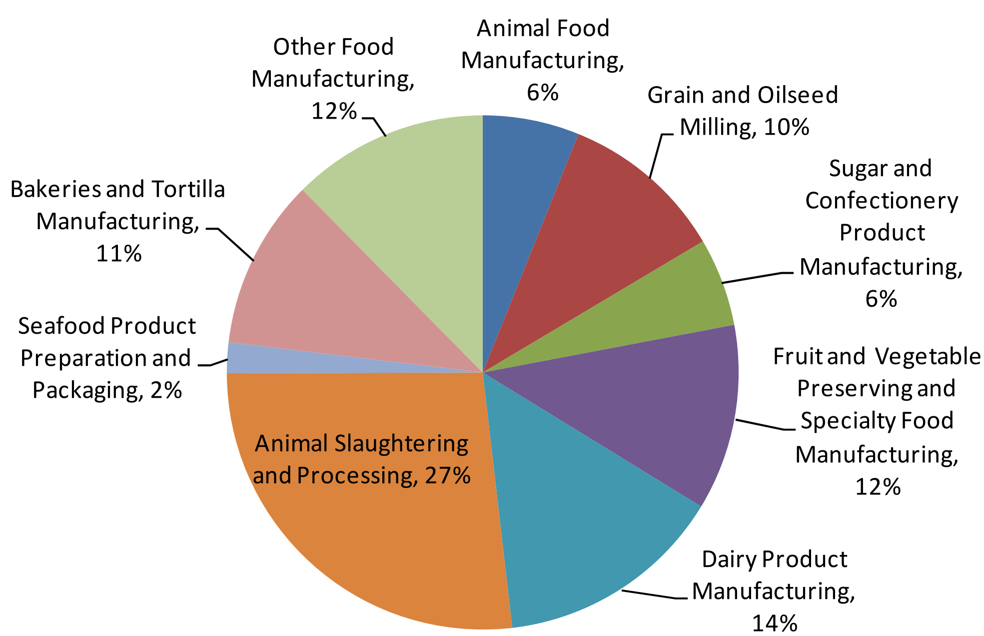

Figure 2-2. Distribution of Total Value of Shipments within Food Manufacturing (NAICS 311): 2006

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

Many major environmental regulations directly affect the food manufacturing industry and/or other markets that provide key goods and services to the industry (e.g., energy). RTI's multimarket model is specifically designed to analyze these types of regulations. The model emphasizes the links among industrial sectors and provides policy makers with new insights about the direct and indirect effects of a regulatory program and the distribution of costs across the U.S. economy.

2.1.2 Supply and Demand Characteristics

Next, we provide a broad overview of the supply and demand sides of the food manufacturing industry. We emphasize the economic interactions this industry has with other industries and people, including identifying the key goods and services used by the industry and the major uses and consumers of food manufacturing products.

2.1.2.1 Goods and Services Used in Food Manufacturing

In 2006, the cost of materials made up 57% of the value of shipments in food production. Total employee compensation accounted for 12% of this value, with half of that coming from production workers' wages (Table 2-3).

The top 10 industry groups supplying inputs to food production accounted for 84% of the total intermediate inputs to the industry, with the top three industry groups (food products, animal products, and crop products) accounting for over half of the total intermediate inputs (Table 2-4). Electric power generation, transmission, and distribution accounted for 2% of the total intermediate inputs, whereas boilers, tanks, and shipping containers accounted for 1%.

2.1.2.2 Energy

The Department of Energy (DOE) classifies the entire food products industry as an energy-intensive industry to model within its Industrial Demand Module (DOE, 2008). In 2002, food manufacturing accounted for 6.86% of the total fuel consumption by all manufacturing industries (NAICS 311–339) and 19.24% of the conventional boiler use fuel consumption by all manufacturing industries (DOE, Energy Information Administration, 2007a).

Table 2-3. Costs of Goods and Services Used in Food Manufacturing (NAICS 311) ($2007)

Industry Ratios	2005	Share	2006	Share
Total shipments ($millions)	$563,797	100%	$552,075	100%
Total compensation ($millions)	$64,909	12%	$64,027	12%
Annual payroll	$50,650	9%	$50,151	9%
Fringe benefits	$14,259	3%	$13,877	3%
Total employees	1,440,283		1,417,274	
Average compensation per employee	$45,067		$45,176	
Total production workers' wages ($millions)	$33,983	6%	$33,670	6%
Total production workers	1,099,530		1,090,081	
Total production hours (thousands)	2,242,558		2,198,396	
Average production wages per hour	$15		$15	
Total cost of materials ($thousands)	$315,993	56%	$312,847	57%
Materials, parts, packaging	$286,895	51%	$284,028	51%
Purchased electricity	$4,513	1%	$4,787	1%
Purchased fuel	$5,136	1%	$5,398	1%
Other	$19,449	3%	$18,634	3%

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

Table 2-4. Key Goods and Services Used in Food Manufacturing (NAICS 311) ($2007, millions)

Sector	BEA Code	Food Products
Food products	3110	$91,518
Animal products	1120	$85,785
Crop products	1110	$43,109
Management of companies and enterprises	5500	$34,235
Wholesale trade	4200	$27,849
Converted paper products	3222	$18,782
Truck transportation	4840	$12,943
Plastics and rubber products	3260	$9,641
Electric power generation, transmission, and distribution	2211	$6,004
Boilers, tanks, and shipping containers	3324	$4,564
Total intermediate inputs	T005	$400,067

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

In both 2005 and 2006, purchased electricity and fuel each accounted for 1% of the total value of shipments in food manufacturing (Table 2-3). In 2002, total energy consumption totaled 1,116 TBTU, a 7% increase over 1998 (Table 2-5). Of this total fuel consumption, the largest share (41.72%) was consumed for indirect uses including conventional boiler use and combined heat and power (CHP) and/or cogeneration process (MECS Table 5.2). Between 1997 and 2005, while the manufacturing sector as a whole used less electricity, food manufacturing used more electricity (Figure 2-3). From 2005 to 2006, the electricity consumption increased by nearly 9% (Table 2-5).

Table 2-5. Energy Used in Food Manufacturing (NAICS 311)

Fuel Type	1998	2002	2006
Net electricity[a] (million kWh)	62,457	67,521	73,440
Residual fuel oil (million bbl)	2	2	4
Distillate fuel oil[b] (million bbl)	3	3	3
Natural gas[c] (billion cu ft)	553	560	618
LPG and NGL[d] (million bbl)	1	1	1
Coal (million short tons)	6	8	7
Coke and breeze (million short tons)	*	*	*
Other[e] (trillion BTU)	97	90	107
Total (trillion BTU)	1,044	1,116	1,186

[a] Net electricity is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from on-site cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal).

[b] Distillate fuel oil includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[c] Natural gas includes natural gas obtained from utilities, local distribution companies, and any other supplier(s), such as independent gas producers, gas brokers, marketers, and any marketing subsidiaries of utilities.

[d] Examples of liquefied petroleum gases (LPGs) are ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas liquids (NGLs).

[e] Other includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power.

* Estimate less than 0.5.

Sources: U.S. Department of Energy, Energy Information Administration. 2007a. "2002 Energy Consumption by Manufacturers—Data Tables." Tables 3.2 and N3.2. Washington, DC: DOE <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>.

U.S. Department of Energy, Energy Information Administration. 2009a. "2006 Energy Consumption by Manufacturers—Data Tables." Table 3.1. Washington, DC: DOE. <http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html>.

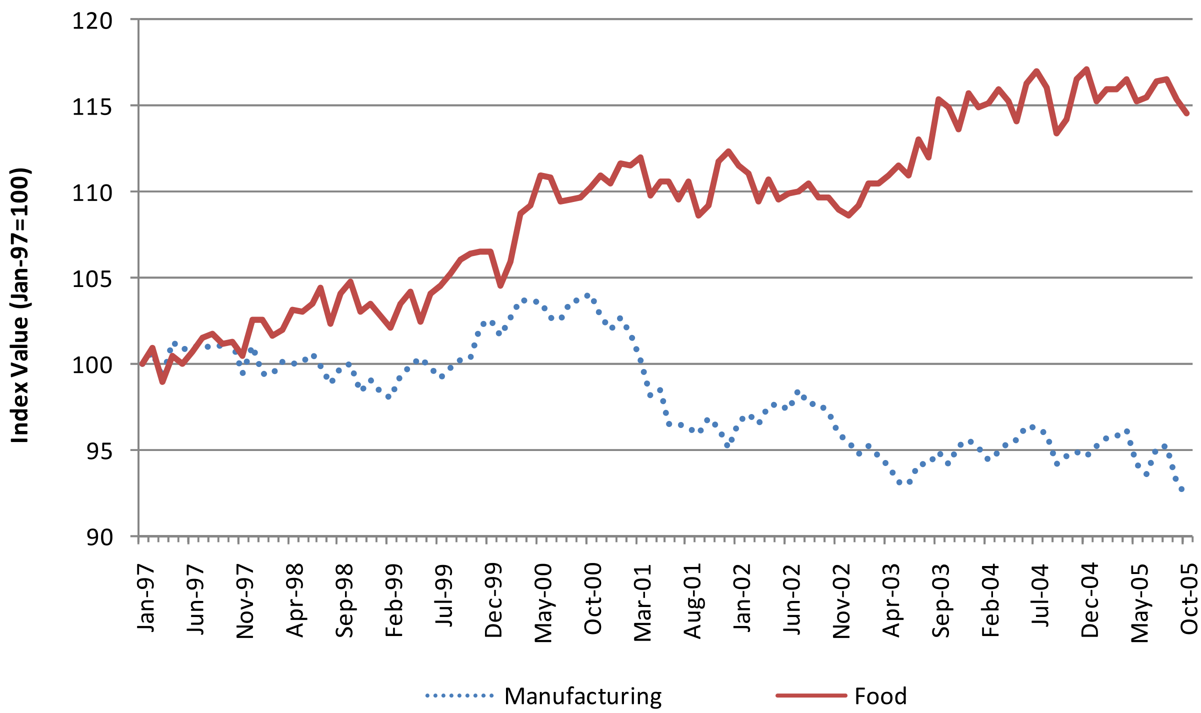

Figure 2-3. Electric Power Use Trends in Food Manufacturing (NAICS 311): 1997–2005

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Electric Power Use: Manufacturing and Mining." <http://www.federalreserve.gov/datadownload/>.

2.1.2.3 Uses and Consumers

The majority of food manufacturing's total commodity output (58%) is sold for personal consumption. Of the sales for intermediate use, 42% are sold back into the food manufacturing industry (Table 2-6).

2.1.3 Firm and Market Characteristics

This remaining subsection describes geographic, production, and market data. These data provide the basis for further analysis, including regulatory flexibility analyses, and give a complete picture of the recent historical trends of production and pricing.

2.1.3.1 Location

In 2002, California had the most food manufacturing establishments in the United States, followed by New York and Texas (see Figure 2-4). In addition, Pennsylvania, Illinois, Wisconsin, New Jersey, and Florida had over 1,000 establishments in their states.

Table 2-6. Demand by Sector: Food Manufacturing (NAICS 311) ($2007, millions)

Sector	BEA Code	Food Products
Food manufacturing	3110	$91,518
Food services and drinking places	7220	$37,291
Animal production	1120	$15,870
General state and local government services	S007	$15,170
Retail trade	4A00	$13,985
Beverage manufacturing	3121	$11,703
Hospitals	6220	$9,539
Educational services	6100	$4,485
Nursing and residential care facilities	6230	$4,187
Social assistance	6240	$2,277
Total intermediate use	T001	$217,570
Personal consumption expenditures	F010	$301,748
Exports of goods and services	F040	$28,151
Imports of goods and services	F050	−$33,119
Total final uses (GDP)	T004	$299,470
Total commodity output	T007	$517,040

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

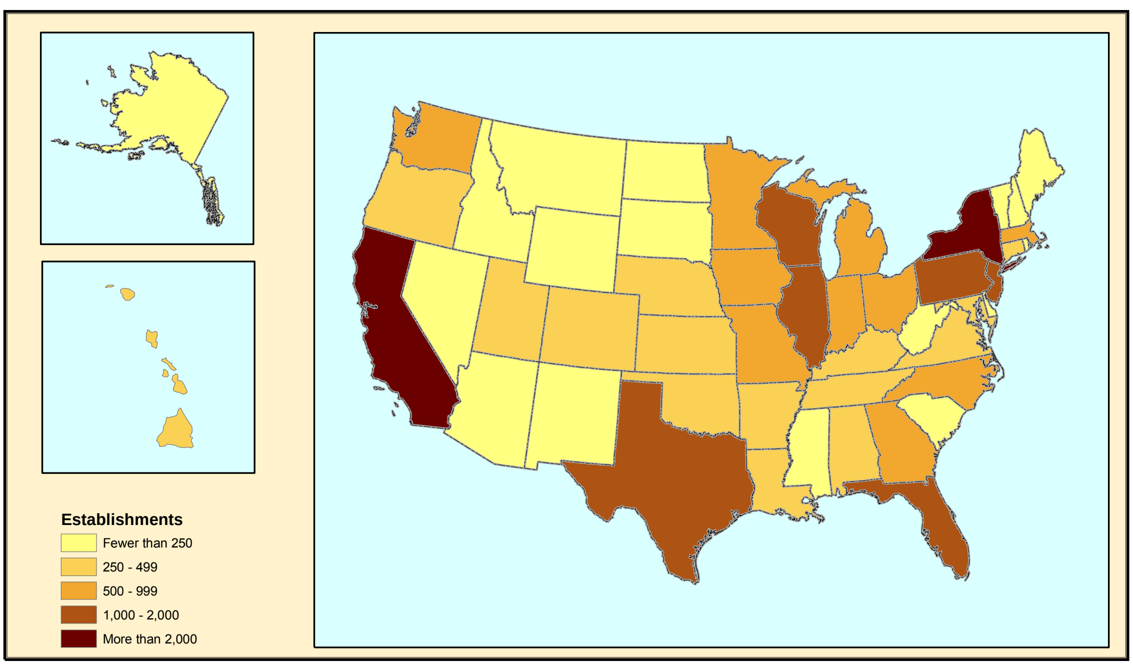

Figure 2-4. Establishment Concentration in Food Manufacturing (NAICS 311): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.1.3.2 Production Capacity and Utilization

Capacity utilization of the food manufacturing industry did not fall off during the recession of 2001 as much as the manufacturing sector as a whole (Figure 2-5). Food manufacturing's capacity utilization has remained higher than manufacturing as a whole and went above 85% in the spring of 2008. The effects of the recent economic downturn have not affected capacity utilization as sharply in the food industry relative to the overall manufacturing sector (Figure 2-5).

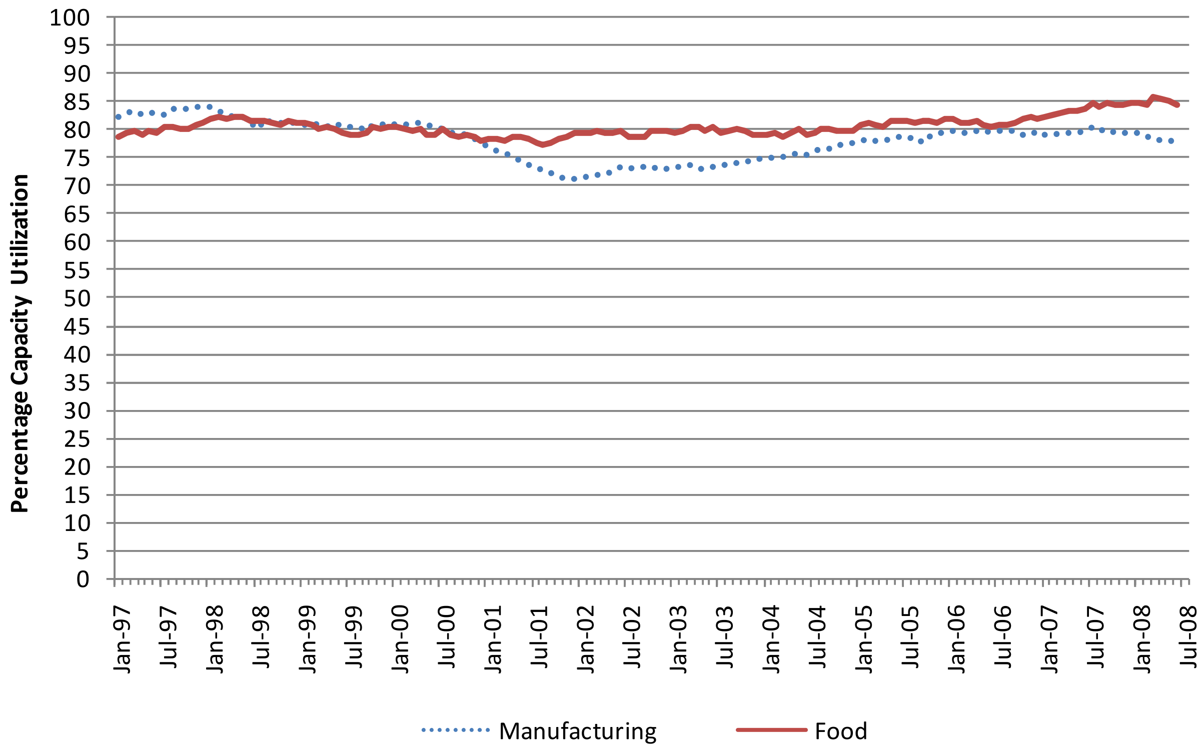

Figure 2-5. Capacity Utilization Trends in Food Manufacturing (NAICS 311)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Capacity Utilization." <http://www.federalreserve.gov/datadownload/>.

2.1.3.3 Employment

The geographic distribution of employment in food manufacturing varies substantially from the distribution of establishments. In 2002, Arkansas, ranked thirty-first in number of establishments and had the eighth most employees (53,844) because of its national high of 199 employees per establishment. New York, ranked second in number of establishments, had only the tenth most employees (50,012). North Carolina and Georgia also had greater than 50,000 employees, despite having fewer than 600 establishments (Figure 2-6).

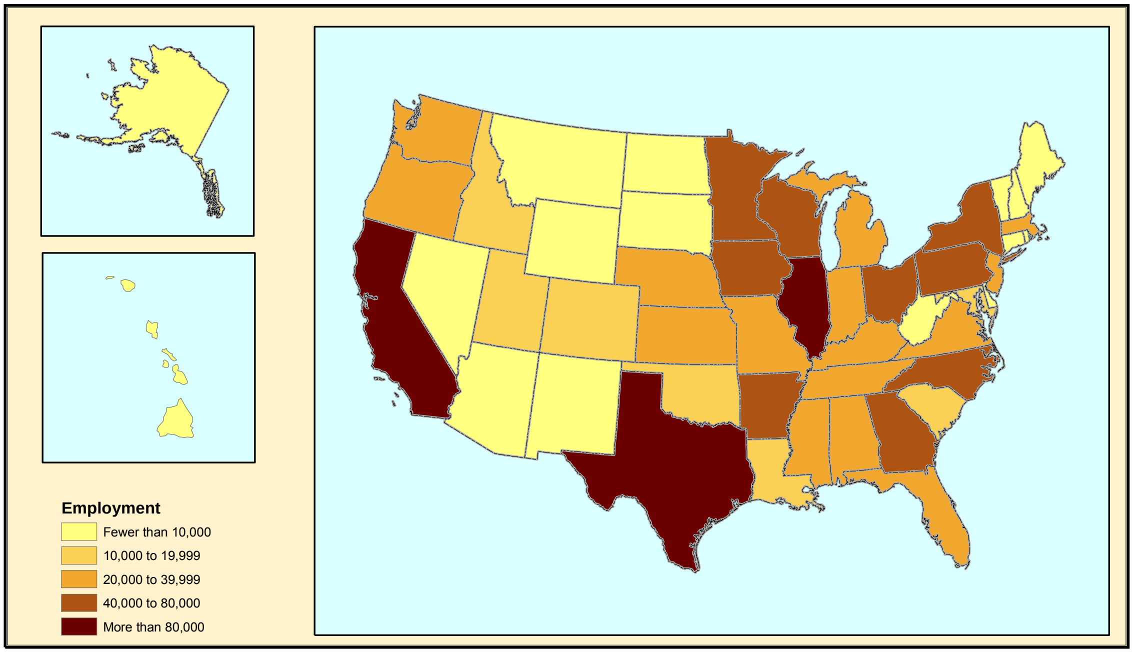

Figure 2-6. Employment Concentration in Food Manufacturing (NAICS 311): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.1.3.4 Plants and Capacity

Production capacity in food manufacturing only grew 17.94% between 1997 and early 2008, a compound annual growth rate (CAGR) of 1.45%. This is substantially less than the 42.50% growth for the manufacturing industry as a whole (Figure 2-7).

2.1.3.5 Firm Characteristics

In fiscal year 2007, the top eight food manufacturing companies each had greater than $10 billion in sales. These companies, however, are global, many with a large portion of both sales and production coming from operations outside of the United States (Table 2-7). The largest U.S. food manufacturing company, Kraft Foods Inc., has 50.27% of its long-lived assets located outside of the United States (Kraft Foods Inc., 2008).

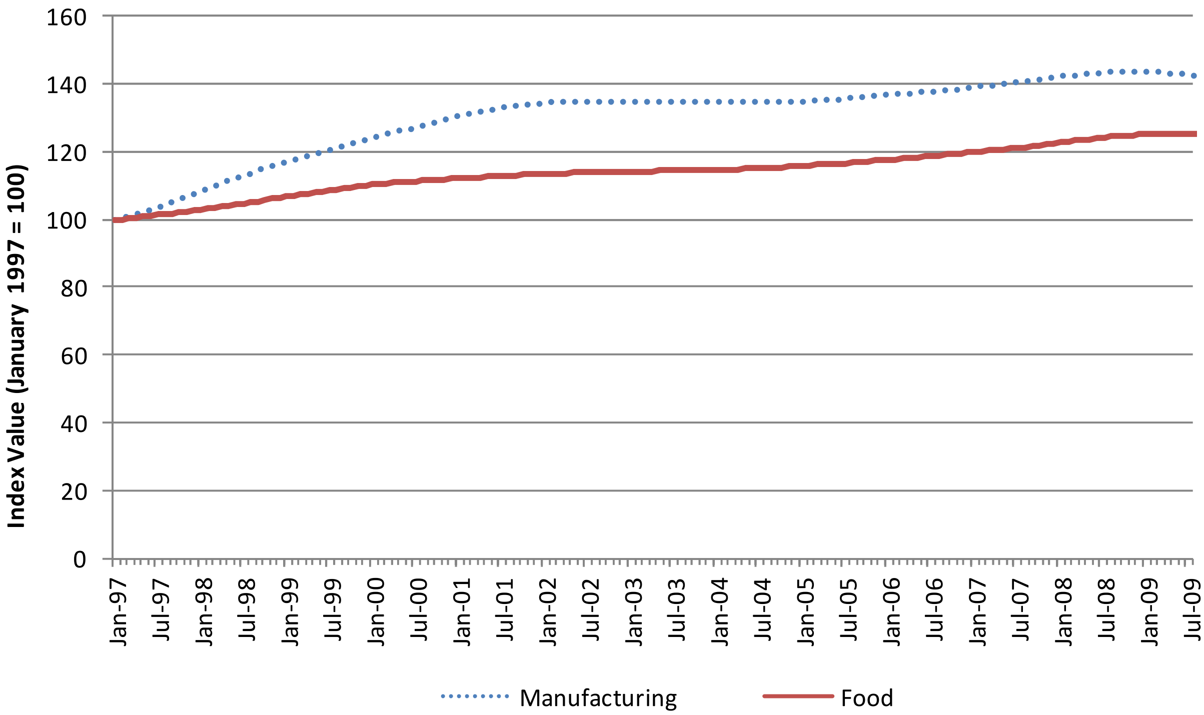

Figure 2-7. Capacity Trends in Food Manufacturing (NAICS 311)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Capacity." <http://www.federalreserve.gov/datadownload/>.

Table 2-7. Top Publicly Held U.S. Food Companies: 2007

	Sales ($millions)	% of Sales in North America
Kraft Foods Inc.	37,241	57.8%
Tyson Foods Inc.	26,900	90.0%
General Mills Inc.	12,442	82.9%
Sara Lee Corp.	12,278	53.8%
ConAgra Foods Inc.	12,028	89.2%
Smithfield Foods Inc.[a]	11,911	86.2%
Dean Foods Co.	11,822	>99.0%
Kellogg Co.[a]	11,776	66.1%
H.J. Heinz Co.	9,002	42.3%
Campbell Soup Co.	7,867	69.0%

[a] Percentage of sales in the United States is actually percentage of sales in North America.

Source: Graves, T. 2008. "Food and Nonalcoholic Beverages." *Standard and Poor's Industry Surveys*. 176(25).

For the industry as a whole, the number of corporations as well as the number of corporations with net income in the food manufacturing industry grew between 2004 and 2005. Although the overall number of companies continued to grow in 2006, the number of those with a positive net income declined along with profit margins and total receipts (Table 2-8).

Table 2-8. Corporate Income and Profitability for Food Manufacturing (NAICS 311)

	2004	2005	2006
Number of corporations	14,408	14,956	16,146
Number of corporations with net income	6,541	7,503	7,333
Total receipts (thousands)	$502,149,944	$504,944,378	$484,193,319
Business receipts (thousands)	$477,906,423	$465,369,666	$459,884,663
Before-tax profit margin	5.27%	10.09%	7.43%
After-tax profit margin	3.74%	7.62%	5.11%

Source: Internal Revenue Service, U.S. Department of Treasury. 2008a. "Corporation Source Book: Data File 2005." <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>; (January 14, 2009).

2.1.3.6 Size Distribution

The primary criterion for categorizing a business as small is number of employees, using definitions by the SBA for regulatory flexibility analyses. The data describing size standards are provided in Table 2-9. Over 80% of the NAICS industries within the food manufacturing industry use a cutoff of 500 employees. In 2002, enterprises with fewer than 500 employees accounted for 32% of employment and 23% of receipts within food manufacturing (Table 2-10).

2.1.3.7 Domestic Production

Between 1997 and early 2008, overall manufacturing production grew faster (34.88%) than the food manufacturing component (26.18%) (Figure 2-8). The food manufacturing industry has been less volatile, particularly during the recession of 2001 and the current economic downturn.

2.1.3.8 International Trade

In 2006, the United States regained a trade surplus in food manufacturing it had briefly lost during 2004 to 2005 (see Figure 2-9). The trade surplus in 2007 was over $4 billion. Both exports and imports have declined since their 2008 peak as a result of the global economic recession.

Table 2-9. Small Business Size Standards: Food Manufacturing (NAICS 311)

NAICS	Description	Employees
311111	Dog and Cat Food Manufacturing	500
311119	Other Animal Food Manufacturing	500
311211	Flour Milling	500
311212	Rice Milling	500
311213	Malt Manufacturing	500
311221	Wet Corn Milling	750
311222	Soybean Processing	500
311223	Other Oilseed Processing	1,000
311225	Fats and Oils Refining and Blending	1,000
311230	Breakfast Cereal Manufacturing	1,000
311311	Sugarcane Mills	500
311312	Cane Sugar Refining	750
311313	Beet Sugar Manufacturing	750
311320	Chocolate and Confectionery Manufacturing from Cacao Beans	500
311330	Confectionery Manufacturing from Purchased Chocolate	500
311340	Non-Chocolate Confectionery Manufacturing	500
311411	Frozen Fruit, Juice and Vegetable Manufacturing	500
311412	Frozen Specialty Food Manufacturing	500
311421	Fruit and Vegetable Canning3	3,500
311422	Specialty Canning	1,000
311423	Dried and Dehydrated Food Manufacturing	500
311511	Fluid Milk Manufacturing	500
311512	Creamery Butter Manufacturing	500
311513	Cheese Manufacturing	500
311514	Dry, Condensed, and Evaporated Dairy Product Manufacturing	500
311520	Ice Cream and Frozen Dessert Manufacturing	500
311611	Animal (except Poultry) Slaughtering	500
311612	Meat Processed from Carcasses	500
311613	Rendering and Meat By-product Processing	500
311615	Poultry Processing	500
311711	Seafood Canning	500
311712	Fresh and Frozen Seafood Processing	500
311811	Retail Bakeries	500
311812	Commercial Bakeries	500
311813	Frozen Cakes, Pies, and Other Pastries Manufacturing	500
311821	Cookie and Cracker Manufacturing	750
311822	Flour Mixes and Dough Manufacturing from Purchased Flour	500

(continued)

Table 2-9. Small Business Size Standards: Food Manufacturing (NAICS 311) (continued)

NAICS	Description	Employees
311823	Dry Pasta Manufacturing	500
311830	Tortilla Manufacturing	500
311911	Roasted Nuts and Peanut Butter Manufacturing	500
311919	Other Snack Food Manufacturing	500
311920	Coffee and Tea Manufacturing	500
311930	Flavoring Syrup and Concentrate Manufacturing	500
311941	Mayonnaise, Dressing and Other Prepared Sauce Manufacturing	500
311942	Spice and Extract Manufacturing	500
311991	Perishable Prepared Food Manufacturing	500
311999	All Other Miscellaneous Food Manufacturing	500

Source: U.S. Small Business Administration (SBA). 2008. "Table of Small Business Size Standards Matched to North American Industry Classification System Codes." Effective August 22, 2008. <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

Table 2-10. Distribution of Economic Data by Enterprise Size: Food Manufacturing (NAICS 311)

		Enterprises with:					
Variable	Total	1 to 20 Employees[a]	20 to 99 Employees	100 to 499 Employees	500 to 749 Employees	750 to 999 Employees	1,000 to 1,499 Employees
Firms	21,384	13,645	3,935	1,247	147	63	96
Establishments	25,698	13,719	4,254	1,951	370	211	319
Employment	1,443,766	85,850	156,158	218,041	67,104	30,099	72,262
Receipts ($millions)	$457,521	$12,665	$32,274	$56,661	$23,103	$10,007	$21,878
Receipts/firm ($thousands)	$21,395	$928	$8,202	$45,438	$157,163	$158,835	$227,898
Receipts/establishment ($thousands)	$17,804	$923	$7,587	$29,042	$62,440	$47,425	$68,584
Receipts/employment ($)	$316,894	$147,523	$206,678	$259,862	$344,286	$332,457	$302,762

[a] Excludes *Statistics of U.S. Businesses* (SUSB) employment category for zero employees. These entities only operated for a fraction of the year.

Source: U.S. Census Bureau. 2008. "Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002." <http://www.census.gov/csd/susb/download_susb02.htm>.

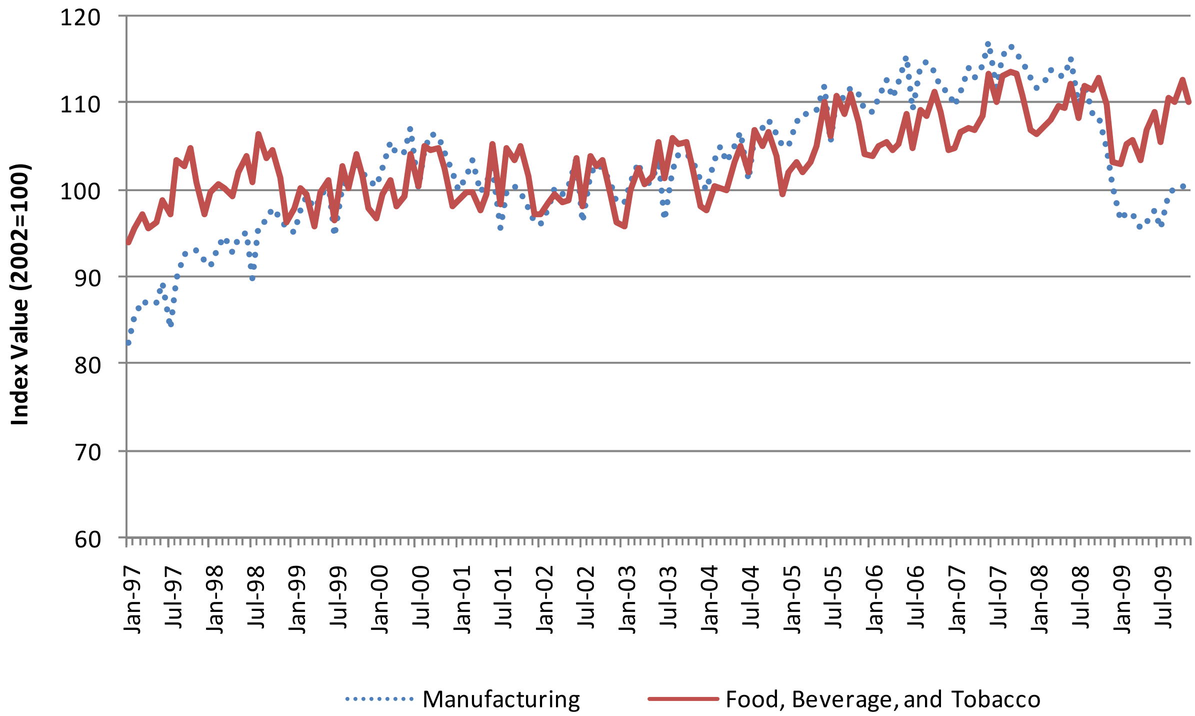

Figure 2-8. Industrial Production Trends in Food Manufacturing (NAICS 311)

Source: Federal Reserve Board. 2008. "Industrial Production and Capacity Utilization: Industrial Production." <http://www.federalreserve.gov/datadownload/>.

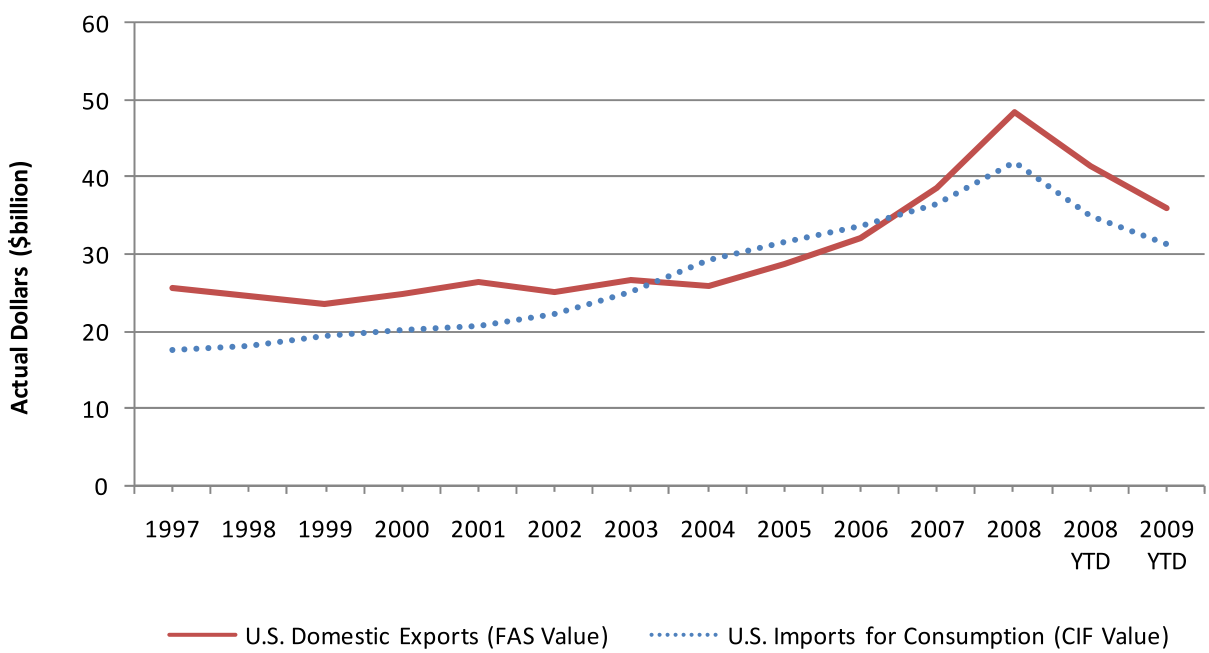

Figure 2-9. International Trade Trends in Food Manufacturing (NAICS 311)

Source: U.S. International Trade Commission. 2008. "U.S. Domestic Exports" & "U.S. Imports for Consumption." <http://dataweb.usitc.gov/scripts/user_set.asp>.

2.1.3.9 Market Prices

Prices of goods in food manufacturing have moved generally in line with prices in overall manufacturing (see Figure 2-10). Both indexes increased over 31% since between early 2003 and early 2008, a CAGR of 5.13%. This rise was followed by a marked decline in recent years along with the downward trend in prices throughout the economy.

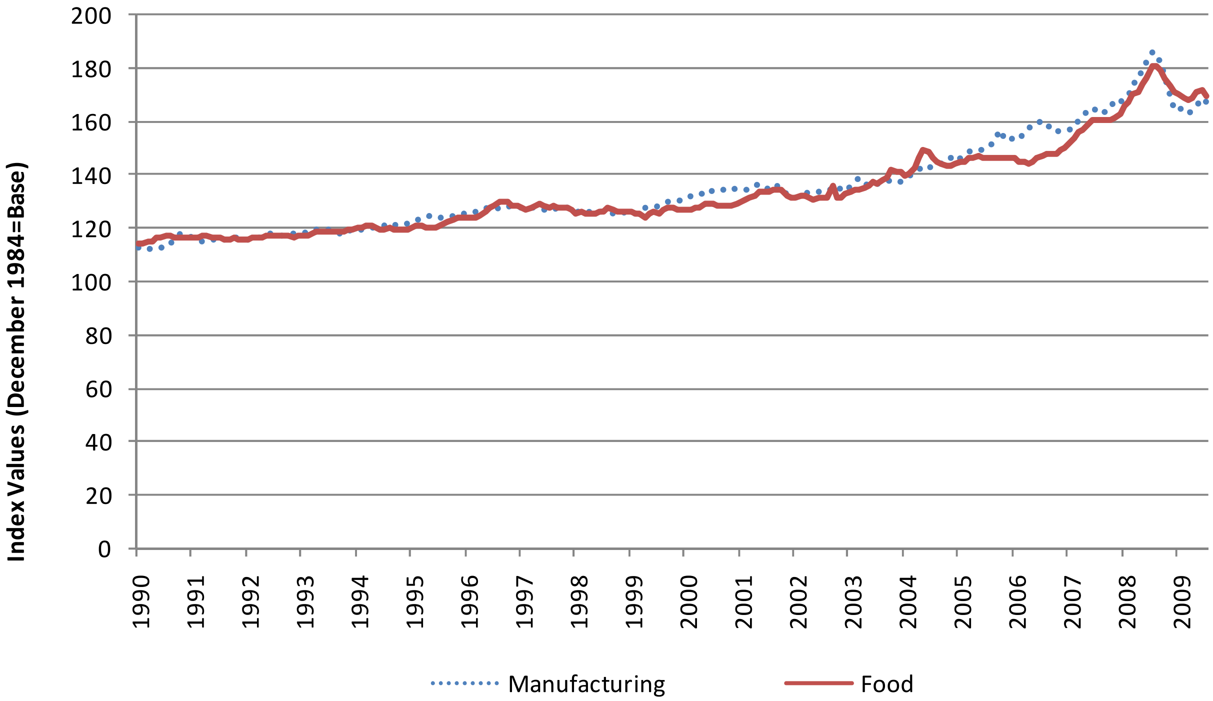

Figure 2-10. Producer Price Trends in Food Manufacturing (NAICS 311)

Source: U.S. Department of Labor; Bureau of Labor Statistics. 2010. "Producer Price Indexes." <http://www.bls.gov/pPI/Series Id: PCU311—311—Food Manufacturing & PCUOMFG–OMFG–Total Manufacturing>.

2.2 Wood Product Manufacturing

2.2.1 Introduction

According to a report by Standard & Poor's (2008), a number of factors are shaping the current economic environment for wood products, including, but not limited to, the housing slump, high input costs, low prices for lumber and other building materials, and a weak dollar. Table 2-11 shows that revenues in this industry are not entirely predictable, exhibiting a drop in shipment revenue between 1997 and 2002 but a rise back to within $5 billion of the 1997 value in 2006 and a decline to within $14 billion of the 2006 value in 2007.

Table 2-11. Key Statistics: Wood Product Manufacturing (NAICS 321)

	1997	2002	2006	2007
Shipments ($2007, millions)	$110,956	$102,721	$115,390	$101,879
Payroll ($2007, millions)	$17,959	$18,528	$18,623	$17,439
Employees	570,034	543,459	536,094	519,651
Establishments	17,367	17,255	NA	14,862

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." Accessed on December 27, 2009.

While total payroll dropped 3% over from 1997 to 2007, annual payroll per employee rose 6.5% because of the decline in the number of employees (Table 2-12). Shipments per employee grew 10.6% from 1997 to 2006 and dropped 8.9% from 2006 to 2007 (Table 2-12).

Table 2-12. Industry Data: Wood Product Manufacturing (NAICS 321)

Industry Data	1997	2002	2006	2007
Total shipments ($2007, millions)	$110,956	$102,721	$115,390	$101,879
Shipments per establishment ($thousands)	$25,613	$5,953	NA	$6,855
Average Shipments per employee ($2007)	$194,648	$189,014	$215,243	$196,053
Average Shipments per $ of payroll ($2007)	$6.18	$5.54	$6.20	$5.84
Average Annual payroll per employee ($2007)	$31,504	$34,093	$34,738	$33,558
Average Employees per establishment	33	31	NA	35

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." Accessed on December 27, 2009.

The U.S. Census Bureau categorizes this industry's facilities into three categories: "sawmills and wood preservation;" "veneer, plywood, and engineered wood product manufacturing;" and "other wood product manufacturing." These are further divided into the following types of facilities as defined by the Census Bureau:

- Sawmills and Wood Preservation
  - Sawmills and Wood Preservation (NAICS 32111): This industry comprises establishments primarily engaged in one or more of the following manufacturing activities: (a) sawing dimension lumber, boards, beams, timber, poles, ties, shingles, shakes, siding, and wood chips from logs or bolts; (b) sawing round wood poles, pilings, and posts and treating them with preservatives; and (c) treating wood sawed, planed, or shaped in other establishments with creosote or other preservatives to prevent decay and to protect against fire and insects. Sawmills may plane the rough lumber that they make with a planning machine to achieve smoothness and uniformity of size.
- Veneer, Plywood, and Engineered Wood Product Manufacturing
  - Veneer, Plywood, and Engineered Wood Product Manufacturing (NAICS 32121): This industry comprises establishments primarily engaged in one or more of the following manufacturing activities: (a) veneer and/or plywood, (b) engineered wood members, and (c) reconstituted wood products. This industry includes manufacturing plywood from veneer made in the same establishment or from veneer made in other establishments, and manufacturing plywood faced with non-wood materials, such as plastics or metal.
- Other Wood Product Manufacturing
  - Millwork (NAICS 32191): This industry comprises establishments primarily engaged in manufacturing hardwood and softwood cut stock and dimension stock (i.e., shapes); wood windows and wood doors; and other millwork including wood flooring. Dimension stock or cut stock is defined as lumber and worked wood products cut or shaped to specialized sizes. These establishments generally use woodworking machinery, such as jointers, planers, lathes, and routers to shape wood.
  - Wood Container and Pallet Manufacturing (NAICS 32192): This industry comprises establishments primarily engaged in manufacturing wood pallets, wood box shook, wood boxes, other wood containers, and wood parts for pallets and containers.
  - All Other Wood Product Manufacturing (NAICS 32199): This industry comprises establishments primarily engaged in manufacturing wood products (except establishments operating sawmills and wood preservation facilities; and establishments manufacturing veneer, plywood, engineered wood products, millwork, wood containers, or pallets).

Figure 2-11 shows that the industry proportion of the value of shipments for other wood product manufacturing (51%) was greater than the value of shipments for sawmills and wood preservation (27%) and veneer, plywood, and engineered wood products (22%). Figure 2-12 indicates that the majority of employees in this industry fell under other wood products (60%). Veneer, plywood, and engineered wood products had the same percentage (20%) of employees as sawmills and wood preservation (20%), even though it contributed to a lesser portion of the value of shipments.

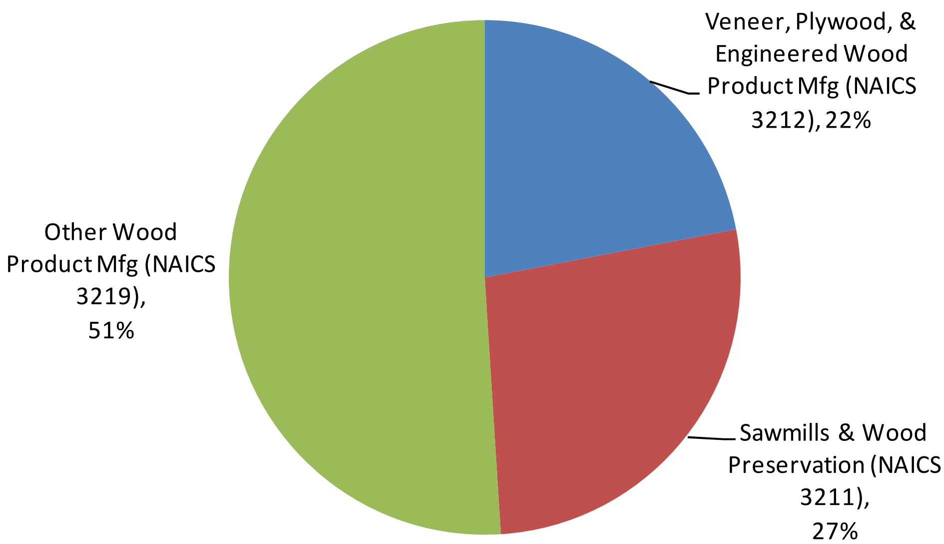

Figure 2-11. Distribution of Value of Shipments within Wood Product Manufacturing (NAICS 322): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." <http://factfinder.census.gov>. Accessed on December 27, 2009. [Source for 2007 numbers]

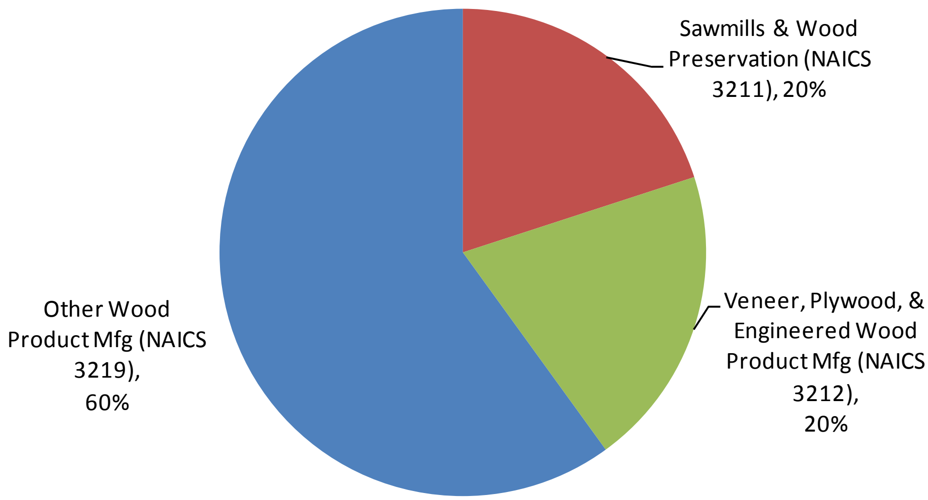

Figure 2-12. Distribution of Employment within Wood Product Manufacturing (NAICS 322): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007" Release Date: 12/22/09. <http://factfinder.census.gov>. Accessed on December 27, 2009.

2.2.2 Supply and Demand Characteristics

Next, we provide a broad overview of the supply and demand sides of the wood product manufacturing industry. We emphasize the economic interactions this industry has with other industries and people and identify the key goods and services used by the industry and the major uses and consumers wood products.

2.2.2.1 Goods and Services Used in Wood Product Manufacturing

In 2007, the cost of materials made up 59% of the total shipment value of goods in the wood product manufacturing industry (Table 2-13). Total compensation of employees represented 22% of the total value in 2007. Both the number of total shipments and the number of employees in this industry decreased between 2005 and 2007—the former by 14% and the latter by 3%.

The top 10 industry groups supplying inputs to the wood product industry accounted for 80% of the total intermediate inputs according to 2008 Bureau of Economic Analysis data (Table 2-14). The largest comes from the wood product industry itself. This is quite understandable, since the descriptions of the various industries within wood product manufacturing imply that they supply each other with products in order to add value and distribute their products to the broader market. The top five inputs are rounded out by forestry and logging products, wholesale trade, management of companies and enterprises, and truck transportation, which together make up 70% of the total cost of input.

Table 2-13. Costs of Goods and Services in Wood Product Manufacturing (NAICS 321) ($2007)

Industry Ratios	2005	Share	2006	Share	2007	Share
Total shipments (millions)	$118,705	100%	$115,390	100%	$102,002	100%
Total compensation (millions)	$23,327	20%	$23,306	20%	$22,513	22%
Annual payroll millions	$18,884	16%	$18,623	16%	$17,444	17%
Fringe benefits	$4,442	4%	$4,683	4%	$5,069	5%
Total employees	538,890		536,094		524,212	
Average compensation per employee	$43,286		$43,473		$42,947	
Total production workers' wages (millions)	$13,363	11%	$13,132	11%	$12,086	12%
Total production workers	431,569		432,315		417,471	
Total production hours (thousands)	911,332		887,613		837,074	
Average production wages per hour ($2007)	$15		$15		$14	
Total cost of materials (thousands)	$71,808	60%	$69,892	61%	$60,682	59%
Materials, parts, packaging	$65,319	55%	$63,499	55%	$54,462	53%
Purchased electricity	$1,530	1%	$1,625	1%	$1,446	1%
Purchased fuel	$810	1%	$835	1%	$843	1%
Other	$4,149	3%	$3,933	3%	$3,931	4%

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment: using American FactFinder; "Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007." Accessed on December 27, 2009.

2.2.2.1.1 Energy. The Department of Energy (DOE) categorizes wood product manufacturing (NAICS 321) as a non-energy-intensive industry. The 2008 Annual Energy Outlook predicts that the wood product industry will be one of five (out of eight) non-energy-intensive industries experiencing positive average growth of delivered energy consumption between 2006 and 2030 (DOE, 2008).

Table 2-14. Key Goods and Services Used in Wood Product Manufacturing (NAICS 321) ($2007, millions)

Description	BEA Commodity Code	Wood Products
Wood products	3210	$20,989
Forestry and logging products	1130	$18,914
Wholesale trade	4200	$5,417
Management of companies and enterprises	5500	$2,853
Truck transportation	4840	$2,542
Electric power generation, transmission, and distribution	2211	$1,388
Other fabricated metal products	332B	$1,310
Nonmetallic mineral products	3270	$1,110
Real estate	5310	$799
All other administrative and support services	561A	$748
Architectural and structural metal products	3323	$725
Rail transportation	4820	$723
Other inputs		$14,650
Total intermediate inputs	T005	$72,169

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

Table 2-15 shows that total energy use between 1998 and 2002. Figure 2-13 shows that electrical power use decreased, since 2000.

2.2.2.2 Uses and Consumers

Table 2-16 shows that three of the top four consumers of wood products are represented by the construction sector of the economy (NAICS 23). New residential construction, new nonresidential construction, and maintenance and repair construction consume 35% of the total commodity output in this industry. The top 10 consumers of wood products make up 54% of the demand for wood products. Although many of the top consumers deal with construction, repair, or real estate services, other types of consumers, such as food services and drinking places, rail transportation, plastics and rubber products manufacturing, and other, use these products.

Table 2-15. Energy Used in Wood Product Manufacturing (NAICS 321)

Fuel Type	1998	2002	2006
Net electricity[a] (million kWh)	21,170	20,985	26,723
Residual fuel oil (million bbl)	*	*	1
Distillate fuel oil[b] (million bbl)	2	2	3
Natural gas[c] (billion cu ft)	71	56	84
LPG and NGL[d] (million bbl)	1	1	1
Coal (million short tons)	*	*	Q
Coke and breeze (million short tons)	—	—	*
Other[e] (trillion BTU)	341	229	228
Total (trillion BTU)	504	375	445

[a] Net electricity is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from on-site cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal).

[b] Distillate fuel oil includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[c] Natural gas includes natural gas obtained from utilities, local distribution companies, and any other supplier(s), such as independent gas producers, gas brokers, marketers, and any marketing subsidiaries of utilities.

[d] Examples of liquefied petroleum gases (LPGs) are ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas liquids (NGLs).

[e] Other includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power.

* Estimate less than 0.5.
Q = Withheld because relative standard error is greater than 50%.

Sources: U.S. Department of Energy, Energy Information Administration. 2007a. “2002 Energy Consumption by Manufacturers—Data Tables.” Tables 3.2 and N3.2. <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>. Washington, DC: DOE.

U.S. Department of Energy, Energy Information Administration. 2007b. “2006 Energy Consumption by Manufacturers—Data Tables.” Tables 3.1. <http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html>. [Source for 2006 numbers]

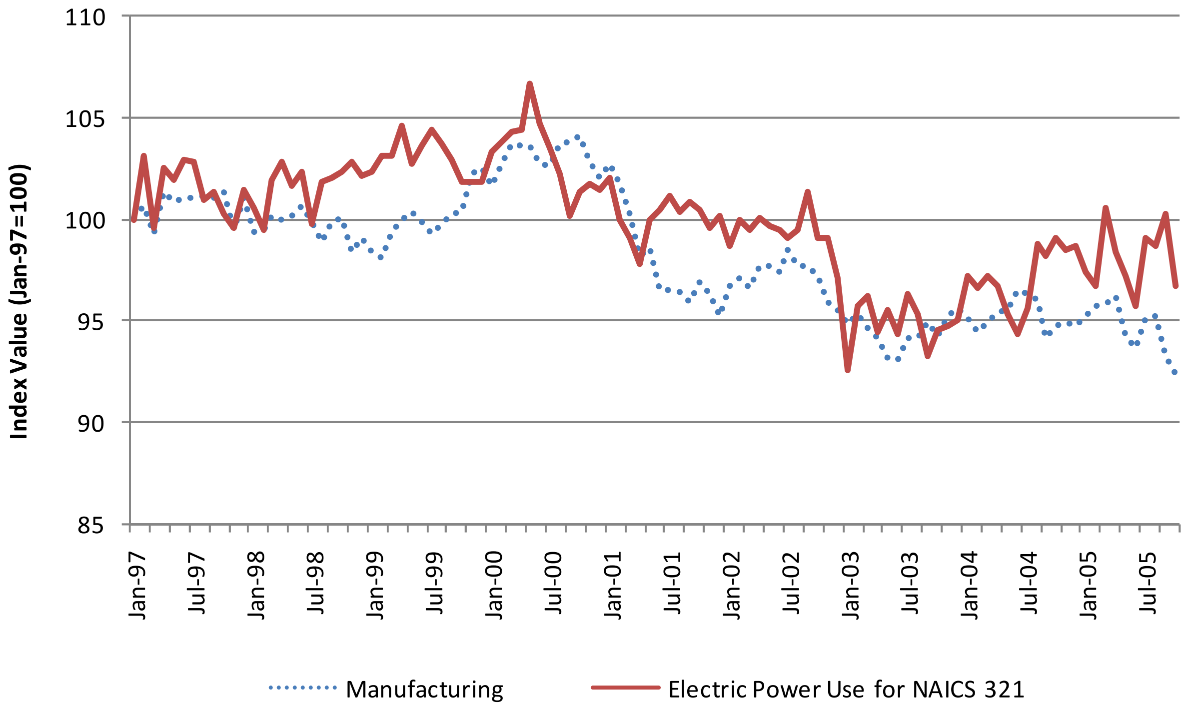

Figure 2-13. Electrical Power Use Trends in the Wood Product Manufacturing Industry (NAICS 321): 1997–2005

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Electric Power Use: Manufacturing and Mining." <http://www.federalreserve.gov/datadownload/>

2.2.3 Firm and Market Characteristics

This section describes geographic, production, and market data. These data provide the basis for further analysis, including regulatory flexibility analyses, as well as a complete picture of the recent historical trends of production and pricing.

2.2.3.1 Location

As Figure 2-14 illustrates, the states with the largest number of wood product manufacturing establishments are dispersed throughout the country, with a significant concentration of establishments in the northeastern states. Other states with many establishments include California, Texas, and North Carolina.

Table 2-16. Demand by Sector: Wood Product Manufacturing (NAICS 321) ($2007, millions)

Sector	BEA Code	3210 Wood Products
New residential construction	2302	$19,997
New nonresidential construction	2301	$11,854
Furniture and related product manufacturing	3370	$8,197
Maintenance and repair construction	2303	$4,048
Motor vehicle body, trailer and parts manufacturing	336A	$2,516
Real estate	5310	$2,335
Food services and drinking places	7220	$2,307
Other miscellaneous manufacturing	3399	$1,311
Wholesale trade	4200	$1,284
Rail transportation	4820	$1,138
Retail trade	4A00	$1,047
Plastics and rubber products manufacturing	3260	$877
General state and local government use	S007	$3,116
Owner occupied dwelling	S008	$11,209
Private fixed investment	F020	$7,933
Exports of goods and services	F040	$3,978
Total final uses (gross domestic product [GDP])	T004	$3,719
Total commodity output	T007	$101,753

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

2.2.3.2 Production Capacity and Utilization

Capacity utilization of the wood product manufacturing industry has been experiencing capacity utilization increases and declines with more extreme fluctuations than those of all manufacturing industries combined. The decline in wood product manufacturing is similar to total manufacturing between 1997 and 2002. However, capacity utilization in total manufacturing, which peaked in 2006, started increasing at a faster rate than wood product manufacturing, but decreased sharply after its peak. Wood product manufacturing experienced its own rapid decrease in capacity utilization between 2007 and 2009, though not at the same rate as total manufacturing (Figure 2-15).

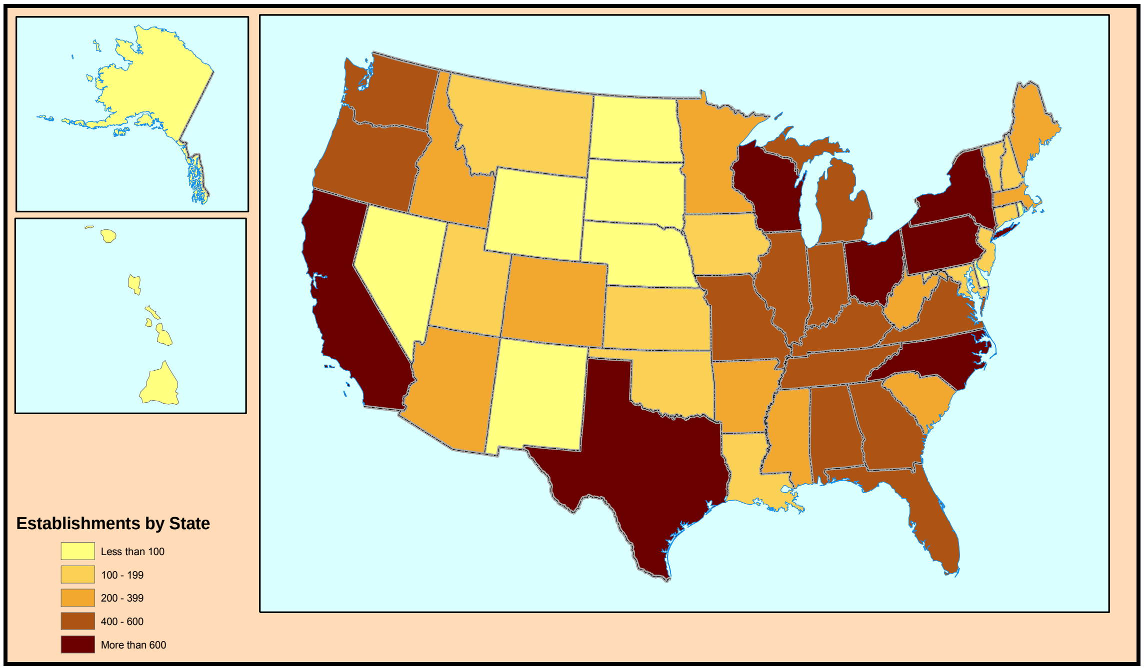

Figure 2-14. Establishment Concentration in the Wood Product Manufacturing Industry (NAICS 321): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.2.3.3 Employment

California has the largest number of employees in the wood product manufacturing industry with over 39,000 reported in the 2002 census followed by over 32,000 in Oregon (Figure 2-16). The states with the highest number of employees do not directly correlate with the states with the highest number of establishments. States such as Indiana, Georgia, Arkansas, and Oregon had fewer than 600 establishments, as shown in Figure 2-14, but had more than 20,000 employees, whereas states such as Ohio and New York had fewer than 20,000 employees but more than 600 establishments.

2.2.3.4 Plants and Capacity

While the capacity of the manufacturing sector has been growing consistently since 1997, the wood product manufacturing industry has experienced inconsistent growth. After a small amount of growth in capacity between 1997 and 2001, the wood product manufacturing industry's capacity dipped between 2002 and 2005 but has been growing at a slow rate since then though it started to dip again in 2008 and 2009 (Figure 2-17).

Figure 2-15. Capacity Utilization Trends in the Wood Product Manufacturing Industry (NAICS 321)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Capacity Utilization." <http://www.federalreserve.gov/datadownload/>

2.2.3.5 Firm Characteristics

In 2006, the top 10 paper and forest product companies produced over $75 billion in sales, with the top two companies—International Paper and Weyerhaeuser—generating nearly $22 billion each (Table 2-17). The top two companies' revenue consists of 58% of the revenue of the top 10 companies in Standard & Poor's (S&P's) list (Benwart, 2006). Although these numbers do not exclusively reflect wood products, they do convey the market environment in which firms in this sector compete.

2.2.3.6 Size Distribution

The primary criterion for categorizing a business as small is the number of employees, using definitions by the SBA for regulatory flexibility analyses. According to SUSB reports for 2002, small companies were the recipients of the majority of receipts in 2002; 53% of receipts were generated by companies with fewer than 500 employees (Table 2-18). The number of employees in the small business cutoff is 500 employees for all subindustries in the wood product manufacturing industry (Table 2-19).

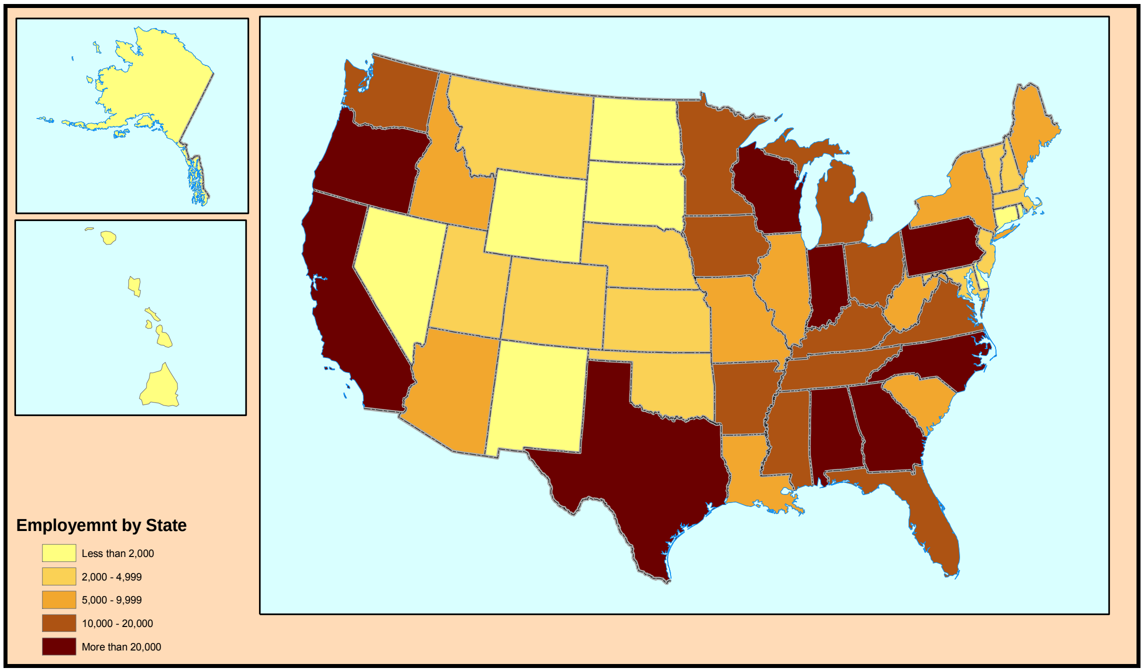

Figure 2-16. Employment Concentration in the Wood Product Manufacturing Industry (NAICS 321): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.2.3.7 Domestic Production

Similar to industry capacity rates, industry production rates for wood product manufacturing have decreased since 2006 compared to the steady increase in production for the manufacturing sector since 1997 (Figure 2-18). Similar to capacity utilization trends (Figure 2-16), the index shows a faster rate of decline for wood products than the entire manufacturing sector.

2.2.3.8 International Trade

Since 1997, the wood product manufacturing industry has contributed to an increasing trade deficit (Figure 2-16). The value of imports has fluctuated greatly since 1997; however, exports have remained fairly constant, with seasonal changes, since 1997.

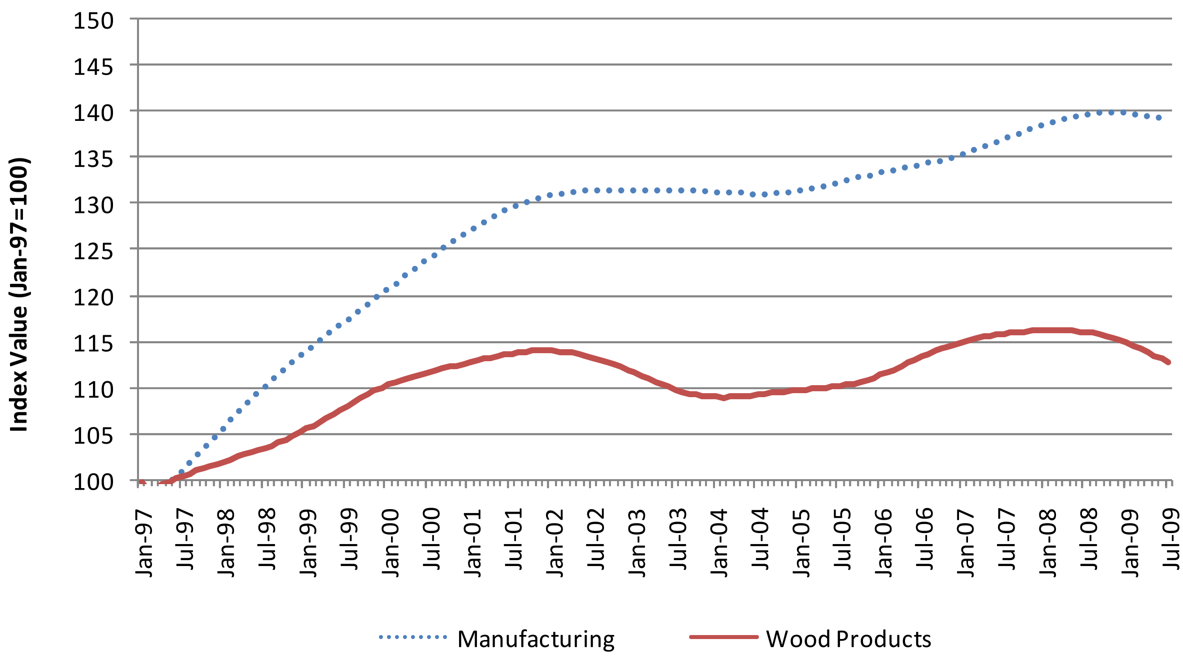

Figure 2-17. Capacity Trends in the Wood Product Manufacturing Industry (NAICS 321)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Capacity." <http://www.federalreserve.gov/datadownload/>.

Table 2-17. Largest U.S. Paper and Forest Products Companies: 2006

Company	Revenues ($millions)[a]
International Paper	21,995
Weyerhaeuser	21,896
Smurfit-Stone	7,157
MeadWestvaco	6,530
Temple-Inland	5,558
Bowater	3,530
Grief Inc.	2,628
Louisiana-Pacific	2,235
Packaging Corp.	2,187
Plum Creek	1,627

[a] Includes revenues from operations other than paper and forest products in certain cases.

Source: Benwart, S.J. 2006. "Paper & Forest Products." *Standard and Poor's Industry Surveys*. 176(28).

Table 2-18. Distribution of Economic Data by Enterprise Size: Wood Product Manufacturing (NAICS 321)

		Enterprises with					
Variable	Total	1 to 20 Employees[a]	20 to 99 Employees	100 to 499 Employees	500 to 749 Employees	750 to 999 Employees	1,000 to 1,499 Employees
Firms	15,198	9,740	3,280	791	63	27	30
Establishments	17,052	9,758	3,482	1,271	166	91	133
Employment	534,011	65,423	132,612	118,910	19,784	11,944	18,533
Receipts ($thousands)	$88,649	$8,204	$18,276	$19,717	$3,192	$1,902	$3,118
Receipts/firm ($thousands)	$5,833	$842	$5,572	$24,927	$50,673	$70,453	$103,927
Receipts/establishment ($thousands)	$5,199	$841	$5,249	$15,513	$19,231	$20,904	$23,442
Receipts/employment ($)	$166,006	$125,393	$137,818	$165,814	$161,363	$159,262	$168,231

[a] Excludes *Statistics of U.S. Businesses* (SUSB) employment category for zero employees. These entities only operated for a fraction of the year.

Source: U.S. Census Bureau. 2008. “Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002.” <http://www.census.gov/csd/susb/download_susb02.htm>.

Table 2-19. Small Business Size Standards: Wood Product Manufacturing (NAICS 321)

NAICS	NAICS Description	Employees
321113	Sawmills	500
321114	Wood Preservation	500
321211	Hardwood Veneer and Plywood Manufacturing	500
321212	Softwood Veneer and Plywood Manufacturing	500
321213	Engineered Wood Member (except Truss) Manufacturing	500
32121	Truss Manufacturing	500
321219	Reconstituted Wood Product Manufacturing	500
321911	Wood Window and Door Manufacturing	500
321912	Cut Stock, Resawing Lumber, and Planing	500
321918	Other Millwork (including Flooring)	500
321920	Wood Container and Pallet Manufacturing	500
321991	Manufactured Home (Mobile Home) Manufacturing	500
321992	Prefabricated Wood Building Manufacturing	500
321999	All Other Miscellaneous Wood Product Manufacturing	500

Source: U.S. Small Business Administration (SBA). 2008. "Table of Small Business Size Standards Matched to North American Industry Classification System Codes." Effective August 22, 2008. <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

2.2.3.9 Market Prices

Prices of goods in the wood product manufacturing industry have remained roughly the same since 2005. The prices for the entire manufacturing sector increased between 2003 and 2008 but have decreased since August 2008. Producer price indices (PPIs) show that producer prices for wood products increased by 6% from 2004 to 2007 (Figure 2-20).

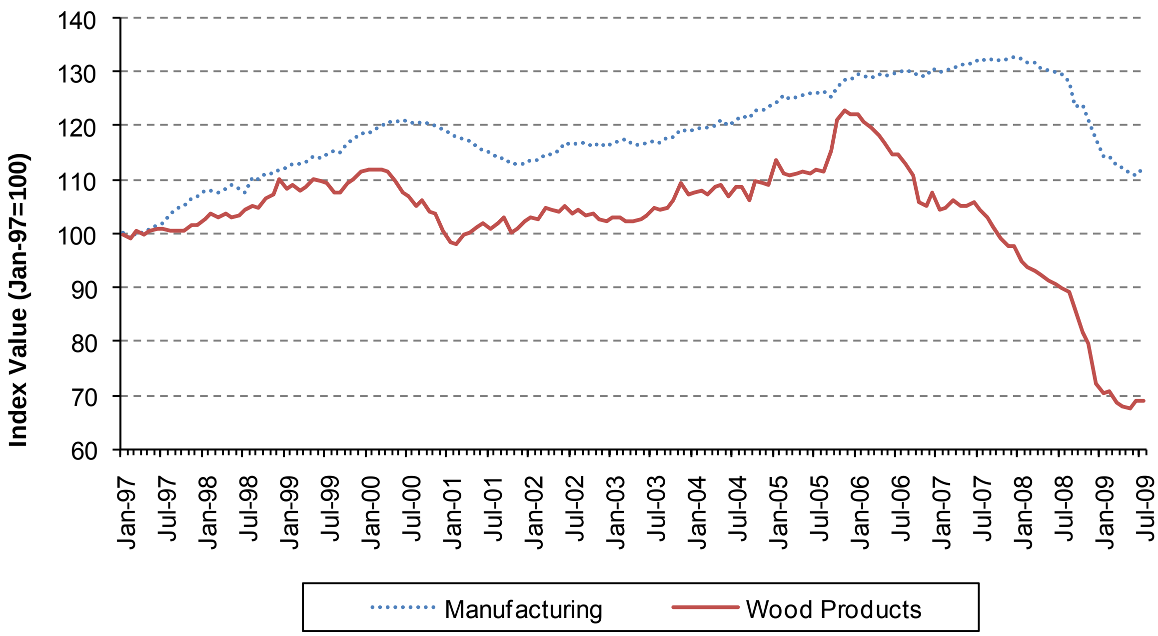

Figure 2-18. Industrial Production Trends in the Wood Product Manufacturing Industry (NAICS 321): 1997–2009

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Production." <http://www.federalreserve.gov/datadownload/>.

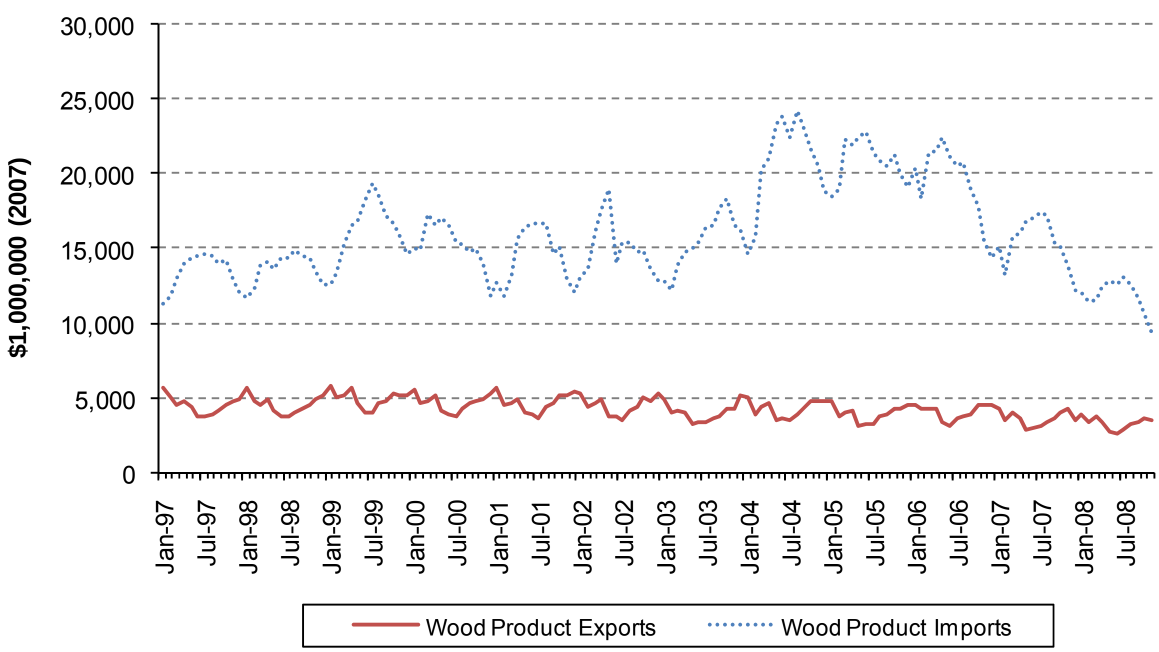

Figure 2-19. International Trade Trends in the Wood Product Manufacturing Industry (NAICS 321)]

Source: U.S. International Trade Commission. 2008. "U.S. Domestic Exports" & "U.S. Imports for Consumption." <http://dataweb.usitc.gov/scripts/user_set.asp>.

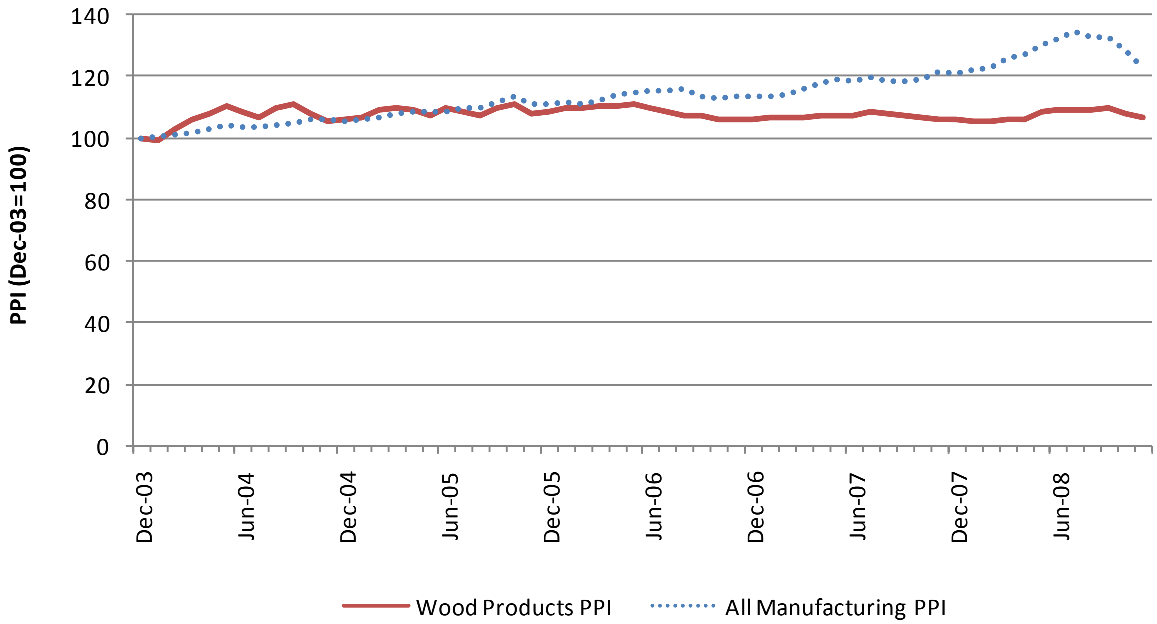

Figure 2-20. Producer Price Trends in the Wood Product Manufacturing Industry (NAICS 321)

Source: U.S. Bureau of Labor Statistics (BLS). 2009a. "Producer Price Index." Series ID: PCU321—321—& PCUOMFG—OMFG—. <http://www.bls.gov/ppi/home.htm>. Accessed on January 8, 2010.

2.3 Paper Manufacturing

2.3.1 Introduction

The paper manufacturing subsector is an essential component of all business operations worldwide. Broadly speaking, paper and paperboard are manufactured by converting timber or other recycled material into products such as printing and writing papers, newsprint, tissue, and containerboard (Benwart, 2006). The subsector has been experiencing a decline in shipments as of late. From 1997 to 2007, shipments in the industry declined 7%, and employment declined by 27% (Table 2-21). While total payroll dropped 26% over this time, annual payroll per employee rose 2% from 1997 to 2007 because of the decline in the number of employees (Table 2-20). Shipments per employee grew 28% from 1997 to 2007, with much of that growth taking place between 2002 and 2006 (Table 2-21).

Table 2-20. Key Statistics: Paper Manufacturing (NAICS 322)

	1997	2002	2006	2007
Shipments ($2007, millions)	$188,496	$175,983	$174,887	$175,806
Payroll ($2007, millions)	$27,983	$24,561	$21,188	$20,804
Employees	574,274	489,367	414,049	416,886
Establishments	5,868	5,495	NA	4,803

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." Accessed on December 28, 2009. [Source for 2007 numbers]

Table 2-21. Industry Data: Paper Manufacturing (NAICS 322)

Industry Data	1997	2002	2006	2007
Total shipments ($2007, millions)	$188,496	$175,983	$174,887	$175,806
Shipments per establishment ($2007, thousands)	$32,123	$32,026	NA	$36,603
Average Shipments per employee ($2007)	$328,233	$359,614	$422,381	$421,712
Average Shipments per $ of payroll ($2007)	$6.74	$7.17	$8.25	$8.45
Average Annual payroll per employee ($2007)	$48,727	$50,189	$51,174	$49,904
Average Employees per establishment	98	89	NA	87

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." <http://factfinder.census.gov>. Accessed on December 28, 2009. [Source for 2007 numbers]

The U.S. Census Bureau categorizes this industry's facilities into two categories: pulp, paper, and paperboard manufacturing and converted paper product manufacturing. These are further divided into the following types of facilities as defined by the Census Bureau (2001):

- Pulp, Paper, and Paperboard:
  - Pulp Mills (NAICS 32211): This industry comprises establishments primarily engaged in manufacturing pulp without manufacturing paper or paperboard. The pulp is made by separating the cellulose fibers from the other impurities in wood or other materials, such as used or recycled rags, linters, scrap paper, and straw.
  - Paper Mills (NAICS 32212): This industry comprises establishments primarily engaged in manufacturing paper from pulp. These establishments may manufacture or purchase pulp. In addition, the establishments may convert the paper they make. The activity of making paper classifies an establishment into this industry regardless of the output.
  - Paperboard Mills (NAICS 32213): This industry comprises establishments primarily engaged in manufacturing paperboard from pulp. These establishments may manufacture or purchase pulp. In addition, the establishments may also convert the paperboard they make.
- Converted Paper Products:
  - Paperboard Containers Manufacturing (NAICS 32221): This industry comprises establishments primarily engaged in converting paperboard into containers without manufacturing paperboard. These establishments use corrugating, cutting, and shaping machinery to form paperboard into containers. Products made by these establishments include boxes; corrugated sheets, pads, and pallets; paper dishes; and fiber drums and reels.
  - Paper Bag and Coated and Treated Paper Manufacturing (NAICS 32222): This industry comprises establishments primarily engaged in one or more of the following manufacturing activities: cutting and coating paper and paperboard; cutting and laminating paper and paperboard and other flexible materials (except plastics film to plastics film); bags or multiwall bags or sacks of paper, metal foil, coated paper, or laminates or coated combinations of paper and foil with plastics film; laminated aluminum and other converted metal foils from purchased foils; and surface coating paper or paperboard.
  - Stationary Product Manufacturing (NAICS 32223): This industry comprises establishments primarily engaged in converting paper or paperboard into products used for writing, filing, art work, and similar applications.
  - Other Converted Paper Products (NAICS 32229): This industry comprises establishments primarily engaged in one of the following manufacturing activities:
    - converting paper and paperboard into products (except containers, bags, coated and treated paper and paperboard, and stationery products), or

- converting pulp into pulp products, such as disposable diapers, or molded pulp egg cartons, food trays, and dishes.

Figure 2-21 shows that the value of shipments for converted paper products was 54% of the value of all paper products in 2007, while the value of shipments for pulp, paper, and paperboard products was 46%. Figure 2-22 indicates that 70% of industry employees worked in the converted paper product category of the industry due to the labor intensive aspects of those facilities.

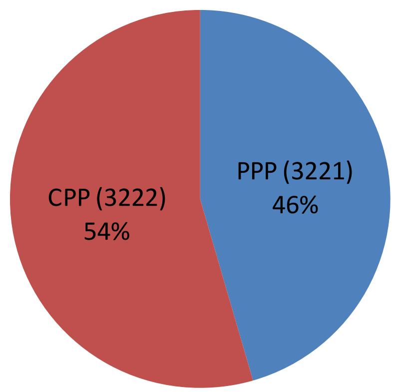

Figure 2-21. Distribution of Value of Shipments within Paper Manufacturing (NAICS 322): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder: "Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007." Accessed on December 28, 2009.

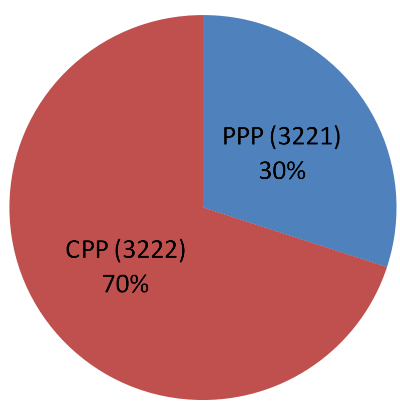

Figure 2-22. Distribution of Employment within Paper Manufacturing (NAICS 322): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007." <http://factfinder.census.gov>. Accessed on December 28, 2009.

2.3.2 Supply and Demand Characteristics

Next, we provide a broad overview of the supply and demand sides of the paper manufacturing industry. We emphasize the economic interactions this industry has with other industries and people and identify the key goods and services used by the industry and the major uses and consumers of paper manufacturing products.

2.3.2.1 Goods and Services Used in Paper Manufacturing

In 2007, the cost of materials made up 53% of the total shipment value of goods in the paper manufacturing industry (Table 2-22). Total compensation of employees represented 15% of the total value in 2007, down from 17% in 2005. The total number of employees dropped by 2%, between 2005 and 2007, while shipments increased by 3% in the same period.

The top 10 industry groups supplying inputs to the paper manufacturing subsector accounted for 70% of the total intermediate inputs according to 2008 Bureau of Economic Analysis (BEA) data (Table 2-23). Inputs for pulp, paper, and paperboard products are notably different from inputs for converted paper products because the NAICS 3221 group represents the initial step in the paper manufacturing process; thus, its inputs include more raw resources such as wood products, forestry and logging products, natural gas, and electricity. This becomes evident when observing inputs for converted paper products: 49% of the cost of inputs comes from pulp, paper, and paperboard products.

2.3.2.1.1 Energy. The Department of Energy (DOE) categorizes paper manufacturing (NAICS 322) as an energy-intensive subsector. The 2008 Annual Energy Outlook predicts that the paper-producing subsector will be one of four subsectors experiencing positive average growth of delivered energy consumption between 2006 and 2030 (DOE, 2008).

Energy generation from the recovery boiler is often insufficient for total plant needs, so facilities augment recovery boilers with fossil fuel–fired and wood waste–fired boilers (hogged fuel) to generate steam and often electricity. Industry wide, the use of pulp wastes, bark, and other papermaking residues supplies 58% of the energy requirements of pulp and paper companies (EPA, 2002).

Likewise, Table 2-24 shows that total energy use decreased between 1998 and 2006 by 14%. Figure 2-24 indicates that total electrical power use changed sporadically between 2002 and 2004 but decreased consistently and rapidly after 2004.

Table 2-22. Costs of Goods and Services Used in the Paper Manufacturing Industry (NAICS 322)

Variable	2005	Share	2006	Share	2007	Share
Total shipments ($2007, millions)	$171,477	100%	$174,887	100%	$176,018	100%
Total compensation ($2007, millions)	$28,846	17%	$27,791	16%	$27,150	15%
Annual payroll	$21,792	13%	$21,188	12%	$20,804	12%
Fringe benefits	$7,054	4%	$6,603	4%	$6,346	4%
Total employees	426,748		414,049		417,367	
Average compensation per employee	$67,596		$67,121		$65,051	
Total production workers wages ($2007, millions)	$14,965	9%	$14,689	8%	$14,190	8%
Total production workers	331,228		321,684		321,937	
Total production hours (thousands)	716,963		691,134		680,732	
Average production wages per hour	$21		$21		$21	
Total cost of materials ($2007, thousands)	$91,897	54%	$92,452	53%	$94,029	53%
Materials, parts, packaging	$77,494	45%	$78,202	45%	$79,984	45%
Purchase electricity	$3,788	2%	$3,841	2%	$3,780	2%
Purchased fuel ($2007)	$5,537	3%	$5,509	3%	$5,511	3%
Other	$5,078	3%	$4,901	3%	$4,755	3%

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007." <http://factfinder.census.gov>. Accessed on December 28, 2009. [Source for 2007 numbers]

Table 2-23. Key Goods and Services Used in the Paper Manufacturing Industry (NAICS 322) ($millions, $2007)

Description	BEA Code	NAICS 3221 Pulp, Paper, and Paperboard	NAICS 3222 Converted Paper Products	Total
Pulp, paper, and paperboard	3221	$4,155	$30,448	$34,603
Wholesale trade	4200	$3,916	$6,356	$10,273
Management of companies and enterprises	5500	$3,154	$3,838	$6,993
Forestry and logging products	1130	$5,389	$0	$5,389
Basic chemicals	3251	$3,734	$263	$3,997
Electric power generation, transmission, and distribution	2211	$2,690	$913	$3,603
Wood products	3210	$3,450	$33	$3,484
Converted paper products	3222	$1,415	$1,745	$3,159
Natural gas distribution	2212	$2,680	$345	$3,026
Truck transportation	4840	$1,428	$1,571	$2,999
Total intermediate inputs	T005	$47,835	$62,690	$110,525

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

Table 2-24. Energy Used in Paper Manufacturing (NAICS 322)

Fuel Type	1998	2002	2006
Net electricity[a] (million kWh)	70,364	65,503	72,518
Residual fuel oil (million bbl)	24	16	15
Distillate fuel oil[b] (million bbl)	2	2	2
Natural gas[c] (billion cu ft)	570	490	461
LPG and NGL[d] (million bbl)	1	2	1
Coal (million short tons)	12	11	10
Coke and breeze (million short tons)	—	*	—
Other[e] (trillion BTU)	1,476	1,276	1,303
Total (trillion BTU)	2,744	2,361	2,354

[a] Net electricity is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from on-site cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal).

[b] Distillate fuel oil includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[c] Natural gas includes natural gas obtained from utilities, local distribution companies, and any other supplier(s), such as independent gas producers, gas brokers, marketers, and any marketing subsidiaries of utilities.

[d] Examples of liquefied petroleum gases (LPG) are ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas liquids (NGLs).

[e] Other includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power.

* Estimate less than 0.5.

Sources: U.S. Department of Energy, Energy Information Administration. 2007a. “2002 Energy Consumption by Manufacturers—Data Tables.” Tables 3.2 and N3.2. <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>. Washington, DC: DOE.

U.S. Department of Energy, Energy Information Administration. 2007b. “2006 Energy Consumption by Manufacturers—Data Tables.” Table 3.1. <http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html>. Accessed on December 27, 2009. [Source for 2006 numbers]

Over the last 25 years, the pulp and paper subsector has changed its energy generation methods from fossil fuels to a greater use of processes such as increases in the use of wood wastes in place of fuel (Table 2-25). During the 1972–1999 period, the proportion of total industry power generated from the combination of woodroom wastes, spent liquor solids, and other self-generated methods increased from about 41% to about 56%, while coal, fuel oil, and natural gas use decreased from about 54% to about 36% (EPA, 2002).

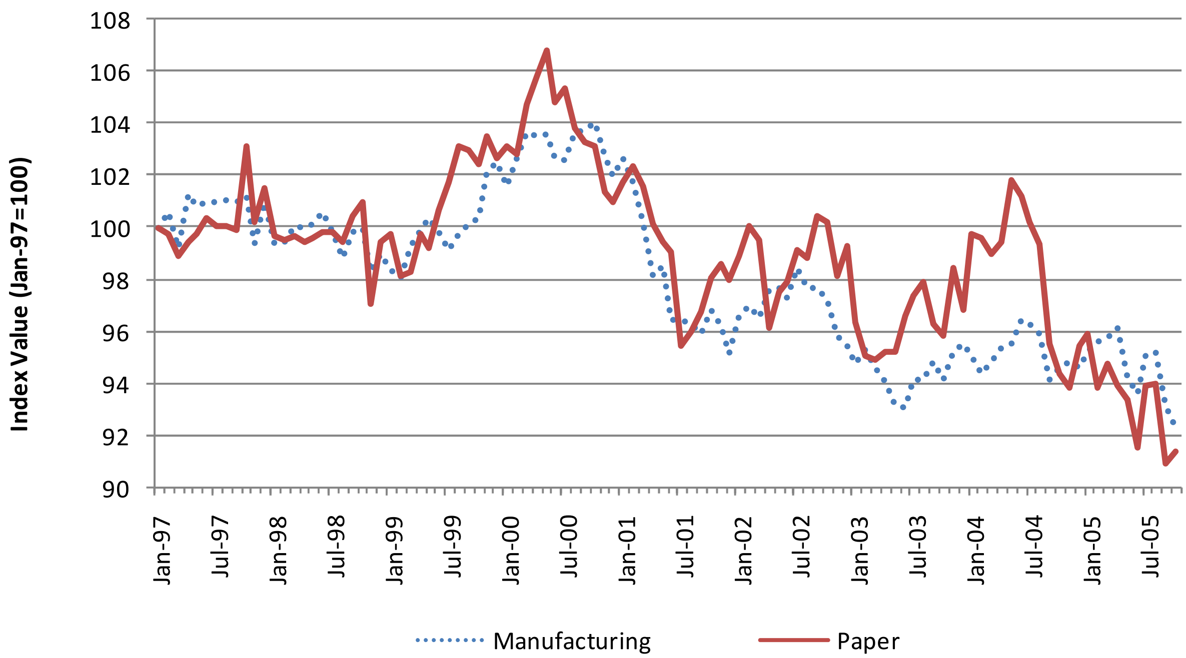

Figure 2-23. Electrical Power Use Trends in the Paper Manufacturing Industry: 1997–2005

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Electric Power Use: Manufacturing and Mining." <http://www.federalreserve.gov/datadownload/>.

Table 2-25. Estimated Energy Sources for the U.S. Pulp and Paper Industry

Energy Source	1972	1979	1990	1999
Purchased steam	5.4%	6.7%	7.3%	1.5%
Coal	9.8%	9.1%	13.7%	12.5%
Fuel oil	22.3%	19.1%	6.4%	6.3%
Natural gas	21.5%	17.8%	16.4%	17.6%
Other purchased energy	—	—	—	6.7%
Waste wood and wood chips (hogged fuel) and bark	6.6%	9.2%	15.4%	13.5%
Spent liquor solids	33.7%	37.3%	39.4%	40.3%
Other self-generated power	0.6%	0.8%	1.2%	1.6%

Source: U.S. Environmental Protection Agency. 2002. "Profile of the Pulp and Paper Industry." Sector Notebook Project. <http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/index.html>.

2.3.2.2 Uses and Consumers

Products manufactured in the NAICS groups 3221 and 3222 have different, but complementary, consumer profiles. NAICS 3221 supplies a significant portion of NAICS 3222 demand (37% of total commodity output). Both industries specialize in products with intermediate uses, with an average of 92% of sales between the two going toward this purpose. NAICS 3222 has a very diverse assortment of subsector groups from which it receives demand. Food manufacturing makes up 21% of the demand, making members of this industry the largest consumer of converted paper products (Table 2-26). Pulp, paper, and paperboard products have a large trade deficit, while converted paper products have a very small trade surplus.

Table 2-26. Demand by Sector: Paper Manufacturing Industry (NAICS 322) ($millions, $2007)

Sector	BEA Code	3221 Pulp, Paper, and Paperboard	3222 Converted Paper Products	Total
Converted paper product manufacturing	3222	$30,448	$1,745	$32,193
Food manufacturing	3110	$638	$18,782	$19,421
Printing and related support activities	3230	$13,320	$3,874	$17,194
General state and local government services	S007	$6,065	$7,792	$13,857
Pulp, paper, and paperboard mills	3221	$4,155	$1,415	$5,569
Newspaper, periodical, book, and directory publishers	5111	$4,851	$168	$5,018
Plastics and rubber products manufacturing	3260	$1,249	$3,403	$4,651
Wholesale trade	4200	$990	$2,619	$3,609
Food services and drinking places	7220	$1,510	$2,597	$4,107
Total intermediate use	T001	$76,729	$80,862	$157,591
Personal consumption expenditures	F010	$11,882	$9,295	$21,177
Exports of goods and services	F040	$7,724	$5,799	$13,523
Imports of goods and services	F050	−$15,284	−$5,720	−$21,005
Total final uses (GDP)	T004	$4,996	$9,607	$14,604
Total commodity output	T007	$81,725	$90,469	$172,195

Source: U.S. Bureau of Economic Analysis (BEA). 2008. “2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level.” Table 2. Washington, DC: BEA.

2.3.3 *Firm and Market Characteristics*

This section describes geographic, production, and market data. These data provide the basis for further analysis, including regulatory flexibility analyses, and give a complete picture of the recent historical trends of production and pricing.

2.3.3.1 Location

As Figure 2-24 illustrates, California is home to the most paper manufacturing establishments in the United States, followed by Illinois and some bordering northeastern states. The location of establishments in the paper manufacturing industry varies a great deal by subsector. Wisconsin and New York have the most pulp, paper, and paperboard establishments, while California dominates with over 500 converted paper product establishments. Overall, the United States has 561 pulp, paper, and paperboard establishments and 4,956 converted paper product establishments.

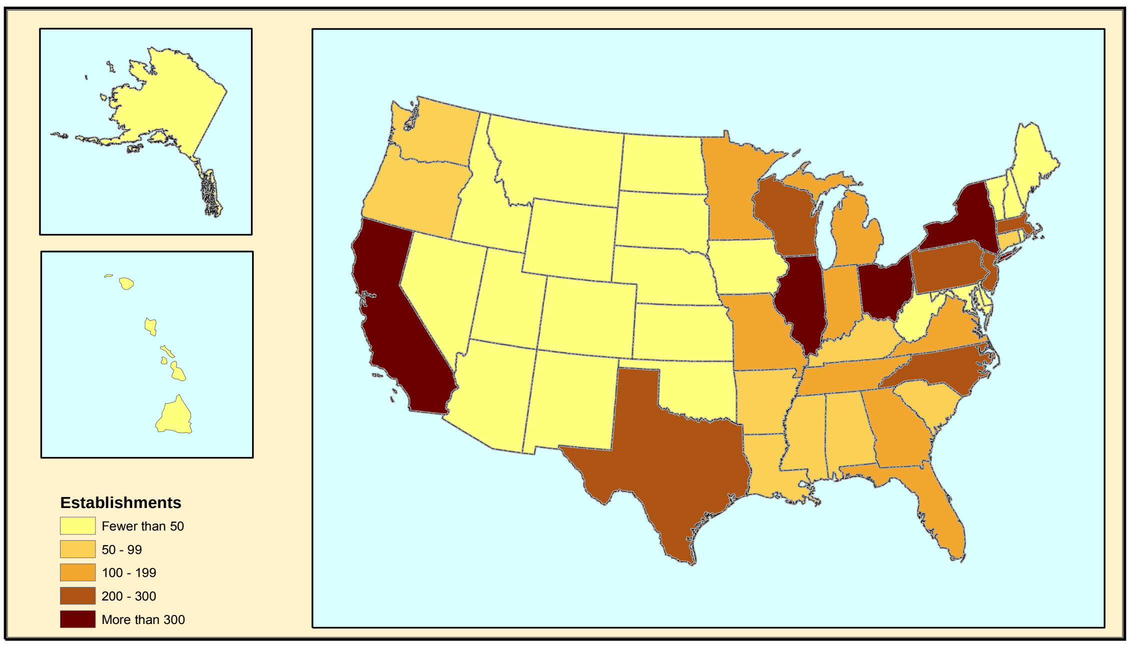

Figure 2-24. Establishment Concentration in Paper Manufacturing Industry (NAICS 322): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.3.3.2 Production Capacity and Utilization

Capacity utilization of the paper manufacturing subsector has been experiencing a steady decline, similar to the decline of the total manufacturing sector. However, paper manufacturing has managed to use its capacity at a consistently higher rate than the average for manufacturing industries (Figure 2-25).

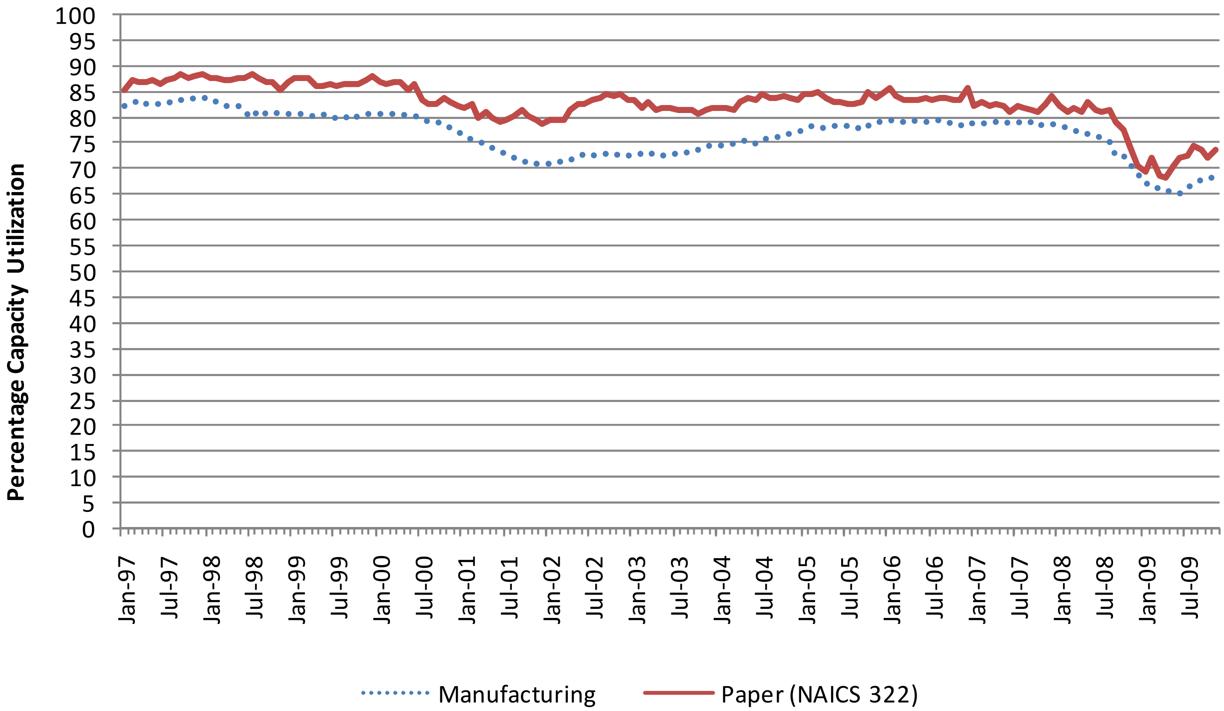

Figure 2-25. Capacity Utilization Trends in the Paper Manufacturing Industry (NAICS 322)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Capacity Utilization." <http://www.federalreserve.gov/datadownload/>.

2.3.3.3 Employment

Wisconsin has the largest number of employees in the paper manufacturing subsector with over 38,008 reported in the 2002 census followed by 29,379 in California (Figure 2-26). The converted paper products group has more employees per establishment, 283, than the pulp, paper, and paperboard group, 67.

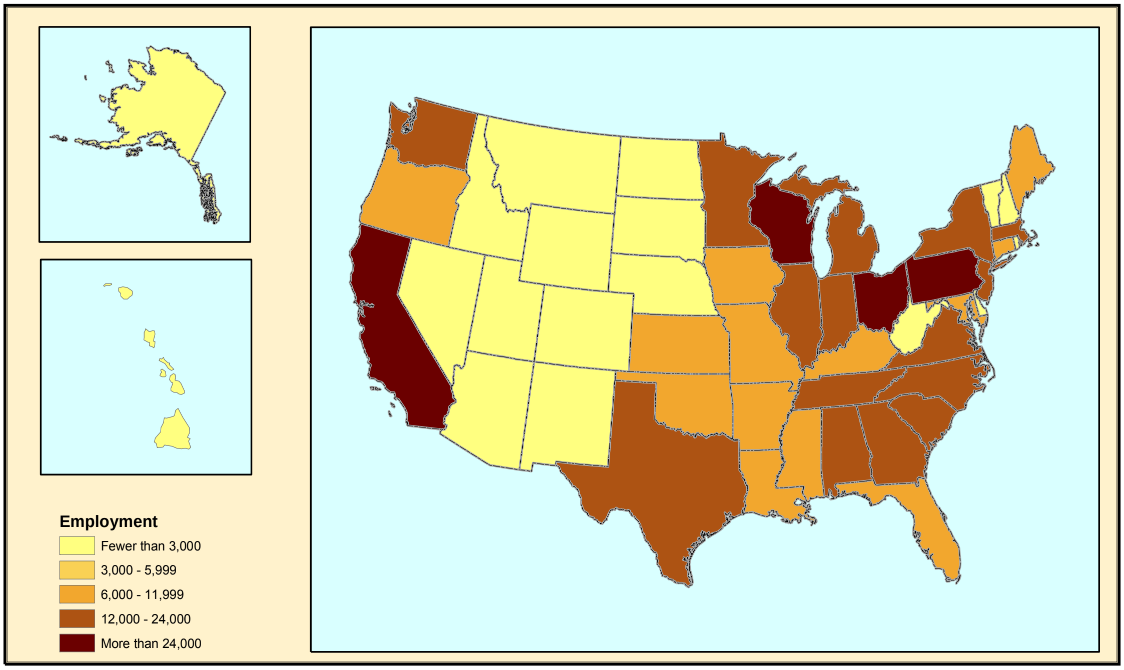

Figure 2-26. Employment Concentration in the Paper Manufacturing Industry (NAICS 322): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.3.3.4 Plants and Capacity

While the manufacturing sector has been growing consistently since 1997, the paper manufacturing sector has not experienced the same amount of success in the same period. Despite a small amount of growth in capacity between 1997 and 2001, the paper manufacturing subsector's capacity has declined to as much as 7% below 1997 capacity levels (Figure 2-27).

2.3.3.5 Firm Characteristics

In 2006, the top 10 paper and forest product companies produced over $75 billion in sales, with the top two companies—International Paper and Weyerhaeuser—generating nearly $22 billion each (Table 2-27). The top two companies' revenue consists of 58% of the revenue of the top 10 companies in Standard & Poor's (S&P's) list (Benwart, 2006). Although these numbers do not exclusively reflect paper products, they do convey the market environment in which firms in this sector compete.

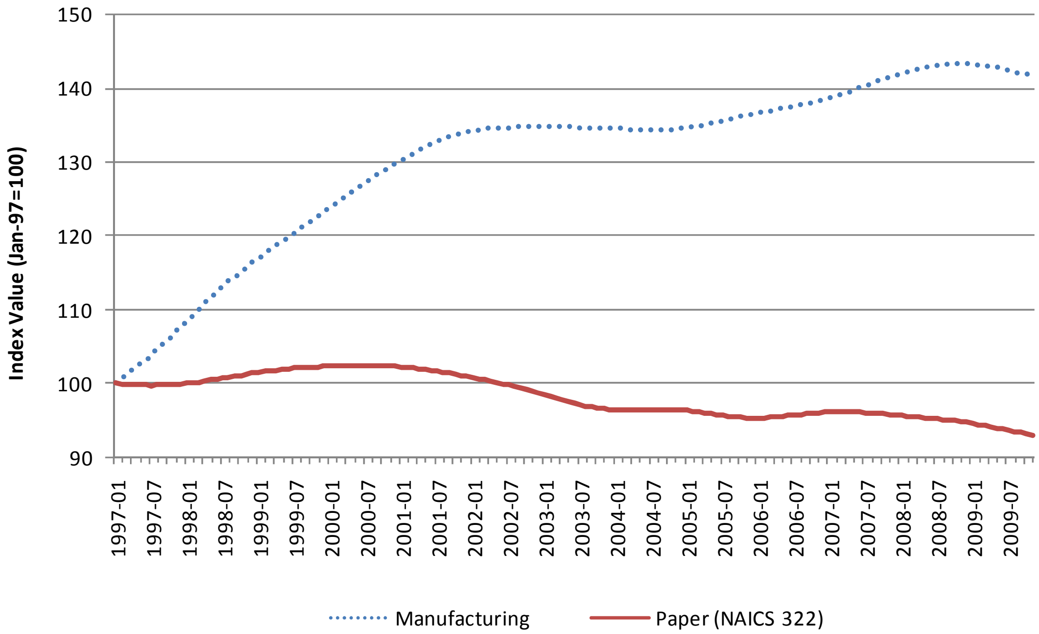

Figure 2-27. Capacity Trends in the Paper Manufacturing Industry (NAICS 322)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Capacity." <http://www.federalreserve.gov/datadownload/>.

Table 2-27. Largest U.S. Paper and Forest Products Companies: 2006

Company	Revenues ($millions)[a]
International Paper	21,995
Weyerhaeuser	21,896
Smurfit-Stone	7,157
MeadWestvaco	6,530
Temple-Inland	5,558
Bowater	3,530
Grief Inc.	2,628
Louisiana-Pacific	2,235
Packaging Corp.	2,187
Plum Creek	1,627

[a] Includes revenues from operations other than paper and forest products in certain cases.

Sources: Benwart, S.J. 2006. "Paper & Forest Products. Standard and Poor's Industry Surveys." 176(28). U.S. and international sales data from company reports.

2.3.3.6 Size Distribution

The primary criterion for categorizing a business as small is the number of employees, using definitions by the SBA for regulatory flexibility analyses. According to SUSB reports for 2002, large companies dominated revenue-generating transactions in the paper manufacturing subsector; 80% of receipts were generated by companies with 500 employees or more (Table 2-28). This was especially true in the pulp, paper, and paperboard group, in which large companies generated 92% of receipts. The number of employees in the small business cutoff varies according to six-digit NAICS codes (Table 2-29). The cutoff for all subsectors in the pulp, paper, and paperboard group is 750 employees, while the cutoff for most converted paper product groups is 500 employees.

Table 2-28. Distribution of Economic Data by Enterprise Size: Paper Manufacturing (NAICS 322)

		Enterprises with					
Variable	**Total**	**1 to 20 Employees[a]**	**20 to 99 Employees**	**100 to 499 Employees**	**500 to 749 Employees**	**750 to 999 Employees**	**1,000 to 1,499 Employees**
Firms	3,538	1,482	1,200	476	43	22	33
Establishments	5,546	1,488	1,271	755	83	69	138
Employment	495,990	11,325	52,334	78,402	13,293	12,496	23,283
Receipts ($millions)	$154,746	$2,218	$9,483	$17,620	$3,034	$3,951	$6,798
Receipts/firm ($thousands)	$43,738	$1,497	$7,903	$37,017	$70,561	$179,577	$206,001
Receipts/establishment ($thousands)	$27,902	$1,491	$7,461	$23,338	$36,556	$57,256	$49,261
Receipts/employment ($)	$311,994	$195,850	$181,203	$224,742	$228,250	$316,157	$291,974

[a] Excludes SUSB employment category for zero employees. These entities only operated for a fraction of the year.

Source: U.S. Census Bureau. 2008. “Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002.” <http://www.census.gov/csd/susb/download_susb02.htm>.

Table 2-29. Small Business Size Standards: Paper Manufacturing (NAICS 322)

NAICS	NAICS Description	Employees
322110	Pulp Mills	750
322121	Paper (except Newsprint) Mills	750
322122	Newsprint Mills	750
322130	Paperboard Mills	750
322211	Corrugated and Solid Fiber Box Manufacturing	500
322212	Folding Paperboard Box Manufacturing	750
322213	Setup Paperboard Box Manufacturing	500
322214	Fiber Can, Tube, Drum, and Similar Products Manufacturing	500
322215	Non-Folding Sanitary Food Container Manufacturing	750
322221	Coated and Laminated Packaging Paper Manufacturing	500
322222	Coated and Laminated Paper Manufacturing	500
322223	Coated Paper Bag and Pouch Manufacturing	500
322224	Uncoated Paper and Multiwall Bag Manufacturing	500
322225	Laminated Aluminum Foil Manufacturing for Flexible, Packaging Uses	500
322226	Surface-Coated Paperboard Manufacturing	500
322231	Die-Cut Paper and Paperboard Office Supplies, Manufacturing	500
322232	Envelope Manufacturing	500
322233	Stationery, Tablet, and Related Product Manufacturing	500
322291	Sanitary Paper Product Manufacturing	500
322299	All Other Converted Paper Product Manufacturing	500

Source: U.S. Small Business Administration (SBA). 2008. "Table of Small Business Size Standards Matched to North American Industry Classification System Codes." Effective August 22, 2008. <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

2.3.3.7 Domestic Production

Similar to industry capacity rates, subsector production rates for paper manufacturing have witnessed a decreasing rate of production compared to the steady increase in production for the manufacturing sector since 1997 (Figure 2-28). It seems that the paper manufacturing sector was not able to return to its former levels of growth following the 2001 recession; it has experienced a downward production trend since then.

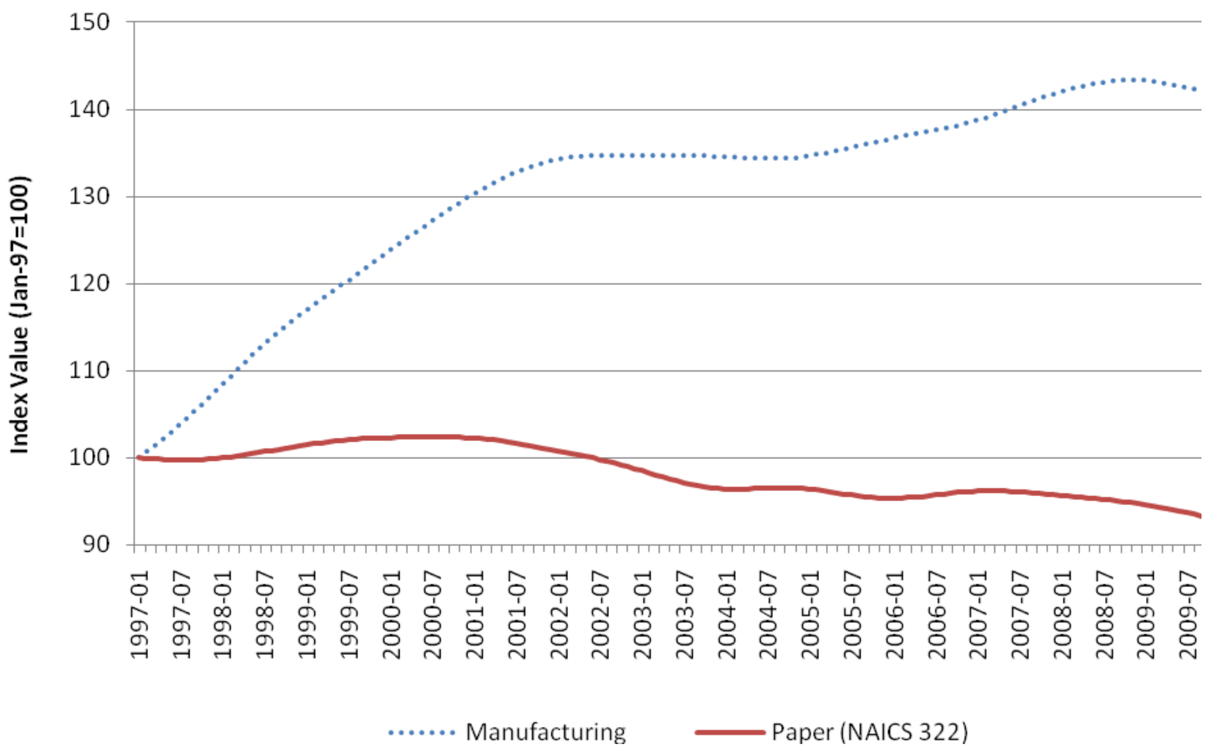

Figure 2-28. Industrial Production Trends in the Paper Manufacturing Industry (NAICS 322): 1997–2009

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Production." <http://www.federalreserve.gov/datadownload/>.

2.3.3.8 International Trade

Since 1997, paper manufacturing products, both pulp, paper, and paperboard products and converted paper products, have contributed to an increasing trade surplus in this sector (Figure 2-29). Imports and exports have been changing at similar rates since 1999.

2.3.3.9 Market Prices

Prices of goods in paper manufacturing have been increasing at a rate consistent with all manufacturing products (Figure 2-30). Producer price indices (PPIs) show that producer prices for paper in 2007 increased by 20% since 1997, while producer prices for all manufacturing goods increased by roughly 27%.

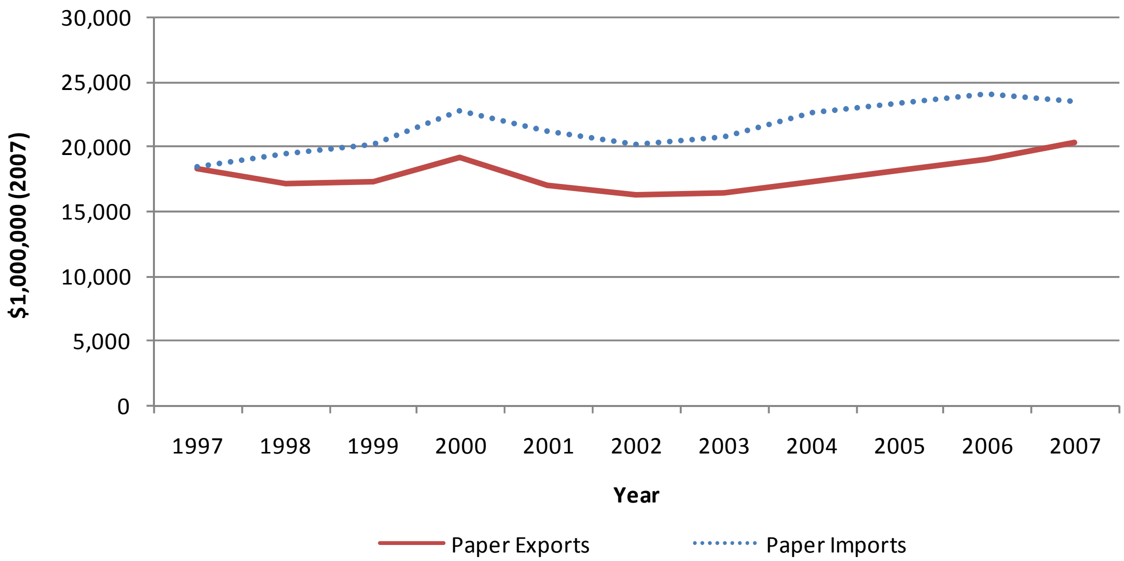

Figure 2-29. International Trade Trends in the Paper Manufacturing Industry (NAICS 322)

Source: U.S. International Trade Commission. 2008. "U.S. Domestic Exports" & "U.S. Imports for Consumption." <http://dataweb.usitc.gov/scripts/user_set.asp>.

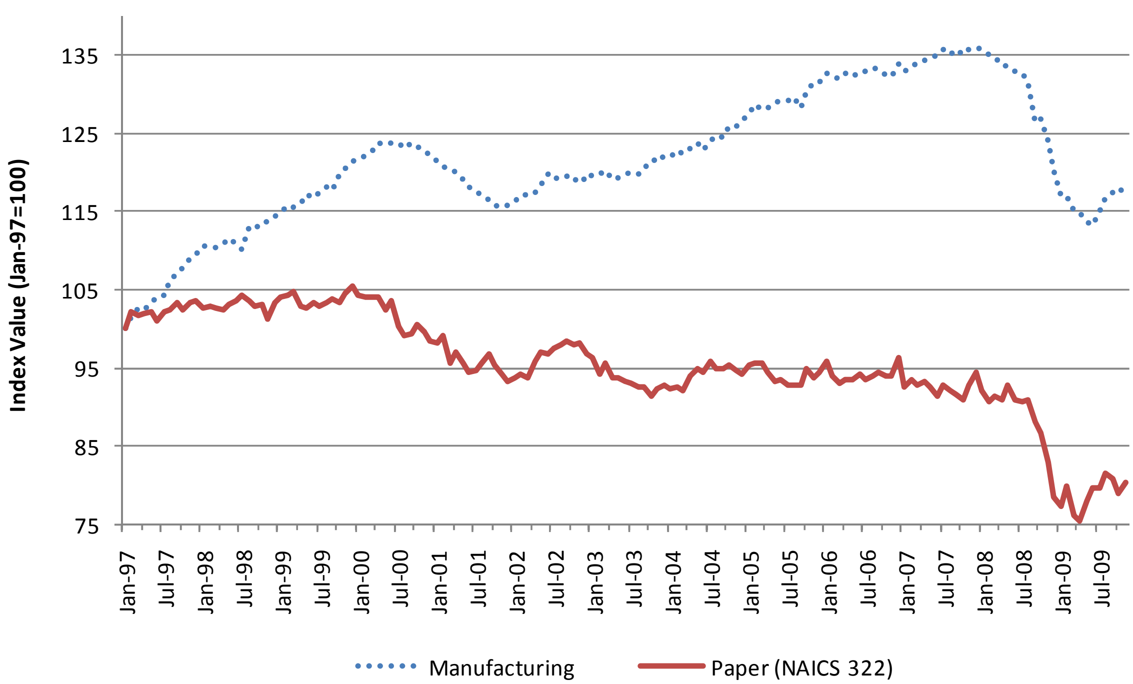

Figure 2-30. Producer Price Trends in the Paper Manufacturing Industry (NAICS 222)

Source: U.S. Bureau of Labor Statistics (BLS). 2009b. "Producer Price Index." Series ID: PCU322–322– & PCUOMFG–OMFG–. <http://www.bls.gov/ppi/home.htm>.

2.4 Chemical Manufacturing

2.4.1 Introduction

The chemical manufacturing industry produces over 70,000 chemical substances, many of which are ubiquitous in American life. Broadly speaking, chemical manufacturing operates by converting feedstocks into chemical products that can serve as intermediate goods or final products such as medicine, soap, and printer ink. From 1997 to 2007, shipments in the industry grew 42%, while employment declined by 8% (Table 2-30). While total payroll dropped 0.6% over this time, annual payroll per employee rose 7.8% from 1997 to 2007 because of the decline in the number of employees (Table 2-31). Shipments per employee grew 54% from 1997 to 2007, with much of that growth taking place between 2002 and 2006 (Table 2-31).

Chemical manufacturing (NAICS 325) covers a diverse set of industry groups, which we have aggregated into the following three groups:

- Bulk Chemicals—Includes the most energy-intensive industry groups as aggregated by the Department of Energy (DOE). Basic Chemical Manufacturing (NAICS 3251); Resin, Rubber, and Artificial Fibers Manufacturing (NAICS 3252); and Agricultural Chemical Manufacturing (NAICS 3253).
- Pharmaceutical and Medicine Manufacturing (NAICS 3254)—Consists primarily of pharmaceutical preparation manufacturing. This industry group is the largest importer of goods within chemical manufacturing.
- Other Chemical Manufacturing: Consists of Paint, Coating, and Adhesive Manufacturing (NAICS 3255); Soap, Cleaning Compound, and Toiletry Manufacturing (NAICS 3256); and Other Chemical Product and Preparation Manufacturing (NAICS 3259).

In 2007, each of these groups generated approximately one-third of the total employment in chemical manufacturing (Figure 2-31). The bulk chemicals group accounted for the biggest share of chemical manufacturing's total value of shipments (Figure 2-32).

Table 2-30. Key Statistics: Chemical Manufacturing (NAICS 325)

	1997	2002	2006	2007
Shipments ($2007, millions)	$521,251	$531,173	$675,223	$738,303
Payroll ($2007, millions)	$49,961	$51,317	$46,981	$49,648
Employees	882,645	853,224	747,134	814,024
Establishments	13474	13,475	NA	12,937

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." <http://factfinder.census.gov>. Accessed on December 27, 2009. [Source for 2007 numbers]

Table 2-31. Industry Data: Chemical Manufacturing (NAICS 325)

Industry Data	1997	2002	2006	2007
Total shipments ($2007, millions)	$521,251	$531,173	$675,223	$738,303
Shipments per establishment ($thousands)	$38,686	$39,419	NA	$57,069
Shipments per employee ($2007)	$590,556	$622,548	$903,750	$906,979
Shipments per $ of payroll ($2007)	$10.43	$10.35	$14.37	$14.87
Annual payroll per employee ($2007)	$56,603	$60,145	$62,882	$60,991
Employees per establishment	66	63	NA	63

NA = Not available.

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007." <http://factfinder.census.gov>. Accessed on December, 27, 2009. [Source for 2007 numbers]

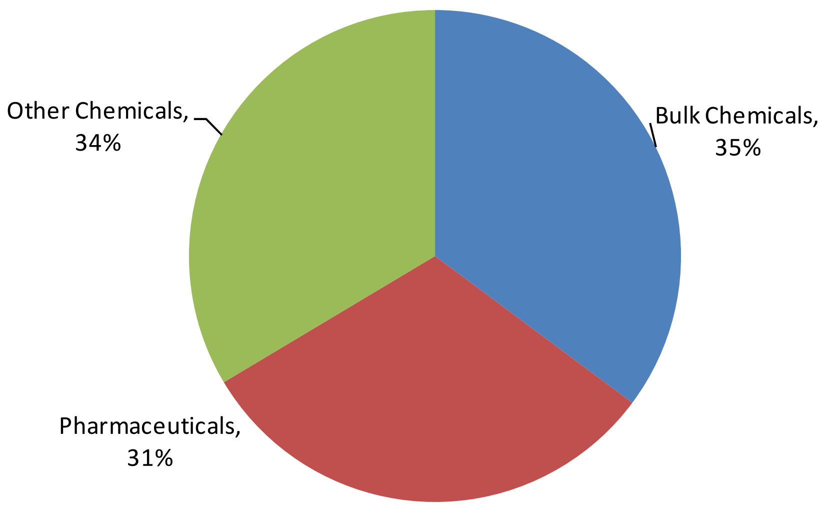

Figure 2-31. Distribution of Employment within Chemical Manufacturing (NAICS 325): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; “Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the U.S.: 2007.” Release date: October 30, 2009. Accessed on December 27, 2009.

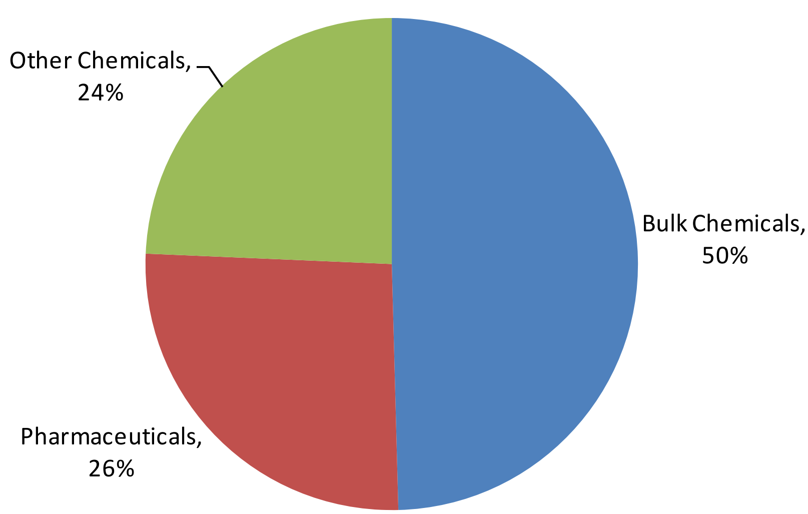

Figure 2-32. Distribution of Total Value of Shipments within Chemical Manufacturing (NAICS 325): 2007

Source: U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; “Sector 31:EC0731I1: Manufacturing Industry Series: Detailed Statistics by Industry for U.S.: 2007.” <http://factfinder.census.gov>. Accessed on December 27, 2009.

2.4.2 *Supply and Demand Characteristics*

Next, we provide a broad overview of the supply and demand side of the chemical manufacturing industry. We emphasize the economic interactions this industry has with other industries and people, including identifying the key goods and services used by the industry and the major uses and consumers of chemical manufacturing products.

The top 10 industry groups supplying inputs to the chemical manufacturing industry in 2002 accounted for 71% of the total intermediate inputs (Table 2-32). Bulk chemicals' production was the most energy intensive, using 79% of the chemical manufacturing inputs from petroleum and coal products, electric power generation, transmission and distribution, and natural gas distribution.

Table 2-32. Key Goods and Services Used in Chemical Manufacturing (NAICS 325) ($2007, millions)

Good or Service	BEA Code	Bulk Chemicals	Pharmaceuticals	Other Chemicals	Total
Basic chemicals	3251	$59,495	$4,772	$14,021	$78,288
Management of companies and enterprises	5500	$15,071	$19,380	$16,396	$50,846
Pharmaceuticals and medicines	3254	$0	$25,125	$0	$25,125
Wholesale trade	4200	$9,428	$8,367	$6,077	$23,872
Scientific research and development services	5417	$6,172	$6,139	$5,554	$17,865
Petroleum and coal products	3240	$10,066	$398	$3,432	$13,896
Plastics and rubber products	3260	$2,675	$1,132	$5,556	$9,363
Resins, rubber, and artificial fibers	3252	$4,048	$0	$4,949	$8,996
Electric power generation, transmission, and distribution	2211	$6,025	$716	$807	$7,548
Natural gas distribution	2212	$6,390	$154	$390	$6,934
Total intermediate use	T005	$167,699	$82,403	$91,833	$341,935

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

2.4.2.1 Goods and Services Used in Chemical Manufacturing

In 2007, the cost of materials made up 49% of chemical manufacturing's total shipment value (Table 2-32). Total compensation to employees represented 9% of total shipment value, down from 10% in 2005.

2.4.2.1.1 Energy. The Department of Energy (DOE) classifies bulk chemical manufacturing as an energy-intensive industry. Pharmaceuticals and other chemical manufacturing are categorized as non-energy-intensive industries, grouped together with other industry groups under the "Balance of Manufacturing" category (DOE, 2008).

Fuel used in chemical production can either facilitate chemical processes or provide the feedstock to derive value-added chemicals. In 2007, 70% of chemical manufacturing's energy bill was spent on fuel used as feedstocks (O'Reilly, 2008). These fuel costs represented 2% of chemical manufacturing's total value of shipments (Table 2-33).

As a whole, chemical manufacturing use less energy over the last 10 years. According to DOE, natural gas use by the chemical manufacturing industry dropped 30% from 1998 to 2006, and electricity use fell 10% (Table 2-34). From 1997 to 2005, when data ceased to be available, chemical manufacturing used less electricity relative to the manufacturing sector as a whole (Figure 2-33).

2.4.2.2 Uses and Consumers

Products manufactured in the groups bulk chemicals, pharmaceuticals, and other chemicals have very different consumer profiles. Bulk chemicals is dominated by intermediate use, representing 93% of its total commodity output and 56% of the total intermediate use of chemical manufacturing products. Pharmaceuticals has both a high level of demand from personal consumption, accounting for 67% of the total personal consumption of chemical manufacturing products, and a large trade deficit (Table 2-35).

Table 2-33. Costs of Goods and Services Used in Chemical Manufacturing (NAICS 325) ($2007)

Variable	2005	Share	2006	Share	2007	Share
Total shipments	$646,895	100%	$675,223	100%	$722,494	100%
Total compensation (millions)	$62,669	10%	$61,683	9%	$63,591	9%
Annual payroll	$48,159	7%	$46,981	7%	$48,780	7%
Fringe benefits	$14,510	2%	$14,702	2%	$14,811	2%
Total employees	756,078		747,134		801,567	
Average compensation per employee	$82,887		$82,559		$79,333	
Total production workers' wages (millions)	$22,643	4%	$22,231	3%	$23,157	3%
Total production workers	431,502		430,880		463,802	
Total production hours (thousands)	899,499		885,993		948,244	
Average production wages per hour	$25		$25		$24	
Total cost of materials ($thousands)	$299,859	46%	$318,945	47%	$357,055	49%
Materials, parts, packaging	$247,851	38%	$260,934	39%	$291,656	40%
Purchase electricity	$8,291	1%	$8,490	1%	$8,936	1%
Purchased fuel	$14,568	2%	$13,667	2%	$14,227	2%
Other	$29,148	5%	$35,855	5%	$42,236	6%

Sources: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005." <http://factfinder.census.gov>; (July 8, 2008).

U.S. Census Bureau; generated by Kapur Energy and Environment; using American FactFinder; "Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007." Accessed on December, 27, 2009.

Table 2-34. Energy Used in Chemical Manufacturing (NAICS 325)

Fuel Type	1998	2002	2006
Total (trillion BTU)	3,704	3,769	3,159
Net electricity[a] (million kWh)	169,233	153,104	151,646
Residual fuel oil (million bbl)	8	7	4
Distillate fuel oil[b] (million bbl)	2	2	2
Natural gas[c] (billion cu ft)	1,931	1,634	1,349
LPG and NGL[d] (million bbl)	15	9	2
Coal (million short tons)	13	14	8
Coke and breeze (million short tons)	*	*	*
Other[e] (trillion BTU)	748	1,158	1,045
Total (trillion BTU)	3,704	3,769	3,159

[a] Net electricity is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from on-site cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal).

[b] Distillate fuel oil includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[c] Natural gas includes natural gas obtained from utilities, local distribution companies, and any other supplier(s), such as independent gas producers, gas brokers, marketers, and any marketing subsidiaries of utilities.

[d] Examples of liquefied petroleum gases (LPGs) are ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas liquids (NGLs).

[e] Other includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power.

* Estimate less than 0.5.

Sources: U.S. Department of Energy, Energy Information Administration. 2007b. “2006 Energy Consumption by Manufacturers—Data Tables.” Table 3.1. Washington, DC: DOE. <http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html>. [Source for 2006 numbers]

U.S. Department of Energy, Energy Information Administration. 2007a. “2002 Energy Consumption by Manufacturers—Data Tables.” Tables 3.2 and N3.2. Washington, DC: DOE. <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>.

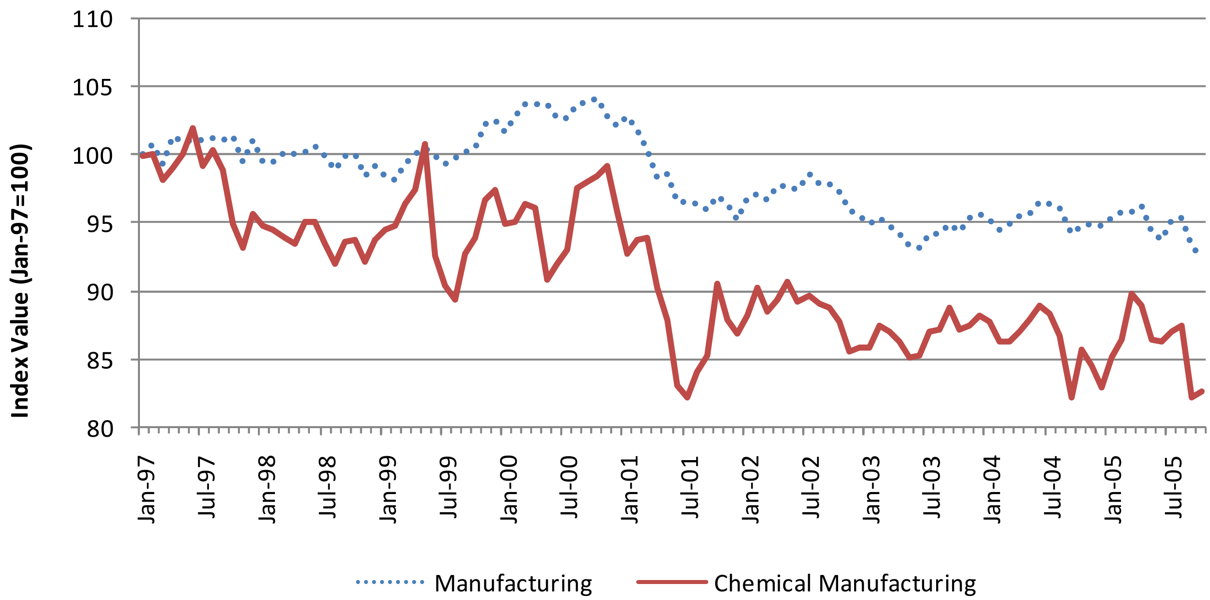

Figure 2-33. Electric Power Use Trends in Chemical Manufacturing (NAICS 325): 1997–2005

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Electric Power Use: Manufacturing and Mining." <http://www.federalreserve.gov/datadownload/>.

2.4.3 Firm and Market Characteristics

This remaining subsection describes geographic, production, and market data. These data provide the basis for further analysis, including regulatory flexibility analyses, and give a complete picture of the recent historical trends of production and pricing.

2.4.3.1 Location

In 2002, California had the most chemical manufacturing establishments in the United States, followed by Texas and New Jersey (Figure 2-34). The composition of establishments in these states differs among the different industry groups. Despite the fact that each group employed an approximately equal share of people in 2002, 54% of the total establishments were other chemicals establishments, and only 13% were pharmaceutical establishments.

Table 2-35. Demand by Sector: Chemical Manufacturing (NAICS 325) ($2007 millions)

Sector	BEA Code	Bulk Chemicals	Pharmaceuticals	Other Chemicals	Total
Plastics and rubber products manufacturing	3260	$39,353	$0	$3,057	$42,410
Basic chemical manufacturing	3251	$33,972	$0	$1,675	$35,647
Pharmaceutical and medicine manufacturing	3254	$4,778	$25,125	$462	$30,365
Resin, rubber, and artificial fibers manufacturing	3252	$28,249	$0	$1,076	$29,325
Ambulatory health care services	6210	$2,716	$22,900	$934	$26,550
General state and local government services	S007	$7,150	$10,586	$8,807	$26,543
Hospitals	6220	$2,936	$15,390	$394	$18,720
Other chemical product and preparation manufacturing	3259	$8,021	$0	$2,680	$10,701
Textile mills	3130	$9,568	$0	$930	$10,498
Soap, cleaning compound, and toiletry manufacturing	3256	$3,886	$0	$6,289	$10,176
Total intermediate use	T001	$212,996	$83,279	$82,107	$378,382
Personal consumption expenditures	F010	$4,449	$123,746	$55,882	$184,077
Exports of goods and services	F040	$47,121	$15,683	$13,136	$75,940
Imports of goods and services	F050	−$38,732	−$67,950	−$10,906	−$117,588
Total final uses (GDP)	T004	$15,733	$73,485	$58,023	$147,241
Total commodity output	T007	$228,729	$156,765	$140,129	$525,623

Source: U.S. Bureau of Economic Analysis (BEA). 2008. "2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level." Table 2. Washington, DC: BEA.

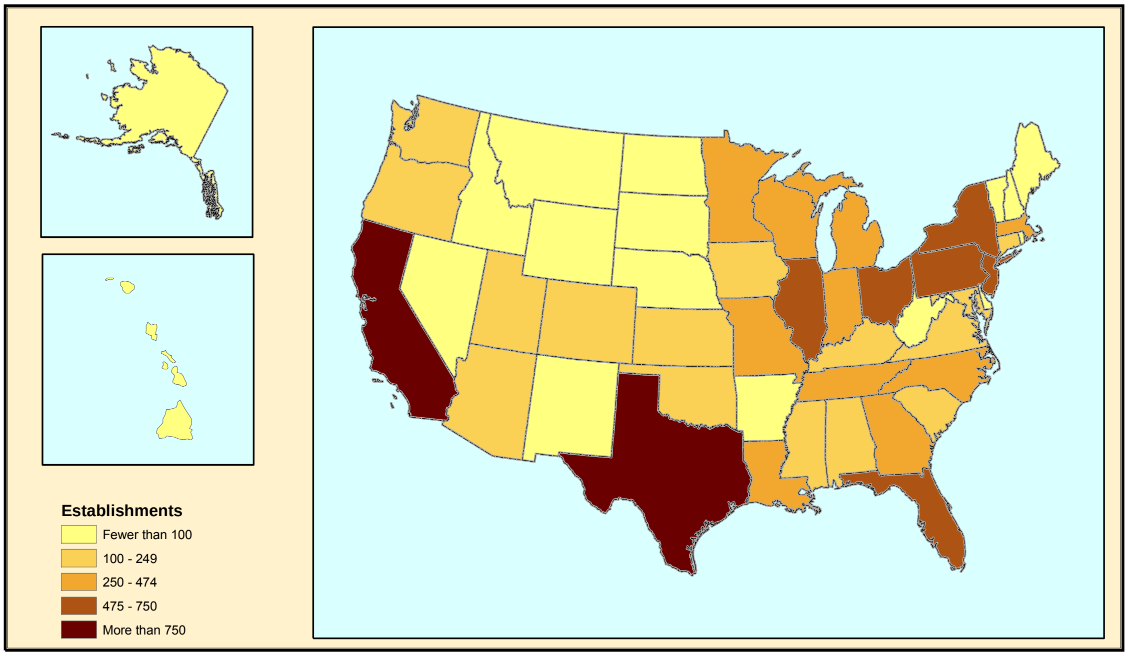

Figure 2-34. Establishment Concentration in Chemical Manufacturing (NAICS 325): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

2.4.3.2 Production Capacity and Utilization

Capacity utilization of the chemical manufacturing industry has been broadly in line with the manufacturing sector (Figure 2-35). In the second half of 2005, the chemical manufacturing industry's capacity utilization fell dramatically because of the multiple hurricanes affecting the Gulf Coast states. The impact of the economic downturn in 2001 can be seen in the capacity utilization of both manufacturing and chemical manufacturing.

2.4.3.3 Employment

The geographic distribution of employment in chemical manufacturing differs largely among the different groups. In California, 52% of the chemical manufacturing employment comes from the pharmaceutical industry, while 60% of the chemical manufacturing employment in the Gulf Coast states comes from bulk chemicals manufacturing (Figure 2-36).

2.4.3.4 Plants and Capacity

Production capacity in chemical manufacturing has grown 33% since 1997. This growth, however, is 9% less than the growth rate for the manufacturing industry as a whole (Figure 2-37).

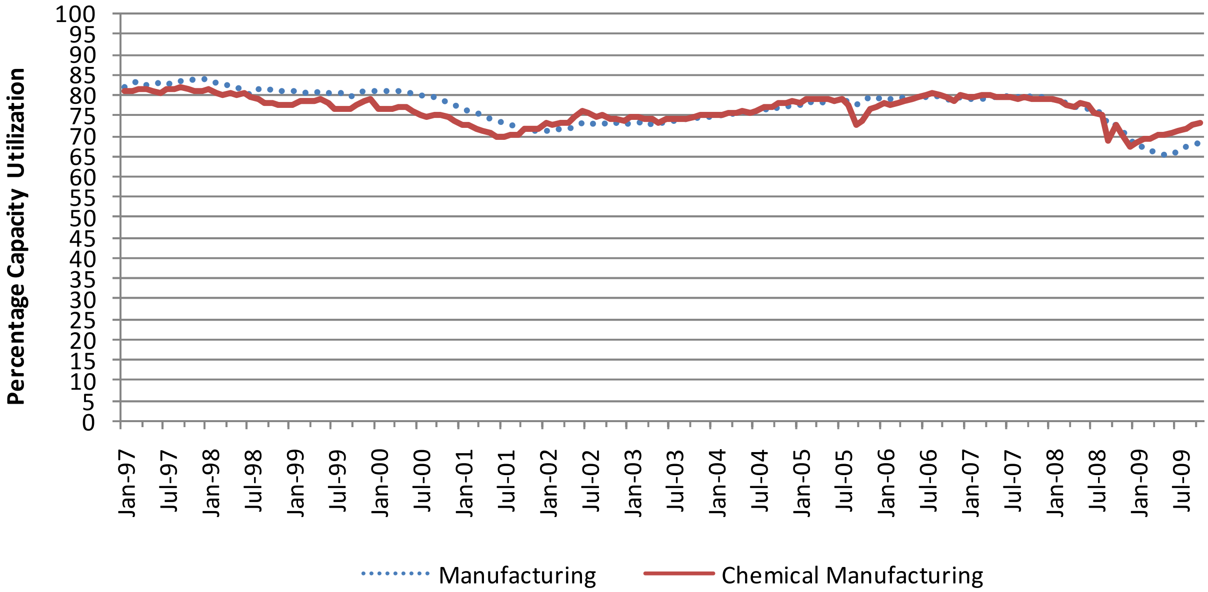

Figure 2-35. Capacity Utilization Trends in Chemical Manufacturing (NAICS 325)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Capacity Utilization." <http://www.federalreserve.gov/datadownload/>.

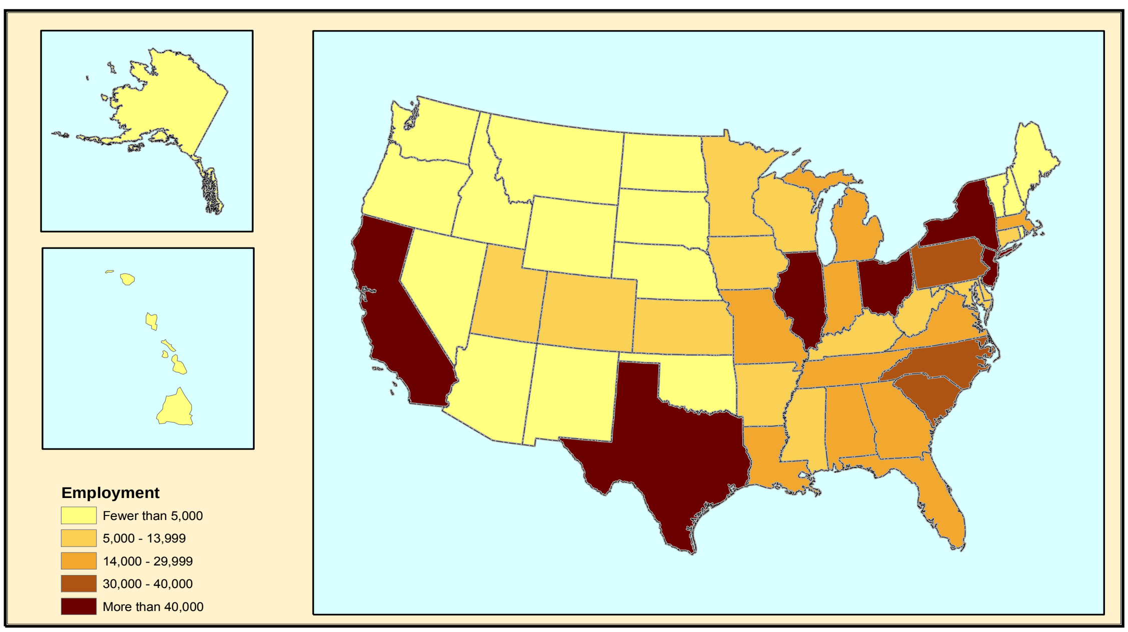

Figure 2-36. Employment Concentration in Chemical Manufacturing (NAICS 325): 2002

Source: U.S. Census Bureau; generated by RTI International; using American FactFinder; "Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002." <http://factfinder.census.gov>; (July 23, 2008).

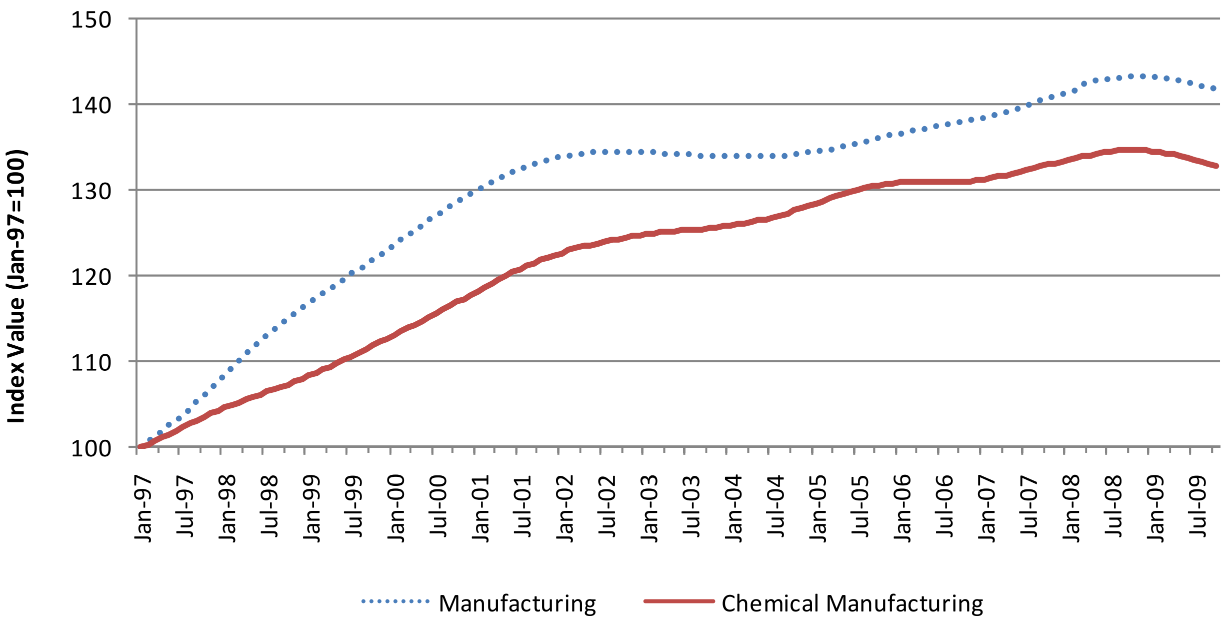

Figure 2-37. Capacity Trends in Chemical Manufacturing (NAICS 325)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Capacity." <http://www.federalreserve.gov/datadownload/>.

2.4.3.5 Firm Characteristics

In 2007, the top six companies by chemical sales had greater than $10 billion in sales. Together, their sales are greater than the next 44 highest chemical companies combined. These, however, are global companies, with a large portion of both sales and production coming from operations outside of the United States (Table 2-36). The largest chemical manufacturing company, Dow Chemicals, has 108 out of 150 manufacturing sites located outside of the United States (Dow Chemical Company, 2008).

In 2007, 58% of U.S. chemical manufacturing corporations generated net income. Including those with and without net income, chemical manufacturers had an average before-tax profit margin of 10.24%. Profitability is highest for pharmaceutical and medicine corporations (Table 2-37).

Table 2-36. Top Chemical Producers: 2007

	Chemical Sales ($millions)	% of Total Sales	% of Sales in United States
Dow Chemical	53,513	100%	35%
ExxonMobil	36,826	9%	38%
DuPont	29,218	100%	38%
Lyondell[a]	16,165	57%	80%
Chevron Phillips	12,534	100%	86%
PPG Industries[a]	10,025	90%	56%
Huntsman Chemical	9,651	100%	50%
Praxair	9,402	100%	43.5%
Air Products[a]	8,820	88%	51%
Rohm & Haas[b]	7,837	88%	49%

[a] Percentage of sales in the United States calculated from total sales, not chemical sales.

[b] Percentage of sales in the United States is actually percentage of sales in North America.

Source: O'Reilly, R. 2008. "Chemicals." Standard and Poor's Industry Surveys. 176(28).

Table 2-37. 2007 Corporate Income and Profitability (NAICS 325)

Industry	Number of Corporations	Number of Corporations with Net Income	Total Receipts ($thousands)	Business Receipts ($thousands)	Before-Tax Profit Margin	After-Tax Profit Margin
Basic chemical	1,244	757	$195,022,700	$178,019,490	5.07%	4.10%
Resin, synthetic rubber, and artificial synthetic fibers and filaments	1,067	648	$44,692,366	$40,078,009	8.06%	6.33%
Pharmaceutical and medicine	1,034	611	$381,339,258	$317,414,432	15.63%	11.66%
Paint, coating, and adhesive	1,411	1,260	$51,778,868	$49,486,744	5.39%	4.02%
Soap, cleaning compound, and toilet preparation	1,862	463	$150,506,485	$139,836,602	9.07%	7.51%
Other chemical product and preparation	2,946	1,773	$89,014,032	$84,062,534	6.71%	5.27%
Chemical manufacturing	**9,564**	**5,512**	**$912,353,710**	**$808,897,810**	**10.24%**	**7.89%**

Source: Internal Revenue Service, U.S. Department of Treasury. 2008b. "Corporation Source Book: Data File 2007." <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>; (January, 15, 2010).

2.4.3.6 Size Distribution

The primary criterion for categorizing a business as small is number of employees, using definitions by the SBA for regulatory flexibility analyses. The data describing size standards are provided in Table 2-38 and Table 2-39. In 2002, enterprises with fewer than 500 employees accounted for 27% of employment and 15% of receipts within the chemical manufacturing industry).

2.4.3.7 Domestic Production

In the late 1990s, overall manufacturing production was growing much faster than the chemical manufacturing component (Figure 2-38). Following the recession of 2001, however, the components have moved broadly in line with one another, except for the drop in chemical manufacturing production caused by the hurricane season of 2005.

2.4.3.8 International Trade

In the year 2000, the United States moved from having a trade surplus to a trade deficit in chemical manufacturing products (Figure 2-39). This change occurred because the trade deficit in pharmaceutical manufacturing, currently at $35 billion, overwhelmed the trade surplus of bulk chemicals and other chemical manufacturing combined, currently at $22 billion.

2.4.3.9 Market Prices

Prices of goods in chemical manufacturing have accelerated rapidly in the last 2 years, having outpaced overall manufacturing since 2002 (Figure 2-40). Much of this recent acceleration seen in the industry PPI is due to the bulk chemicals segment, largely reflecting the rapid increase in fertilizer prices.

Table 2-38. Small Business Size Standards: Chemical Manufacturing (NAICS 325)

NAICS	Description	Employees
325110	Petrochemical Manufacturing	1,000
325120	Industrial Gas Manufacturing	1,000
325131	Inorganic Dye and Pigment Manufacturing	1,000
325132	Synthetic Organic Dye and Pigment Manufacturing	750
325181	Alkalies and Chlorine Manufacturing	1,000
325182	Carbon Black Manufacturing	500
325188	All Other Basic Inorganic Chemical Manufacturing	1,000
325191	Gum and Wood Chemical Manufacturing	500
325192	Cyclic Crude and Intermediate Manufacturing	750
325193	Ethyl Alcohol Manufacturing	1,000
325199	All Other Basic Organic Chemical Manufacturing	1,000
325211	Plastics Material and Resin Manufacturing	750
325212	Synthetic Rubber Manufacturing	1,000
325221	Cellulosic Organic Fiber Manufacturing	1,000
325222	Noncellulosic Organic Fiber Manufacturing	1,000
325311	Nitrogenous Fertilizer Manufacturing	1,000
325312	Phosphatic Fertilizer Manufacturing	500
325314	Fertilizer (Mixing Only) Manufacturing	500
325320	Pesticide and Other Agricultural Chemical Manufacturing	500
325411	Medicinal and Botanical Manufacturing	750
325412	Pharmaceutical Preparation Manufacturing	750
325413	In-Vitro Diagnostic Substance Manufacturing	500
325414	Biological Product (except Diagnostic) Manufacturing	500
325510	Paint and Coating Manufacturing	500
325520	Adhesive Manufacturing	500
325611	Soap and Other Detergent Manufacturing	750
325612	Polish and Other Sanitation Good Manufacturing	500
325613	Surface Active Agent Manufacturing	500
325620	Toilet Preparation Manufacturing	500
325910	Printing Ink Manufacturing	500
325920	Explosives Manufacturing	750
325991	Custom Compounding of Purchased Resins	500
325992	Photographic Film, Paper, Plate and Chemical Manufacturing	500
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing	500

Source: U. S. Small Business Administration (SBA). 2008. “Table of Small Business Size Standards Matched to North American Industry Classification System Codes.” Effective August 22, 2008. <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

Table 2-39. Distribution of Economic Data by Enterprise Size: Chemical Manufacturing (NAICS 325)

		Enterprises with					
Variable	Total	1 to 20 Employees[a]	20 to 99 Employees	100 to 499 Employees	500 to 749 Employees	750 to 999 Employees	1,000 to 1,499 Employees
Firms	9,341	5,413	1,974	790	95	56	71
Establishments	13,096	5,433	2,208	1,352	250	185	276
Employment	827,430	34,838	78,090	113,326	28,025	18,119	28,338
Receipts ($millions)	$468,211	$9,631	$21,394	$39,111	$12,217	$7,324	$14,762
Receipts/firm ($thousands)	$50,124	$1,779	$10,838	$49,507	$128,603	$130,779	$207,913
Receipts/establishment ($thousands)	$35,752	$1,773	$9,689	$28,928	$48,869	$39,587	$53,485
Receipts/employment ($)	$565,862	$276,464	$273,971	$345,117	$435,942	$404,195	$520,920

[a] Excludes SUSB employment category for zero employees. These entities only operated for a fraction of the year.

Source: U.S. Census Bureau. 2008. "Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002." <http://www.census.gov/csd/susb/download_susb02.htm>.

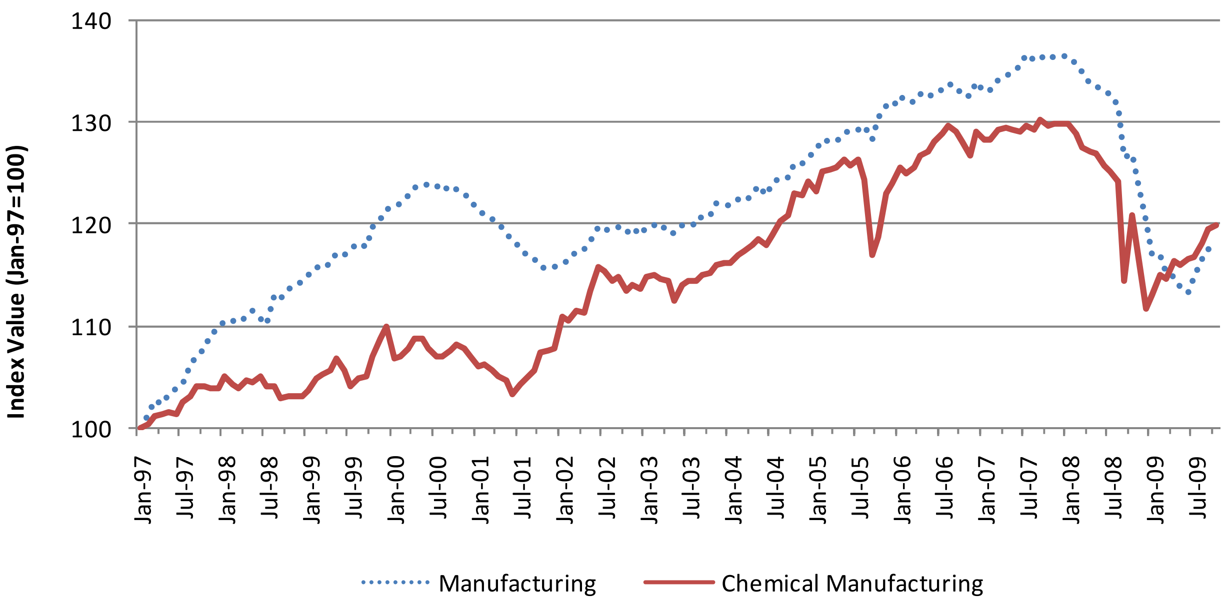

Figure 2-38. Industrial Production Trends in Chemical Manufacturing (NAICS 325)

Source: Federal Reserve Board. 2009. "Industrial Production and Capacity Utilization: Industrial Production." <http://www.federalreserve.gov/datadownload/>.

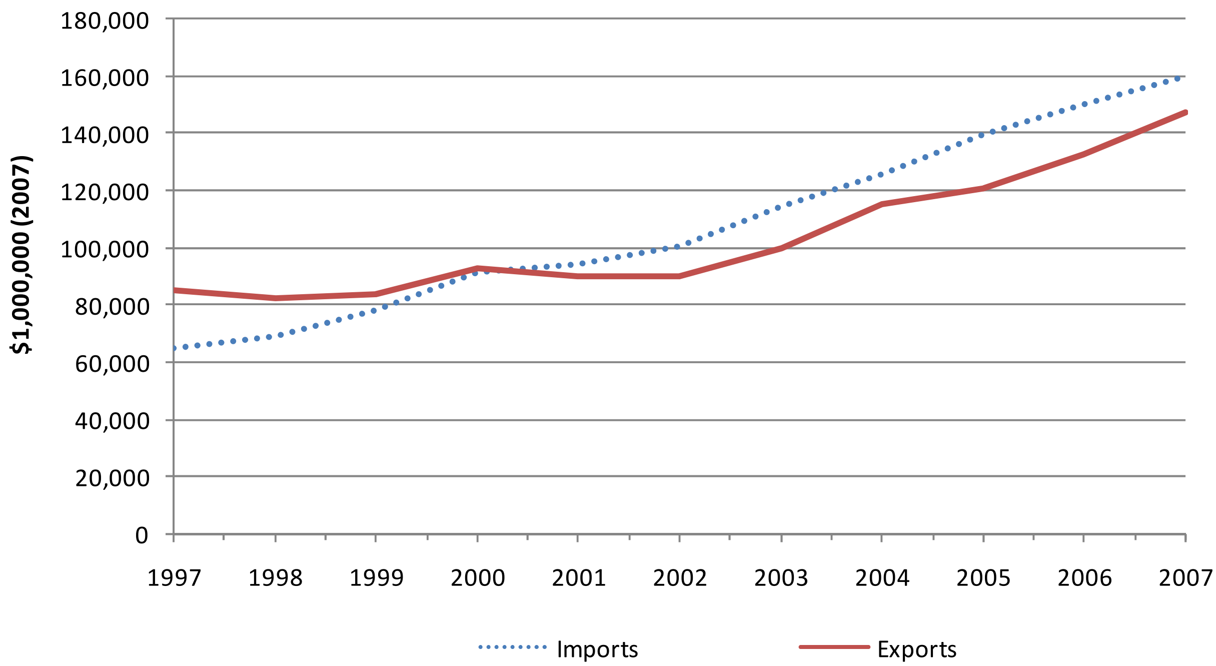

Figure 2-39. International Trade Trends in Chemical Manufacturing (NAICS 325)

Source: U.S. International Trade Commission. 2008. "U.S. Domestic Exports" & "U.S. Imports for Consumption." <http://dataweb.usitc.gov/scripts/user_set.asp>.

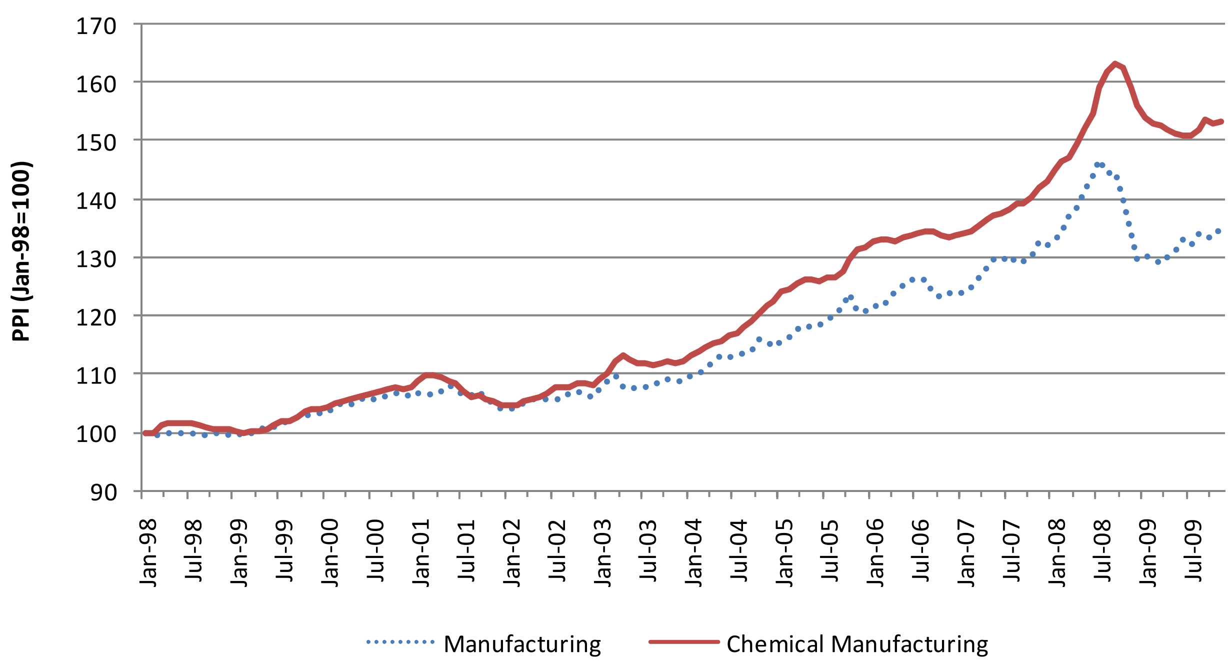

Figure 2-40. Producer Price Trends in Chemical Manufacturing (NAICS 325)

Source: U.S. Bureau of Labor Statistics (BLS). 2009c. Producer Price Index. Series ID: PCU325—325—&PCUOMFG—OMFG—. <http://www.bls.gov/ppi/home.htm>.

2.5 Section 2 References

Benwart, S.J. 2006. “Paper & Forest Products.” *Standard and Poor’s Industry Surveys* 176(28).

Dow Chemical Company. 2008. “Transforming: The Dow Chemical Company 2007 10-K and Stockholder Summary.” <http://www.dow.com/financial/2007ann/>.

Federal Reserve Board. 2009. “Industrial Production and Capacity Utilization.” <http://www.federalreserve.gov/datadownload/>.

Graves, T. 2008. “Food and Nonalcoholic Beverages.” *Standard and Poor’s Industry Surveys* 176(25).

Internal Revenue Service, U.S. Department of Treasury. 2008a. “Corporation Source Book: Data File 2005.” <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>.

Internal Revenue Service, U.S. Department of Treasury. 2008b. “Corporation Source Book: Data File 2007.” <http://www.irs.gov/taxstats/article/0,,id=167415,00.html>.

Kraft Foods Inc. 2008. “Form 10-K, Period ending December 31, 2007.” <http://www.kraft.com/Investor/sec-filings-annual-report/>.

O’Reilly, R. 2008. “Chemicals.” *Standard and Poor’s Industry Surveys.* 176(28).

Standard & Poors, 2008. Standard & Poor’s netAdvantage [electronic resource]. New York: Standard & Poors.

U.S. Bureau of Economic Analysis (BEA). 2008. “2002 Benchmark Input-Output Accounts: 2002 Standard Make and Use Tables at the Summary Level.” Table 2. Washington, DC: BEA. U.S. Bureau of Labor Statistics. 2009a. “Producer Price Index.” Series ID: PCU321—321—& PCUOMFG—OMFG—. <http://www.bls.gov/ppi/home.htm>.

U.S. Bureau of Labor Statistics. 2009b. “Producer Price Index.” Series ID: PCU322–322– & PCUOMFG–OMFG–. <http://www.bls.gov/ppi/home.htm>.

U.S. Bureau of Labor Statistics. 2009c. “Producer Price Index.” Series ID: PCU325—325—&PCUOMFG—OMFG—. <http://www.bls.gov/ppi/home.htm>.

U.S. Census Bureau. 2001. “1997 Census NAICS Definitions.” <http://www.census.gov/epcd/ec97/industry/E322.HTM#def>.

U.S. Census Bureau. 2008. “Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002.” <http://www.census.gov/csd/susb/download_susb02.htm>.

U.S. Census Bureau. “Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (1997 NAICS Basis): 2002 and 1997” (generated by RTI International using American FactFinder). <http://factfinder.census.gov>. Accessed July 8, 2008.

U.S. Census Bureau. “Sector 00: All Sectors: Core Business Statistics Series: Comparative Statistics for the United States and the States (2007 NAICS Basis): 2002 and 2007” (generated by RTI International using American FactFinder). <http://factfinder.census.gov>. Accessed January 4, 2010.

U.S. Census Bureau. “Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economy-Wide Key Statistics: 2007” (generated by Kapur Energy and Environment using American FactFinder). <http://factfinder.census.gov>. Accessed December 27, 2009.

U.S. Census Bureau. “Sector 31: Annual Survey of Manufactures: General Statistics: Statistics for Industry Groups and Industries: 2006 and 2005” (generated by RTI International using American FactFinder). <http://factfinder.census.gov>. Accessed July 8, 2008.

U.S. Census Bureau. “Sector 31: EC0731I1: Manufacturing: Industry Series: Detailed Statistics by Industry for the United States: 2007” (generated by Kapur Energy and Environment using American FactFinder). <http://factfinder.census.gov>. Accessed December 27, 2009.

U.S. Census Bureau. “Sector 31: Manufacturing: Geographic Area Series: Industry Statistics for the States, Metropolitan and Micropolitan Statistical Areas, Counties, and Places: 2002” (generated by RTI International using American FactFinder). <http://factfinder.census.gov>. Accessed July 23, 2008.

U.S. Department of Energy, Energy Information Administration. 2007a. “2002 Energy Consumption by Manufacturers—Data Tables” (Tables 3.2 and N3.2). <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>.

U.S. Department of Energy, Energy Information Administration. 2007b. “2006 Energy Consumption by Manufacturers—Data Tables” (Table 3.1). <http://www.eia.doe.gov/emeu/mecs/mecs2006/ 2006tables.html>.

U.S. Department of Energy, Energy Information Administration. 2008. “Assumptions to the Annual Energy Outlook 2008: With Projections for 2030.” <http://www.eia.doe.gov/oiaf/aeo/assumption/>.

U.S. Department of Labor, Bureau of Labor Statistics. 2010. “Producer Price Indexes.” <http://www.bls.gov/pPI/Series Id: PCU311—311—Food Manufacturing & PCUOMFG–OMFG–Total Manufacturing>.

U.S. Environmental Protection Agency. 2002. “Profile of the Pulp and Paper Industry. Sector Notebook Project.” <http://www.epa.gov/Compliance/resources/publications/assistance/ sectors/notebooks/index.html>.

U.S. International Trade Commission. 2008. “U.S. Domestic Exports” and “U.S. Imports for Consumption.” <http://dataweb.usitc.gov/scripts/user_set.asp>.

U.S. Small Business Administration. 2008. "Table of Small Business Size Standards Matched to North American Industry Classification System Codes." <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

SECTION 3
ENGINEERING COST ANALYSIS

We provide an overview of the engineering cost analysis used to estimate the additional private expenditures industry may make in order to comply with the rule. A detailed discussion of the methodology used to estimate cost impacts is presented in Appendices C and D.

Several provisions in the rule and the data used to generate regulatory impacts analysis between proposal and the final rule. As a result, the costs of the RIA analysis decreased from the proposal to final analysis.

The major regulatory provisions resulting in a reduction in the cost estimates were:

- Consolidating the biomass and coal subcategories into a single solid fuel subcategory for fuel-based HAP and HAP surrogates (Hg, HCl, PM). This provision has reduced the number of biomass units expected to require HCl control in order to meet the emission limits.

- Creating a hybrid grate/suspension category for combustion based HAP and HAP surrogates to address boilers that express unique design features to handle the combustion of fuels with a very high moisture content. This increased the CO emission level for this subcategory which resulting in less units needing CO catalyst or advanced combustion controls in order to meet the limit.

- Creating a limited use subcategory. This subcategory removes the control, testing and monitoring costs for 134 large boilers firing solid and liquid fuels that operate less than 876 hours per year.

- Creating a fuel gas specification to allow additional gaseous fuels to qualify for the gas 1 subcategory. Based on the data in the record, most fuels are expected to meet the mercury specification and will qualify for a work practice standard instead of meeting emission limits. The number of gas 2 units estimated to meet emission limits at proposal was and this has been reduced to an estimated 71 units in the final rule, compared with an estimated 199 gas 2 units in the proposed analysis.

- Removing the CO CEMS monitoring requirement for units with a heat input capacity. Although this change in monitoring is offset in part by O_2 parameter monitoring requirement.

- Removing duplicative monitoring requirements for PM CEMS, opacity monitoring and bag leak detection monitors. The proposal had included requirements to measure more than one of these parameters and this duplication has been removed from the final rule.

- Reducing testing frequency for dioxin/furan emissions. The final rule requires a one-time initial test instead of annual testing.

The major data analysis elements resulting in a reduction in cost were:

- As discussed in detail in the "Handling and Processing of Corrections and New Data in the EPA ICR Databases" memorandum, several new data submissions and corrections to existing entries were received from the public comment process. These new data incorporated into the revised MACT floor, baseline emission, and emission reduction analysis.

- The criteria for considering data in the MACT floor analysis were revised to reduce the low bias impact from tests conducted during co-firing configurations. In the final rule, the test had to be fired with at least 90 percent of its heat input belonging to the same subcategory for existing sources and 100 percent of its heat input belonging to the same subcategory for new sources. At proposal, data were considered relevant for consideration in the MACT floor analysis if at least 10 percent of its heat input belonged to the same subcategory. This modified the make-up of the top performing units and the resulting.

- The CO emission data analysis was revised to incorporate measurement error resulting from calibration error, system bias, and drift requirements using the reported instrument calibration span as the basis for estimating the error. This increased CO emission levels in several cases in order to better incorporate this error in the final standard.

- Several elements of the MACT floor analysis statistical approach were incorporated from public commenters, which resulted in increased emission limits in some cases. The memorandum "Revised MACT Floor Analysis (2011) for the Industrial, Commercial, and Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants—Major Source" details the specific statistical modifications that were made in the final analysis.

3.1 Major Sources

To estimate the national cost impacts of the proposed rule for existing sources, EPA developed average baseline emission factors for each fuel type/control device combination based on the emission data obtained and contained in the Boiler MACT emission database. If a unit reported emission data, we assigned its unit-specific emission data as its baseline emissions. For units that did not report emission data, but similar units at the same facility reported data, we assigned the average emission factors from similar units at the same facility to the baseline emissions of the unit. For all other units that did not report emission data, we assigned the appropriate emission factors to each existing unit in the inventory database, based on the average emission factors for boilers with similar fuel, design, control devices. We then compared each unit's baseline emission factors to the proposed MACT floor emission limit to determine if control devices were needed to meet the emission limits. The control analysis considered fabric filters and activated carbon injection to be the primary control devices for mercury control, electrostatic precipitators for units meeting mercury limits but requiring additional control to meet the PM limits, wet scrubbers and dry injection fabric filter combinations to meet the HCl limits, tune-ups, replacement burners, combustion controls, and CO oxidation catalyst for CO and organic HAP control. We identified where one control device could achieve reductions in multiple pollutants, for example a fabric filter was expected to achieve both PM and mercury control in order to avoid overestimating the costs. We also included costs for testing and monitoring requirements contained in the proposed rule. The resulting total national cost impact of the proposed rule is 5.1 billion dollars in capital expenditures and 1.8 billion dollars per year in total annual costs. Considering estimated fuel savings resulting from work practice standards and combustion controls, the total annualized costs are reduced to 1.4 billion. The total capital and annual costs include costs for control devices, work practices, testing and monitoring. Table 3-1 of this shows the capital and annual cost impacts for each subcategory. Costs include testing and monitoring costs, but not recordkeeping and reporting costs.

Table 3-1. Summary of Capital and Annual Costs for New and Existing Major Sources[a]

Source	Subcategory	Estimated/ Projected No. of Affected Units	Capital Costs (million)	Annualized Cost (million per yr)[a]	Annualized Cost (million per yr)[b]
Existing Units	Solid units	1,014	$2,182	$873	$846
	Liquid units	713	$2,656	$833	$828
	Non-Continental Liquid Units	27	$86	$24	$21
	Gas 1 units	10,797	$70	$31	$(325)
	Gas 1 Metallurgical Furnaces	694	$4.5	$2.0	$(6)
	Gas (other) units	118	$79	$39	$37
	Limited Use	477	$3.1	$1.3	$(25)
Energy Audit	ALL			27	$27
	Total Existing Costs	13,840	$5,081	$1,803	$1,403
New Units	Solid units	0	0	0	0
	Liquid units	13	$21	$6.1	$6.1
	Gas 1 units	34	$0.2	$0.1	0
	Total New Costs	47	$21.2	$6.1	$6.1

[a] Does not include fuel savings.

[b] Includes Fuel Savings.

Using Department of Energy (DOE) projections on fuel expenditures, the number of additional boilers that could be potentially constructed was estimated. A detailed description of how the DOE data was used to project new units expected to be constructed is discussed in the memorandum, "*Revised New Unit Analysis Industrial, Commercial, and Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants—Major Source* (Gibson et al., 2011)." This analysis consisted of two steps, (1) calculating the predicted percent change in fuel consumption in the industrial and commercial/institutional sectors between the baseline year (2008) of the major source boiler and process heater inventory and the target years of the projection (2013 and 2015); and (2) calculating the expected fuel consumption in future in boilers and heaters and predicting the number of new units required to fire a particular fuel. The resulting total national cost impact of the proposed rule in the 3rd year is 21 million dollars in capital expenditures and 6 million dollars per year in total annual costs, when considering a 1 percent fuel savings.

The fuel savings are based on an estimated savings of 1 percent from tuning the boiler to adjust oxygen levels and inspecting the flame pattern, consistent with manufacturer's specifications. For units with an automatic air to fuel ratio control, it also includes inspection and calibration of that system. It is primarily the tune-ups that are expected to obtain these fuel savings, but approximately 440 units are estimated to retrofit their units with linkageless boiler management systems in order to reduce CO emissions and improve boiler efficiency. Fuel savings of one percent was selected for the basis of the fuel savings analysis. The fuel savings was estimated for units firing gaseous, liquid, and coal fuels only. Biomass fuels were not considered in the fuel savings analysis since it is difficult to establish a market value for the various biomass fuel streams

The estimated fuel savings between proposal and promulgation are similar. At proposal, fuel savings from existing units was estimated to be $376 million, this assumed that 12,887 units would install combustion controls or conduct a tune-up in order to meet the CO emission limit or comply with a work practice standard. At the final rule, the fuel savings was estimated to be $428 million, based on 13,279 units installing combustion controls or conducting a work practice standard. The difference resulted from two main changes:

- First, more units were added to the inventory, based on comments received from additional facilities that were left out of the analysis at the proposal. Many of these additional units will conduct a tune-up or install combustion controls in order to meet the work practice or CO emission limit.

- Second, the baseline emission and emission limits have been modified, which have in turn increased some of the limits for CO. As a result, the assumptions associated with how many units will conduct a tune-up or install combustion controls in order to meet the emission limits have changed. At proposal, 458 units were estimated to install a linkageless boiler management system, one boiler was expected to install a replacement burner, and 12,428 boilers were estimated to conduct a tune-up. In the final analysis, 440 units were estimated to install a linkageless boiler management system, 1 unit was expected to install a replacement LNB, and 12,838 boilers were expected to conduct a tune-up.
- Third, the treatment of gas 2 units has been modified to use a fuel gas specification. This is expected to increase the number of gas units eligible for a work practice standard instead of an emission limit. As a result of this change more of these units are expected to conduct a tune-up to fulfill the requirements of the work practice standard.

Although the age of the boiler can affect combustion efficiency, periodic tune-ups are expected to improve the combustion units of both new and existing units. Even new units are susceptible of being operated at air-to-fuel ratios that are not optimal. EPA adopted the same fuel savings assumptions for both new and existing units. The analysis estimates that if the annual tune-up provisions are incorporated, a savings of one percent would be achieved on an annual basis when compared to a new boiler installation that does not conduct routine tune-ups. The analysis projects the construction of 6,424 new liquid fired boilers at area sources, as opposed to 155 new coal units and 200 biomass units, respectively. All of these boilers are expected to conduct a tune-up in order to meet the requirements of the final rule. Liquid-fired units have the greatest energy cost on a per mmBtu basis of any of the subcategories, on which the fuel savings are based. For residual fuels, the energy cost was calculated to be $12.96/mmBtu. Distillate fuels were found to have an energy cost of either $22.66 for commercial units, units or $23.23 for industrial units. The combination of the large number of projected units in the liquid subcategory and the high energy cost resulted in the fuel savings shown.

A discussion of the methodology used to estimate cost impacts is presented in "Revised Methodology for Estimating Cost and Emission Impacts for Industrial, Commercial, and Industrial Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants—Major Source (2011)" in an Appendix.

3.2 Area Sources

To estimate the national cost impacts of the proposed rule for existing sources, EPA developed several model boilers and determined the cost of control for these model boilers. The EPA assigned a model boiler to each existing unit based on the fuel, size, and current controls.

The analysis considered all air pollution control equipment currently in operation at existing boilers. Model costs were then assigned to all existing units that could not otherwise meet the proposed standards. The resulting total national cost impact of the final rule for existing units is $487 million dollars in total annualized costs after considering fuel savings from efficiency improvements. The total annualized costs for installing controls, conducting an annual tune-up and an energy assessment, and implementing testing and monitoring requirements, is $535 million. Table 3-2 of this preamble shows the total annualized cost impacts for each subcategory.

Table 3-2. Summary of Annual Costs for New and Existing Area Sources

Source	Subcategory	Estimated/ Projected No. of Affected Units	Total Annualized Cost (million per yr)[a]
Existing Units	Coal	3,710	$37
	Biomass	10,958	$24
	Oil	168,003	$374
Facility Energy Audit	All		$52
New Units[b]	Coal	155	$0.4
	Biomass	200	$2.6
	Oil	6,424	$45

[a] TAC does not include fuel savings from improving combustion efficiency.
[b] Impacts for new units assume the number of units online in the first 3 years of this rule (2010 to 2013).

EPA also estimated the number of additional boilers that could be potentially constructed. The resulting total national cost impact of the final rule on new sources by the 3rd year, 2013, is $48 million dollars in total annualized costs. When accounting for a 1 percent fuel savings resulting from improvements to combustion efficiency, the total national cost impact on new sources is ($3.6 million). The size of the fuel savings estimate resulted primarily from the large number of new liquid fired boilers, for which the cost of energy is the highest on a per mmBtu basis. This large energy cost created to a correspondingly high cost savings with the increased combustion efficiency.

3.3 Section 3 References

Gibson et al., 2011. *Revised New Unit Analysis Industrial, Commercial, and Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants—Major Source.*

SECTION 4
ECONOMIC IMPACT ANALYSIS

EPA prepares an RIA to provide decision makers with a measure of the social costs of using resources to comply with a program (EPA, 2000). The social costs can then be compared with estimated social benefits (as presented in Section 6). As noted in EPA's (2010) *Guidelines for Preparing Economic Analyses*, several tools are available to estimate social costs and range from simple direct compliance cost methods to the development of a more complex market analysis that estimates market changes (e.g., price and consumption) and economic welfare changes (e.g., changes in consumer and producer surplus).

The Office of Air Quality Planning and Standards (OAQPS) adopted a standard market analysis as described in the Office's resource manual (EPA, 1999). The approach uses a single-period multimarket partial equilibrium model to compare pre-policy market baselines with expected post-policy market outcomes. The analysis' time horizon is the short run; some production factors are fixed and some are variable and is distinguished from the very short run where all factors are fixed and producers cannot adjust inputs or outputs (EPA, 1999, 5-6). The time horizon allows us to capture important transitory stakeholder outcomes. Key measures in this analysis include industry-level changes in price levels, production and consumption, jobs, international trade, and social costs (changes in producer and consumer surplus).

4.1 Partial Equilibrium Analysis (Multiple Markets)

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

4.1.1 Overview

Although several tools are available to estimate social costs, current EPA guidelines suggest that multimarket models "…are best used when potential impacts on related markets might be considerable" and modeling using a computable general equilibrium model is not available or practical (EPA, 2010, p. 9-21). Other guides for environmental economists offer similar advice (Berck and Hoffmann, 2002; Just, Hueth, and Schmitz, 2004). Multimarket models focus on "short-run" time horizons and measure a policy's near-term or transition costs (EPA, 1999). Note that the multimarket model is not designed to directly estimate employment impacts. Job effects are discussed later, in section 4.1.2.4. The multimarket model contains the following features:

- Industry sectors and benchmark data set
  - 100 industry sectors
  - a single benchmark year (2010)
  - industry employment data
- Economic behavior
  - industries respond to regulatory costs by changing production rates
  - market prices rise and fall to reflect higher energy and other non-energy material costs and changes in demand
  - customers respond to these price increases and consumption falls
- Model scope
  - 100 sectors are linked with each other based on their use of energy and other non-energy materials. For example, the construction industry is linked with the petroleum, cement, and steel industries and is influenced by price changes that occur in each sector. The links allow EPA to account for indirect effects the regulation has on related markets.
  - production adjustments influence employment levels
  - international trade (imports/exports) responds to domestic price changes
- Model time horizon ("short run") for a single period (2014)
  - fixed production resources (e.g., capital) lead to an upward-sloping industry supply function
  - firms cannot alter input mixes; there is no substitution among intermediate production inputs
  - price of labor (i.e., wage) is fixed
  - investment and government expenditures are fixed

4.1.2 Economic Impact Analysis Results

4.1.2.1 Market-Level Results

Market-level impacts include price and quantity adjustments including the changes in international trade (Figure 4-1). Under the major source NESHAP, the Agency's economic model suggests the average national price increases for industrial sectors are less than 0.01%, while average annual domestic production may fall by less than 0.01%. Because of higher domestic prices, imports slightly rise. Market-level effects for the area source NESHAP are smaller when compared to the major source rule; average price, production, and import changes are less than 0.01%. Industrial sector details are provided in Appendix B.

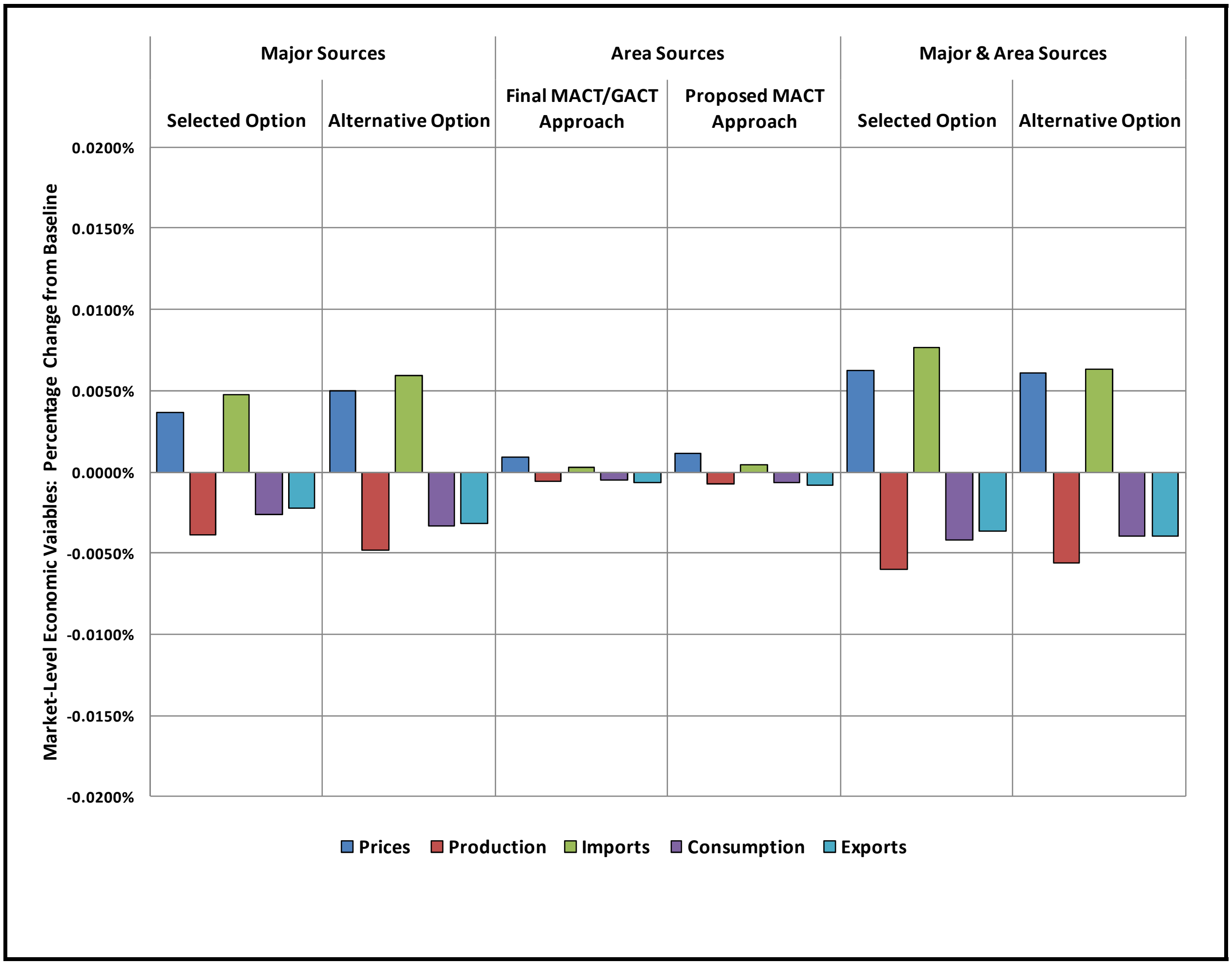

Figure 4-1. Market-Level Changes by Source and Option

4.1.2.2 Social Cost Estimates Major Source Rule

In the near term, the Agency's economic model suggests that industries are able to pass on \$0.5 billion (2008\$) of the major source rule's costs to U.S. households in the form of higher prices (Table 4-1). Existing U.S. industries' surplus falls by \$1.4 billion and the net U.S. loss in aggregate is \$1.9 billion. As U.S. prices rise, other countries are affected through international trade relationships. The price of goods produced in the United States increase slightly and domestic production declines, replaced to a certain degree by imports; the model estimates a net gain of less than \$0.1 billion to foreign companies. As shown in Figure 4-2, the U.S. surplus losses are concentrated in other services (23 percent), lumber, paper, and printing (16 percent), energy industries (15 percent), and chemicals (13 percent).

Table 4-1. Distribution of Social Costs Major Sources (billion, 2008$): 2014

Method	Selected Option	Alternative Option
Partial Equilibrium Model (Multiple Markets)		
Change in U.S. consumer surplus	−$0.530	−$0.600
Change in U.S. producer surplus	−$1.360	−$1.730
Change in U.S. surplus	−$1.890	−$2.330
Direct Compliance Costs Method (Not Modeled)		
Total annualized costs, new major sources[a]	−$0.006	−$0.920
Fuel savings, existing major sources	$0.430	$0.400
Fuel savings, new major sources[a]	Less than $0.001	Less than $0.001
Net Change in U.S. Surplus[b]	**−$1.470**	**−$1.940**
Net change in rest of world surplus	$0.060	$0.090
Net change in total surplus	−$1.410	−$1.850

[a] Estimates for the Alternative option are assumed to be the same as the Selected option.

[b] U.S. surplus changes add the partial equilibrium model estimates and the direct compliance estimates not included in the partial equilibrium model. For example, the selected option's net change in U.S. surplus is $1.890 + (0.430 – 0.006) = –$1.470 billion.

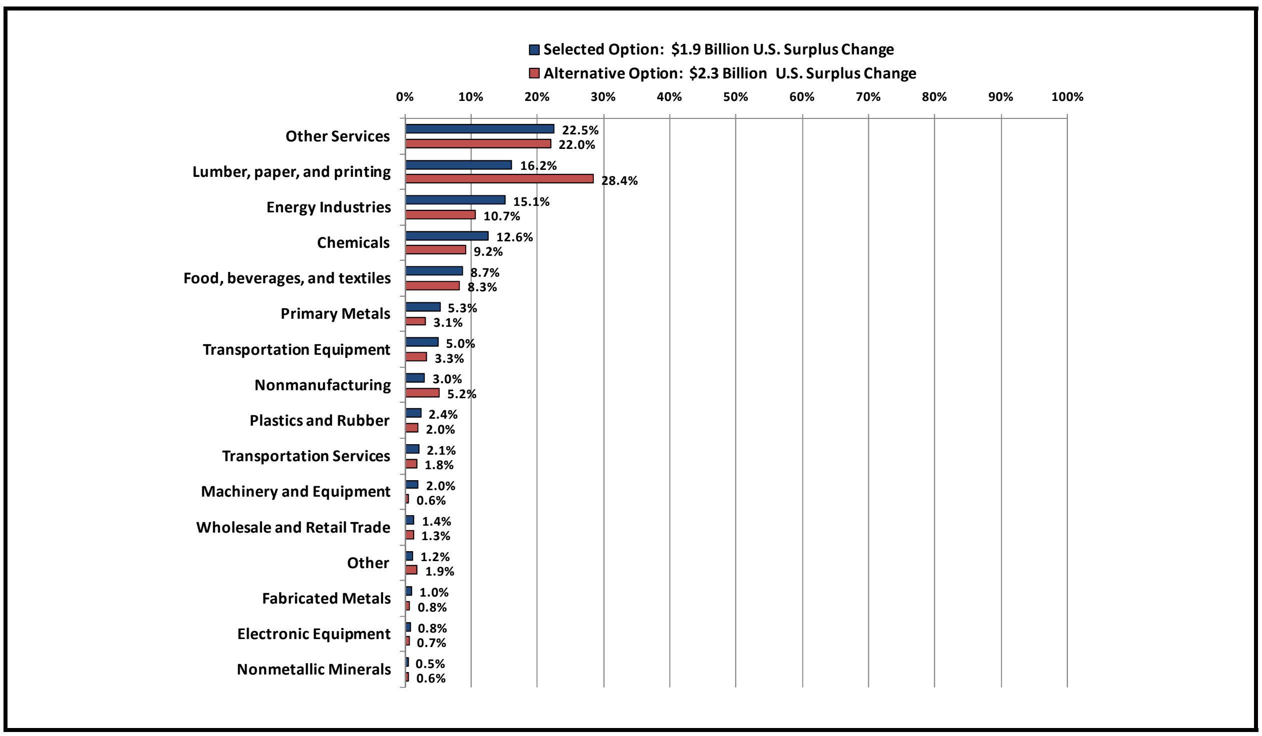

Figure 4-2. Distribution of U.S. Surplus Changes by Sector: Major Sources

The Agency also considered other elements of the engineering cost analysis that could not be modeled within the multimarket model (e.g., fuel savings benefits [existing and new major sources] and total annualized compliance costs [new major sources]). The net effect of the adjustments is a U.S. surplus loss estimate of $1.5 billion.

4.1.2.3 Social Cost Estimates Area Source Rule

In the near term, the Agency's economic model suggests that industries are able to pass on $0.2 billion (2008$) of the area source rule's costs to U.S. households in the form of higher prices (Table 4-2). Existing U.S. industries' surplus falls by $0.3 billion and the net loss for U.S. stakeholders is $0.5 billion. As U.S. prices rise, other countries are affected through international trade relationships. Households that buy U.S. exports pay higher prices and purchase fewer U.S. produced goods. Other countries that that sell goods to the United States benefit; the model estimates a net rest of the world gain of less than $0.01 billion. As shown in Figure 4-3, the U.S. surplus losses are concentrated in the other services (82 percent). Other services include information, finance and insurance, real estate, professional services, management, administrative services, education, health care, arts, accommodations, and public services.

Table 4-2. Distribution of Social Costs Area Sources (billion, 2008$): 2014

Method	Final MACT/GACT Approach	Proposed MACT Approach
Partial Equilibrium Model (Multiple Markets)		
Change in U.S. consumer surplus	−$0.240	−$0.300
Change in U.S. producer surplus	−$0.250	−$0.330
Change in U.S. surplus	−$0.490	−$0.630
Direct Compliance Costs Method (Not Modeled)		
Total annualized costs, unknown existing area sources	−$0.003	−$0.008
Total annualized costs, new area sources	−$0.050	−$0.270
Fuel savings, existing and new area sources)	$0.050	$0.050
Net Change in U.S. Surplus [a]	**−$0.490**	**−$0.850**
Net change in rest of world surplus	$0.004	$0.005
Net change in total surplus	−$0.480	−$0.850

[a] U.S. surplus changes add the partial equilibrium model estimates and the direct compliance estimates not included in the partial equilibrium model. For example, the Final MACT/GACT net change in U.S. surplus is $0.490 + (0.050 – 0.050–0.003) = –$0.490 billion.

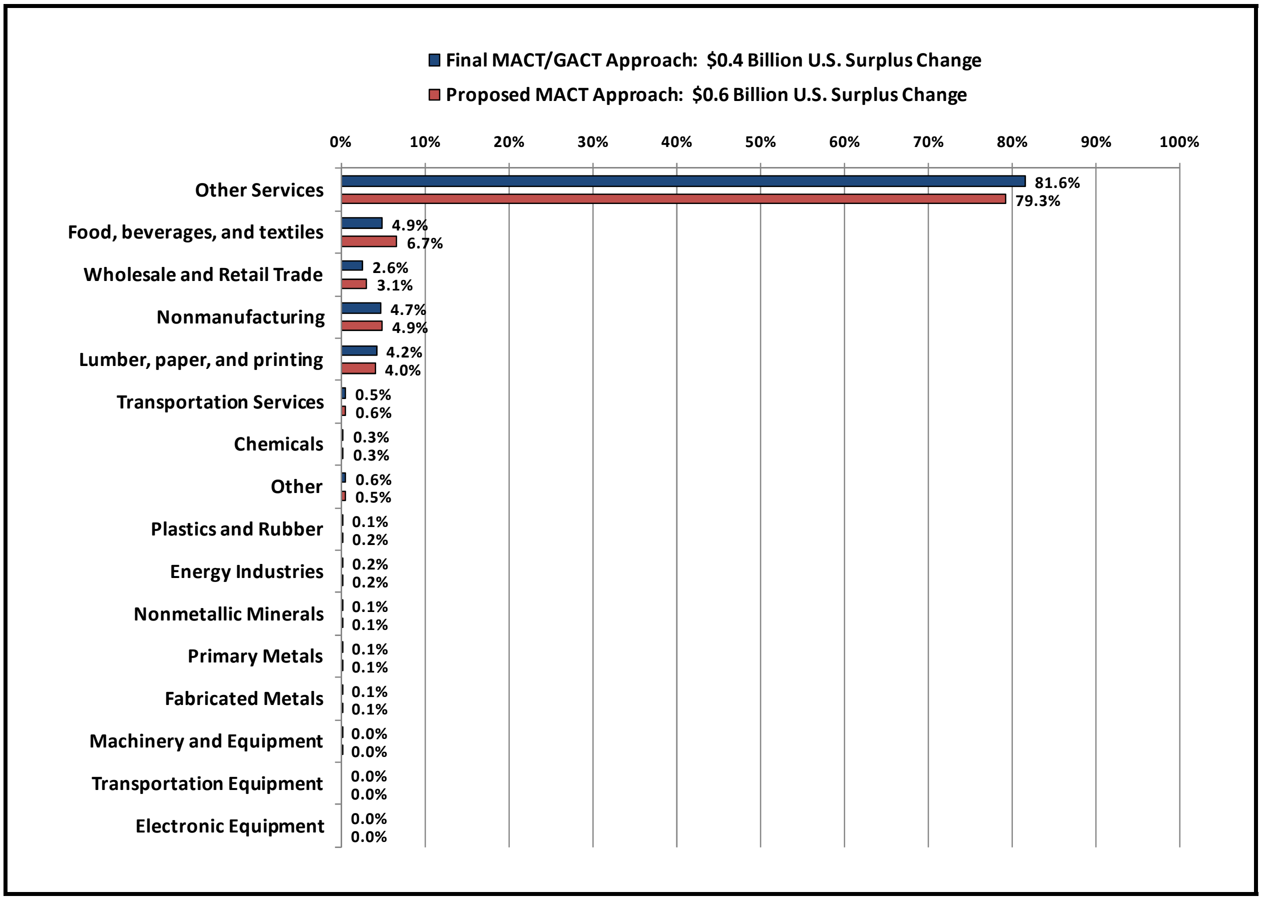

Figure 4-3. Distribution of Total Surplus Changes by Sector: Area Sources

[a] Other services include information, finance and insurance, real estate, professional services, management, administrative services, education, health care, arts, accommodations, and public services.

The Agency also considered other elements of the engineering cost analysis that could not be modeled within the multimarket model (e.g., fuel-savings benefits [existing and new area sources] and total annualized compliance costs [unknown existing and new area sources]). The net effect of the adjustments is a total surplus loss estimate of $0.5 billion.

4.1.2.4 Job Effects

4.1.2.4.1 Background

In addition to estimating this rule's social costs and benefits, EPA has estimated the employment impacts of the final rule based on Morgenstern, Pizer and Shih (2002). A stand-alone analysis of jobs is not included in a standard cost-benefit analysis. Executive Order 13563 however, states, "Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation" (emphasis added). Therefore, we have provided this analysis to inform the discussion of job impacts. EPA continues to explore the relevant theoretical and empirical literature and to seek public comments in order to ensure that such estimates are as accurate as possible.

From an economic perspective labor is an input into producing goods and services; if regulation requires that more labor be used to produce a given amount of output, that additional labor is reflected in an increase in the cost of production. Moreover, when the economy is near full employment, jobs created in one industry as a result of regulation displace jobs in other industries. On the other hand, in periods of high unemployment, an increase in labor demand due to regulation may have a stimulative effect that results in a net increase in overall employment. With significant numbers of workers unemployed, the opportunity costs associated with displacing jobs in other sectors are likely to be much smaller.

For this reason, this RIA looks carefully at a subset of the employment consequences of this final rule. It is important to note that EPA has estimated only a portion of the employment effects -- namely, those associated with the direct impacts on employment in the regulated industry. A full analysis would include estimates of the direct impacts on other industries (e.g. suppliers of pollution control equipment) as well as the indirect and induced effects on employment throughout the economy as a whole in response to changes in output and factor prices.

We expect that the rule's direct impact on employment will be small. The Agency's analysis does not include all the direct effects of this regulation. For example, EPA is currently exploring ways to quantify the job impacts in the pollution control sector that result from these and future regulations. Furthermore, we have not quantified the rule's indirect or induced impacts. What follows is an overview of the various ways that environmental regulation can affect employment, followed by a discussion of the estimated impacts of this rule. An environmental regulation can affect the demand for labor in several ways:

- **Direct Effects**:
  - **Increased prices for industry output may reduce the demand for labor:** Environmental regulations increase production costs causing firms to increase prices; higher prices reduce consumption (and production), thus reducing demand for labor within the regulated industry. The extent of this effect will depend on the extent of the price increase and the elasticity of the demand curve.
  - **Regulated firms demand labor workers to operate and maintain pollution controls within those firms.** Once pollution control equipment is installed, regulated firms may hire workers to operate and maintain it, just as they would hire

workers to produce more output. The extent of this effect will depend in part on whether the operation and maintenance of pollution controls are labor intensive

- **Increased demand for pollution control equipment and services:** When a regulation requiring emission reductions is promulgated, affected sources must immediately place orders for pollution control equipment and services. Filling these orders will require a scale-up in manufacturing of pollution control equipment, performance of engineering analyses and significant expenditures for assembly and installation of such equipment. These activities will be job-creating during the period before firms must comply with the rule, at which point all pollution control equipment must be installed and operating.

Indirect and Induced Effects:

- **Environmental regulations create employment in many basic industries**. In addition to the increase in employment in the environmental protection industry (increased orders for pollution control equipment), environmental regulations also create employment in industries that provide intermediate goods to the environmental protection industry. For example, capital expenditures to reduce air pollution involve the purchase of abatement equipment. The equipment manufacturers, in turn, order steel, tanks, vessels, blowers, pumps, and chemicals to manufacture and install the equipment. On the other hand, demand for labor will decrease in sectors that supply inputs for, or demand the outputs of the regulated industry. None of these impacts is accounted for in the current analysis. We also do not estimate employment impacts "induced" by increased output of the environmental protection sector, or decreased output of the regulated sectors.

4.1.2.4.2 Methodology and Results

The estimated impacts of the final rule on employment in affected sources are based on an empirically derived relationship reported in Morgenstern, Pizer and Shih (2002), a peer-reviewed, published study. Estimates of the employment impacts of the capital investments and other non-recurring requirements of the rule are derived from the cost analysis developed for the regulation.[1]

Morgenstern, Pizer and Shih (2002): Overview of Conceptual Approach

The fundamental insight of Morgenstern, Pizer and Shih (2002) is that environmental regulations can be understood as requiring regulated firms to add a new output (environmental quality) to their product mixes. Although legally compelled to satisfy this new demand, regulated firms have to finance this additional production with the proceeds of sales of their other (market) products. Satisfying this new demand requires additional inputs, including labor, and may alter the relative proportions of labor and capital used by regulated firms in their production processes.

[1] Richard D. Morgenstern, William A. Pizer, and Jhih-Shyang Shih, *Journal of Environmental Economics and Management* | May 2002 | Vol. 43, no. 3 | pp. 412-436.

Thus, Morgenstern et al., decompose the overall effect of a regulation on employment into the following three subcomponents:

- The "Demand Effect": higher production costs raise market prices,reducing consumption (and production), thereby reducing demand for labor within the regulated industry [2;]

- The "Cost Effect": As production costs increase, plants use more of all inputs, including labor, to maintain a given level of output. For example, in order to reduce pollutant emissions while holding output levels constant, regulated firms may require additional labor;

- The "Factor-Shift Effect": Regulated firms' production technologies may be more or less labor intensive after complying with a regulation (i.e., more/less labor is required per dollar of output).

Decomposing the overall employment impact of environmental regulation into three subcomponents clarifies the conceptual relationship between environmental regulation and employment in regulated sectors, and permitted Morgenstern, et al. to provide an empirical estimate of the net impact. For present purposes, the net effect is of particular interest, and is the focus of our analysis.

Morgenstern, Pizer and Shih (2002): Empirical Results

Morgenstern et al. empirically estimate a model for four highly polluting, regulated industries (pulp and paper, plastics, petroleum refining and steel) to examine the effect of higher abatement costs from regulation on employment. They conclude that increased abatement expenditures generally do not cause a significant change in employment. More specifically, their results show that, on average across the four industries, each additional $1 million spending on pollution abatement results in a (statistically insignificant) net increase of 1.55 (+/- 2.24) jobs.[3] "In plastics and petroleum, [Morgenstern et al] find that increased regulation raises employment by a small but statistically significant amount: 6.9 and 2.2 jobs per million dollars of regulatory expense, respectively. In pulp and paper and steel, the estimates are even smaller and insignificantly different from zero."[4] By applying these estimates to pollution abatement costs, we estimated the

[2] The Morgenstern et al. results rely on industry demand and supply elasticities to determine cost pass-through and reductions in output.

[3] These results are similar to Berman and Bui, who find that while sharply increased air quality regulation in Los Angeles to reduce NOx emissions resulted in large abatement costs they did not result in substantially reduced employment. "Environmental regulation and labor demand: evidence from the South Coast Air Basin." *Journal of Public Economics* 79(2): 265-295.

[4] Morgenstern, Pizer and Shih, p. 413.

net employment effect for major and areas sources to range from -4,100 to +8,500 jobs in the directly affected sectors with a central estimate of +2,200 (Table 4-3).[5, 6]

[5] Since Morgenstern's analysis reports environmental expenditures in $1987, we make an inflation adjustment the engineering cost analysis using GDP implicit price deflator (64.76/108.48) = 0.60)

[6] Net employment effect = 1.55× $2,400 million × 0.60

Table 4-3. Employment Impacts Using Morgenstern, Pizer, Shih (2002) (FTE)

	Demand Effect	Cost Effect	Factor Shift Effect	Net Effect
Change in Full-Time Jobs per Million Dollars of Environmental Expenditure[a]	−3.56	2.42	2.68	1.55
Standard Error	2.03	1.35	0.83	2.24
EPA estimate for Major Sources Rule	−3,900 −8,200 to +500	2,600 +900 to +4,400	2,900 0 to +5,800	1,700 −3,100 to +6,500
EPA estimate for Area Source Rule	−1,200 −2,600 to +100	800 +300 to +1,400	900 0 to +1,800	500 −1,000 to +2,000
EPA estimate for both Rules [b]	−5,100 −10,800 to +600	3,500 +1,100 to +5,800	3,900 0 to 7,700	2,200 −4,100 to +8,500

[a] Estimates from Morgenstern, Pizer, and Shih (2002) expressed in 2010 dollars using the GDP price deflator (see footnote 7).
[b] Totals may not add due to independent rounding.

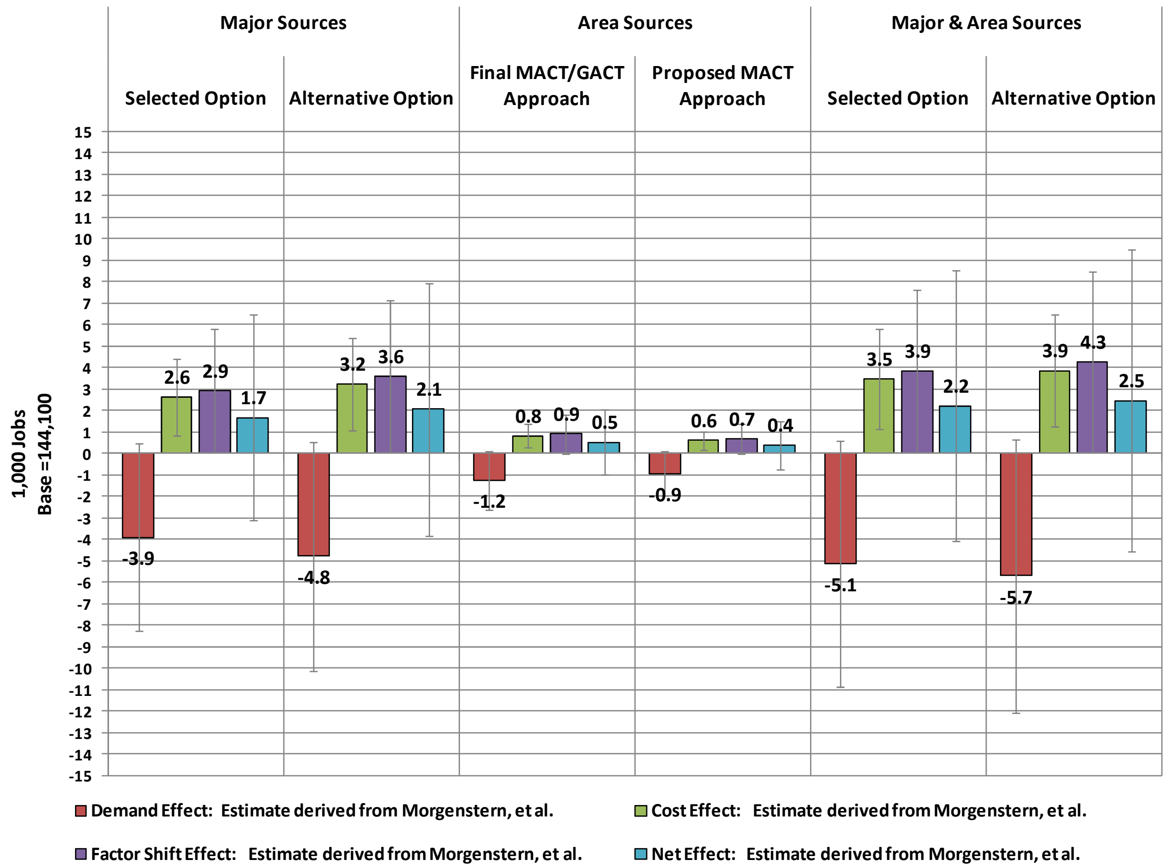

Figure 4-3. Employment Impacts Using Morgenstern, Pizer, Shih (2002) (1,000 FTEs)

Limitations of the Analysis

Although the Morgenstern et al. paper provides information about the potential job effects of environmental protection programs, there are several caveats associated with using those estimates to analyze the final rule. First, the Morgenstern et al. estimates presented in Table 4-3 and used in EPA's analysis represent the weighted average parameter estimates for a set of manufacturing industries (pulp and paper, plastics, petroleum, and steel). This set of industries only partially overlaps with the sectors affected by this rule. Second, relying on Morgenstern et al. implicitly assumes that estimates derived from 1979–1991 data are still applicable. Third, the methodology used in Morgenstern et al. assumes that regulations affect plants in proportion to their total costs. In other words, each additional dollar of regulatory burden affects a plant by an amount equal to that plant's total costs relative to the aggregate industry costs. By transferring the estimates, EPA assumes a similar distribution of regulatory costs by plant size and that the regulatory burden does not disproportionately fall on smaller or larger plants. Further, Morgenstern et al. does not include most indirect effects and all induced effects.

SECTION 5
SMALL ENTITY ANALYSES

The RFA as amended by 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 (SISNOSE). Small entities include small businesses, small governmental jurisdictions, and small not-for-profit enterprises. EPA assessed the potential small entity economic impacts using a screening analysis. After reviewing screening analysis results, EPA has determined it cannot certify that the rules will not have a SISNOSE and presumes that both rules are not eligible for certification under the RFA as amended by SBREFA.

5.1 Small Entity Screening Analysis

5.1.1 Small Businesses

The sectors covered by the rule were identified through lists of small entities at major and area sources provided by the engineering analysis. Table 5-1 provides a list of the sectors affected (3-digit NAICS) and the range of SBA size definitions.

5.1.1.1 Representative Small Business Analysis Using Census Statistics of U.S. Businesses

For each 3-digit NAICS code, the SUSB provides national information on the distribution of economic variables by industry and enterprise size (U.S. Census Bureau, 2008). 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.[1] Statistics include the total number of establishments and receipts for all entities within an industry; however, only a subset of entities will be covered by the rule. SUSB also provides statistics by enterprise employment and receipt size.

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

- *Establishment*: 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.

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

Table 5-1. Affected Sectors and Size Standards

2007 NAICS	Description	Size Standard (Effective August 22, 2008)
211	Oil and Gas Extraction	500 employees
212	Mining (except Oil and Gas)	500 employees
221	Utilities	[a]
311	Food Manufacturing	500 to 1,000 employees
312	Beverage and Tobacco Product Manufacturing	500 to 1,000 employees
313	Textile Mills	500 to 1,000 employees
321	Wood Product Manufacturing	500 employees
322	Paper Manufacturing	500 to 750 employees
323	Printing and Related Support Activities	500 employees
324	Petroleum and Coal Products Manufacturing	Typically 500 to 1,500 employees
325	Chemical Manufacturing	500 to 1,000 employees
326	Plastics and Rubber Products Manufacturing	Typically 500 to 1,000 employees
327	Nonmetallic Mineral Product Manufacturing	500 to 1,000 employees
331	Primary Metal Manufacturing	500 to 1,000 employees
332	Fabricated Metal Product Manufacturing	500 to 1,500 employees
335	Electrical Equipment Manufacturing	500 to 1,000 employees
336	Transportation Equipment Manufacturing	500 to 1,000 employees
337	Furniture and Related Product Manufacturing	500 employees
339	Miscellaneous Manufacturing	500 employees
423	Merchant Wholesalers, Durable Goods	100 employees
493	Warehousing and Storage	$25.5 million in annual receipts
562	Waste Management and Remediation Services	Typically $7 to $14 million in annual receipts
611	Educational Services	Typically $7 to $35.5 million in annual receipts

[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.

- *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 multi-establishment company forms one enterprise—the enterprise employment and annual payroll are summed from the associated establishments. Enterprise size designations are determined by the total 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.

The analysis generated a set of establishment sales tests (represented as cost-to-receipt ratios) for NAICS codes associated with sectors listed in Table 5-2. 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 regulatory program.

Table 5-2. Major Sources: Sales Tests Using Small Companies Identified in the Combustion Survey

Sample Statistic	Proposal	Selected Option	Alternative Option
Mean	4.9%	4.0%	3.8%
Median	0.4%	0.2%	0.4%
Maximum	72.9%	59.8%	31.4%
Minimum	<0.01%	<0.01%	<0.01%
Ultimate parent company observations	50	50	50
Ultimate parent companies with sale tests exceeding 3%	14	8	13

For each representative establishment in the SUSB data, we developed a range of facility-level cost numerators based on the engineering cost analysis. For major sources, we used the maximum and minimum small entity facility-level costs observed within each 3-digit NAICS code. For area sources, we were limited to two representative small entity facility-level costs (approximately $27,000,000 to $43,000).[2] Using these cost data and the Census estimates of average establishment receipts, a substantial number of SUSB NAICS/enterprise categories have ratios over 3% (Figure 5-1).

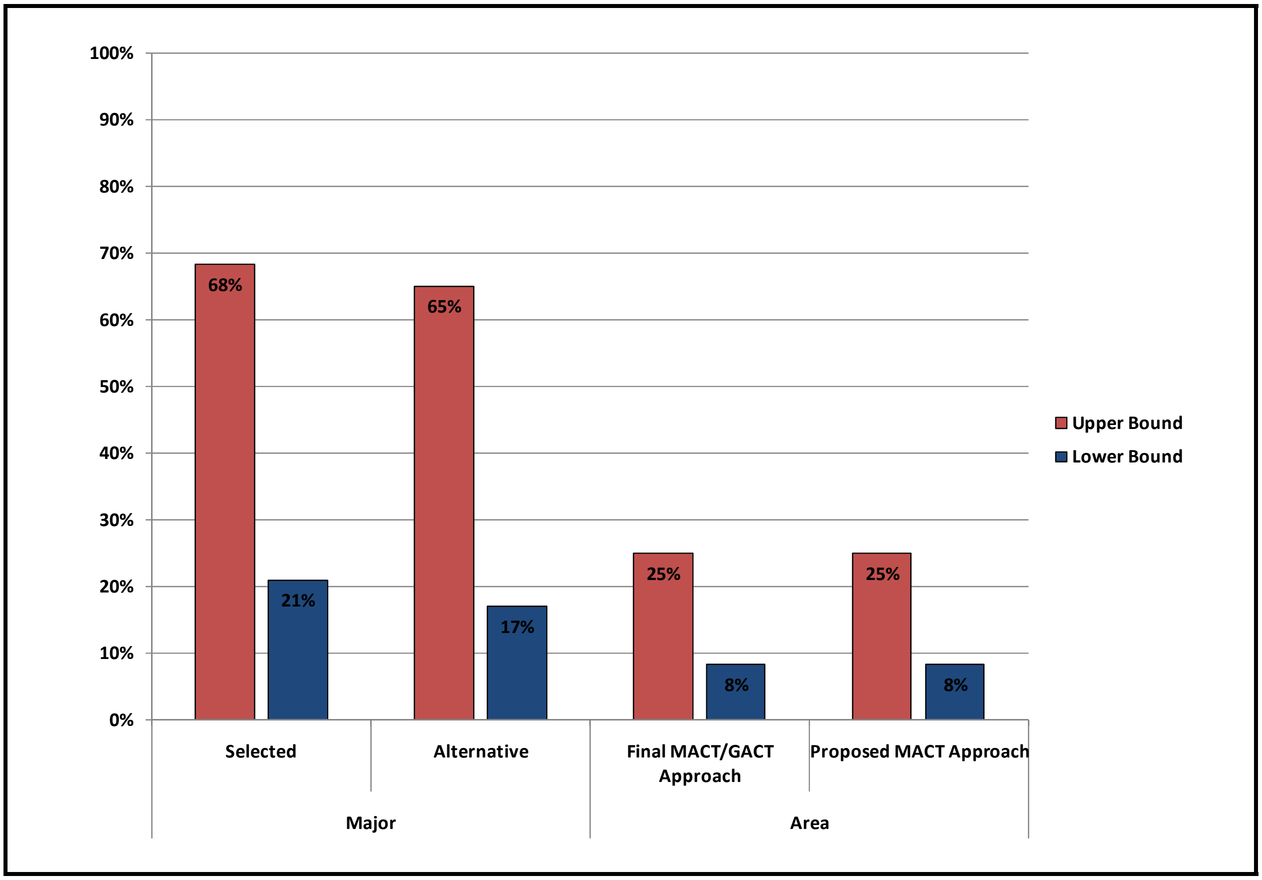

Figure 5-1. Share of NAICS/Enterprise Employment Categories (<500 employees) with Sales Tests Exceeding 3%

5.1.1.2 Additional Small Business Analysis Using Sample of Small Businesses Identified in Combustion Facility Survey

Next, we performed a more detailed analysis that compares the Census SUSB representative small entity results with a firm-specific sample of major small private enterprises. In this approach, we identified a sample of survey facility names listed as small, traced the ultimate parent company name to verify the facility was owned by a small business, and collected

[2] Prior to computing the cost-to-receipt ratios, we adjusted the engineering compliance costs to reflect 2002 dollars using the implicit price deflators for gross domestic product (GDP). The values used are 2002 = 92.118 and 2008 = 108.483 (U.S. BEA, 2010).

the most recent parent company sales and employment figures. As Table 5-2 shows, the average cost-to-sales ratios for small major source companies are above 3%. The median ratios are below one percent.

5.1.2 Small Governmental Jurisdictions and Not-for-Profit Enterprises

In addition to the private sector, this rule also covers sectors that include entities owned by small and large governments and not-for-profit enterprises. Given the uncertainty and data limitations associated with identifying and appropriately classifying these entities, we computed a "revenue" test, where the annualized compliance cost is a percentage of annual revenues (U.S. Census, 2005a and b).

Compliance costs were estimated for model facilities for major and area sources for multiple options. A summary of the compliance costs used for the small entity analysis follows:

Major Sources:

- *Selected option*: $1.1 million (median cost small public facility)
- *Alternative Option*: $0.9 million (median cost small public facility)

Area Sources[3]:

- *Final MACT/GACT Approach and Proposed MACT Approach*:

– Other Public: $45,000
– Hospital: $11,300
– Schools: $4,500
– Churches: $2,200

From the 2002 Census (in 2008 dollars), the average revenue for small governments (counties and municipalities with populations fewer than 10,000) are $3 million per entity, and the average revenue for local governments with populations fewer than 50,000 is $7 million per entity. Churches are assumed to have an operation budget of $150,000.

Representative small major public entities would have cost-to-revenue ratios above 10 percent. The following types of representative small area source facilities would have cost-to-revenue ratios exceeding 1 percent but below 3 percent:

[3] Graham Gibson, Susan McClutchey, and Amanda Singleton, ERG. (January, 2011). Methodology for Estimating Impacts from Industrial, Commercial, Institutional Boilers at Area Sources of Hazardous Air Pollutant Emissions.

- *Final MACT/GACT Approach*: other public (ratio > 1.7 percent) and churches (ratio = 1.5 percent)
- *Proposed MACT Approach*: other public (ratio > 1.7 percent) and churches (ratio = 1.5 percent)

5.2 Final Regulatory Flexibility Analysis (FRFA): Major Sources

Pursuant to section 603 of the RFA, EPA prepared an initial regulatory flexibility analysis (IRFA) for the proposed rule and convened a Small Business Advocacy Review Panel to obtain advice and recommendations of representatives of the regulated small entities. A detailed discussion of the Panel's advice and recommendations is found in the final Panel Report (Docket ID No. EPA-HQ-OAR-2002-0058-0797). A summary of the Panel's recommendations is also presented in the preamble to the proposed rule at 75 FR 32044-32045 (June 4, 2010). In the proposed rule, EPA included provisions consistent with four of the Panel's recommendations. As required by section 604 of the RFA, we also prepared a final regulatory flexibility analysis (FRFA) the final rule.

5.2.1 Need for Rule and Objectives

The rule is intended to reduce emissions of HAP as required under section 112 of the CAA. Section II.A of the final rule's preamble describes the reasons that EPA is finalizing this action.

5.2.2 Summary of the Significant Issues raised by the Public Comments and Agency Assessment

Many significant issues were raised during the public comment period, and EPA's responses to those comments are presented in section V of this preamble or in the response to comments document contained in the docket. Significant changes to the rule that resulted from the public comments are described in section IV of the final rule's preamble.

The primary comments on the IRFA were provided by SBA, with the remainder of the comments generally supporting SBA's comments. Those comments included the following: EPA should have adopted a health-based compliance alternative (HBCA) which provides alternative emission limits for threshold chemicals; EPA should have adopted additional subcategories, including the following: subcategories based on fuel type (including coal rank, bagasse, biomass by type, and oil by type), unit design type (e.g., process heater, fluidized bed, stoker, fuel cell, suspension burner), duty cycle, geographic location, boiler size, burner type (with and without low-NO_x burners), and hours of use (limited use); EPA should have minimized facility monitoring and reporting requirements; EPA should not have proposed the energy audit requirement; EPA's proposed emissions standards are too stringent; and, EPA should provide more flexibility for emissions averaging.

In response to the comments on the IRFA and other public comments, EPA made the following changes to the final rule. EPA adopted additional subcategories, including a limited-use subcategory for units that operate less than 10 percent of the operating hours in a year, a non-continental liquid unit subcategory for units with the unique challenges faced by remote island locations, and a combination suspension/grate boiler subcategory. EPA also consolidated the subcategories for units combusting various types of solid fuels, which will simplify compliance and will allow units to combust varying percentages of different solid fuels without triggering subcategory changes. EPA also decreased monitoring and testing costs by eliminating the CO CEMS requirement for units greater than 100 mmBtu/hr and changing the dioxin testing requirement to a one-time test. The final rule also includes work practice standards for additional subcategories, including limited-use units, new small units, and units combusting gaseous fuels that are demonstrated to have similar contaminant levels to natural gas. Finally, EPA is finalizing emission limits that are less stringent than the proposed limits for most of the category/pollutant combinations. The emission limit changes are largely due to the changes in subcategories, data corrections, and incorporation of new data into the floor calculations. Additional details on the changes discussed in this paragraph are included in sections IV and V of the final rule's preamble.

5.2.3 Description of and Estimate of the Number of Small entities to Which the Rules Will Apply

Based on the distribution of major source facilities with affected boilers or process heaters reported in the 2008 survey entitled "Information Collection Effort for Facilities with Combustion Units. (ICR No. 2286.01)," there are 1,639 existing facilities with affected boilers or process heaters. Of these, 94 percent are located in the private sector and the remaining 6 percent are located in the public sector. Table 5-3 summarizes the types of small entities expected to be affected by the major source rule. The number of small entities is based on the facilities which responded to the ICR by confirming small entity status. If that question was not answered, or if the facility answered that their small entity status was unknown, it was assumed that those facilities were not small entities. The summary in Table 5-3 is for major source facilities which have at least one boiler or process heater expected to be covered by the rule. Table 5-4 summarizes the EPA estimates of the number of area source facilities expected to be affected by the major source rule (84,700 total). EPA does not have sufficient information to estimate the number of small entities expected to be covered by the area source rule.

Table 5-3. Information Collection Effort for Facilities with Combustion Units: Major Sources

NAICS	NAICS Description	Total Number of Facilities	Total Self-Reported Facilities Owned by Small Businesses
111	Crop Production	1	0
113	Forestry and Logging	1	0
115	Support Activities for Agriculture and Forestry	1	0
211	Oil and Gas Extraction	24	3
212	Mining (Except Oil and Gas)	14	1
221	Utilities	183	23
311	Food Manufacturing	110	7
312	Beverage and Tobacco Product Manufacturing	5	0
313	Textile Mills	14	1
314	Textile Product Mills	1	0
316	Leather and Allied Product Manufacturing	3	1
321	Wood Product Manufacturing	183	18
322	Paper Manufacturing	186	14
323	Printing and Related Support Activities	33	5
324	Petroleum and Coal Products Manufacturing	84	8
325	Chemical Manufacturing	220	17
326	Plastics and Rubber Products Manufacturing	89	11
327	Nonmetallic Mineral Product Manufacturing	41	2
331	Primary Metal Manufacturing	57	6
332	Fabricated Metal Product Manufacturing	46	8
333	Machinery Manufacturing	13	0
334	Computer and Electronic Product Manufacturing	2	0
335	Electrical Equipment, Appliance, and Component Manufacturing	12	0
336	Transportation Equipment Manufacturing	100	7
337	Furniture and Related Product Manufacturing	45	8
339	Miscellaneous Manufacturing	15	1
423	Durable Goods Merchant Wholesalers	1	1
424	Nondurable Goods Merchant Wholesalers	1	0
441	Motor Vehicle and Parts Dealers	1	0
481	Air Transportation	7	0
482	Rail Transportation	1	0
486	Pipeline Transportation	60	0
488	Support Activities for Transportation	3	0
493	Warehousing and Storage	5	1

(continued)

Table 5-3. Information Collection Effort for Facilities with Combustion Units: Major Sources (continued)

NAICS	NAICS Description	Total Number of Facilities	Total Self-Reported Facilities Owned by Small Businesses
531	Real Estate	1	0
541	Professional, Scientific, and Technical Services	8	0
561	Administrative and Support Services	1	0
562	Waste Management and Remediation Services	7	2
611	Educational Services	29	2
622	Hospitals	4	0
623	Nursing and Residential Care Facilities	1	0
811	Repair and Maintenance	1	0
921	Executive, Legislative, and Other General Government Support	2	0
928	National Security and International Affairs	23	0

As discussed in Section 5.1 of this RIA, using these cost data and the Census estimates of average establishment receipts, a substantial number of SUSB NAICS/enterprise categories have ratios over 3%. EPA determined 8 of 50 small ultimate parent companies owning major source facilities listed in Table 5-3 will experience an impact of over 3 percent of revenues. Representative small major public entities would have cost-to-revenue ratios above 10 percent.

5.2.4 Description of the Projected Reporting, Record keeping and Other Compliance Requirements of the Rule

The information collection activities in this ICR include initial and annual stack tests, fuel analyses, operating parameter monitoring, continuous O_2 monitoring for all units greater than 10 mmBtu/hr, continuous emission monitoring for PM at units greater than 250 mmBtu/hr, certified energy audits, annual or biennial tune-ups (depending on the size of the combustion equipment), preparation of a startup, shutdown, malfunction plan (SSMP), preparation of a site-specific monitoring plan and a site-specific fuel monitoring plan, one-time and periodic reports, and the maintenance of records.

For sources that can demonstrate compliance through fuel analysis, the regulation requires an initial fuel analysis and monthly fuel analyses. Sources must conduct additional fuel analyses if they burn a new type of fuel. For sources that are demonstrating that their gaseous fuels other than natural gas and refinery gas meet the specifications for H_2S and Hg contained in the final rule, they must conduct either an initial or monthly fuel analysis to remain in the gas 1 subcategory. If the content of these constituents are not going to exceed the specifications, these units may conduct an initial testing and include a statement that the gas will not exceed the specification in the initial Notification of Compliance Status. If the gaseous fuel constituents will vary, the unit is required to conduct monthly testing and maintain records to demonstrate that the gaseous fuels meet the specifications.

An initial performance test must be completed for particulate matter, mercury, hydrogen chloride, carbon monoxide, and dioxin and furans for affected sources with applicable emission limits. During the initial performance test, the owner or operator must establish maximum or minimum values for each operating parameter. Thereafter, the owner or operator must, in some cases, conduct annual stack tests for particulate matter, mercury, hydrogen chloride, carbon monoxide, and dioxin and furans and must continuously monitor the operating parameters. If a source is required to use PM CEMS, performance testing is not required for particulate matter.

Following the initial performance test, the owner or operator must submit a report that documents the performance test results and the values for their required operating parameters.

All existing units will be required to conduct an initial certified energy audit by qualified personnel which includes a visual inspection of the boiler system, establishing operating characteristics, identifying major energy consuming systems and energy savings potential, reviewing available engineering plans, and listing major energy conservation measures. A signed certification that an audit has been completed should be submitted to the Agency for each energy audit.

All new and existing small and limited use units, and all large units firing natural gas, refinery gas, or other gas 1 fuels meeting the fuel spec can demonstrate compliance by conducting a tune-up of the boiler. Small and limited use units are requested to conduct a tune-up biennially and large natural gas, refinery gas, or other gas 1 units will conduct a tune-up annually. Any large natural gas, refinery gas, or other gas 1 unit will also submit a notification of alternative fuel use if the unit fires alternative fuels during periods of gas curtailment or gas supply emergencies.

For all units other than small and limited use boilers and process heaters and units firing natural gas a semiannual report is required that documents the values for the operating parameters; any deviation; the results of any annual stack tests; the results of any fuel analysis and emissions calculations; fuel usage, and if no deviation occurred, a statement that no deviations occurred.

As specified in the ICI Boiler and Process Heater NESHAP, owners or operators of boilers and process heaters must keep records of certain parameters and information for a period of five years. Owners or operators must maintain records of the initial performance test, annual stack tests, fuel analyses, and any subsequent stack tests or fuel analyses. Owners or operators must also maintain records of the monitoring data for the operating parameters and daily fuel usage.

Owners or operators must also maintain records for boiler or process heater malfunctions and any deviations from the operating parameters. Records must also be maintained of all monitoring device calibration data.

The Agency expects that persons with knowledge of .pdf software, spreadsheet and relational database programs will be necessary in order to prepare the report or record. Based on experience with previous emission stack testing, we expect most facilities to contract out preparation of the reports associated with emission stack testing, including creation of the Electronic Reporting Tool submittal, which will minimize the need for in depth knowledge of databases or spreadsheet software at the source. We also expect affected sources will need to work with web-based applicability tools and flowcharts to determine the requirements applicable to them, knowledge of the heat input capacity and fuel use of the combustion units at each facility will be necessary in order to develop the reports and determine initial applicability to the rule. Affected facilities will also need skills associated with vendor selection in order to identify service providers that can help them complete their compliance requirements, as necessary.

5.2.5 Description of the steps the Agency has Taken to Minimize the Significant Economic Impact on Small Entities

While EPA did make significant changes based on public comment, EPA did not finalize a HBCA or HBELs and is maintaining, but clarifying, the energy assessment requirement. The discussion of the HBCA decision is included in section V of this preamble. Some changes to the energy assessment requirement that will reduce costs for small entities include a the following provisions: the energy assessment for facilities with affected boilers and process heaters using less than 0.3 trillion Btu per year heat input will be one day in length maximum. The boiler system and energy use system accounting for at least 50 percent of the energy output will be evaluated to identify energy savings opportunities, within the limit of performing a one-day energy assessment; and the energy assessment for facilities with affected boilers and process heaters using 0.3 to 1.0 trillion Btu per year will be 3 days in length maximum. The boiler system and any energy use system accounting for at least 33 percent of the energy output will be evaluated to identify energy savings opportunities, within the limit of performing a 3-day energy assessment. While EPA did not make major adjustments to the emissions averaging provisions, the change to a solid fuel subcategory will enable all solid fuel-fired units at a facility to use the emissions averaging provision for Hg, PM, and HCl.

As required by section 212 of SBREFA, EPA also is preparing a Small Entity Compliance Guide to help small entities comply with this rule. Small entities will be able to obtain a copy of the Small Entity Compliance guide at the following web site: http://www.epa.gov/ttn/atw/boiler/boilerpg.html.

5.3 Final Regulatory Flexibility Analysis (FRFA): Area Sources

Pursuant to section 603 of the RFA, EPA prepared an initial regulatory flexibility analysis (IRFA) for the proposed rule and convened a Small Business Advocacy Review Panel to obtain advice and recommendations of representatives of the regulated small entities. A detailed discussion of the Panel's advice and recommendations is found in the final Panel Report (Docket ID No. EPA-HQ-OAR-2002-0058-0797). A summary of the Panel's recommendations is also presented in the preamble to the proposed rule at 75 FR 32044-32045 (June 4, 2010). In the proposed rule, EPA included provisions consistent with four of the Panel's recommendations. As required by section 604 of the RFA, we also prepared a final regulatory flexibility analysis (FRFA) the final rule.

5.3.1 Need for Rule and Objectives

The rule is intended to reduce emissions of HAP as required under section 112 of the CAA. Section II.A of the final rule's preamble describes the reasons that EPA is finalizing this action.

5.3.2 Summary of the Significant Issues raised by the Public Comments and Agency Assessment

Many significant issues were raised during the public comment period, and EPA's responses to those comments are presented in section V of this preamble or in the response to comments document contained in the docket. Significant changes to the rule that resulted from the public comments are described in section IV of the final rule's preamble.

The primary comments on the IRFA were provided by SBA, with the remainder of the comments generally supporting SBA's comments. Those comments applicable to the proposal regarding area source boilers included the following: EPA should have adopted additional subcategories, including the following: unit design type (e.g., fluidized bed, stoker, fuel cell, suspension burner), duty cycle, geographic location, boiler size, burner type (with and without low-NO_x burners), and hours of use (limited use); EPA should have minimized facility monitoring and reporting requirements; EPA should not have proposed the energy audit requirement; and EPA's proposed emissions standards are too stringent.

In response to the comments on the IRFA and other public comments, EPA made the following changes to the final rule. EPA is promulgating management practice standards requiring the implementation of a boiler tune-up program for area source boilers in the biomass and oil subcategories instead of the proposed CO emission limits. This change will significantly reduce the monitoring and testing costs for existing and new biomass-fired and oil-fired area source boilers. EPA also decreased monitoring and testing costs for coal-fired area source boilers by eliminating the CO CEMS requirement for boilers greater than 100 MMBtu/h. The final rule also includes work practice standards or management practice standards, instead of emission limits, for new area source boilers less than 10 MMBtu/h. Finally, EPA is finalizing emission limits that are less stringent than the proposed limits. The emission limit changes are largely due to the changes in data corrections and incorporation of new data into the floor calculations. Additional details on the changes discussed in this paragraph are included in sections IV and V of the final rule's preamble.

5.3.3 Description of and Estimate of the Number of Small entities to Which the Rules Will Apply

Table 5-4 summarizes the EPA estimates of the number of area source facilities expected to be affected by the major source rule (84,700 total). EPA does not have sufficient information to estimate the number of small entities expected to be covered by the area source rule.

As discussed in Section 5.1 of this RIA, using these cost data and the Census estimates of average establishment receipts, a substantial number of SUSB NAICS/enterprise categories have ratios over 3%. The following types of representative small area source public facilities would have cost-to-revenue ratios exceeding 1 percent but below 3 percent: other public facilities (ratio > 1.7 percent) and churches (ratio = 1.5 percent).

Table 5-4. **Estimated Affected Facilities Using 13 State Boiler Inspector Inventory: Area Sources**

SIC	Total Number of Affected Facilities in SIC Code
01	0
02	247
07	0
09	0
14	83
16	0
17	247
20	5,733
23	83
24	2,676
26	0
40	329
41	0
42	83
43	0
44	0
45	0
47	0
48	741
50	165
51	247
52	0
53	494
54	0
55	801
56	0
57	0
58	905
59	288
60	329
64	0

(continued)

Table 5-4. Estimated Affected Facilities Using 13 State Boiler Inspector Inventory: Area Sources (continued)

SIC	Total Number of Affected Facilities in SIC Code
65	2,878
70	4,893
72	2,138
73	165
75	1,606
76	0
79	1,151
80	15,293
81	0
82	33,303
83	0
84	165
86	3,330
87	666
91 to 98	5,098
Unknown	576

5.3.4 Description of the Projected Reporting, Record keeping and Other Compliance Requirements of the Rule

The information collection activities in this ICR include initial and annual stack tests, fuel analyses, operating parameter monitoring, continuous O_2 monitoring for all coal-fired area source boilers greater than 10 MMBtu/h, certified energy assessments for area source facilities having a boiler greater than 10 MMBtu/h, biennial tune-ups, preparation of a startup, shutdown, malfunction plan (SSMP), preparation of a site-specific monitoring plan and a site-specific fuel monitoring plan, one-time and periodic reports, and the maintenance of records. Based on 13 states' inventories of boilers, there are an estimated 92,000 existing facilities with affected boilers. It is estimated that 53 percent are located in the private sector and the remaining 47 percent are located in the public sector. Of these, only about 0.3 percent of the area source facilities are subject to emission limits and the testing and monitoring requirements in the final rule. A table included in the FRFA summarizes the types and number of each type of small entities expected to be affected by the area source rule.

The Agency expects that persons with knowledge of .pdf software, spreadsheet and relational database programs will be necessary in order to prepare the report or record. Based on experience with previous emission stack testing, we expect most facilities to contract out preparation of the reports associated with emission stack testing, including creation of the Electronic Reporting Tool submittal which will minimize the need for in depth knowledge of databases or spreadsheet software at the source. We also expect affected sources will need to work with web-based applicability tools and flowcharts to determine the requirements applicable to them, knowledge of the heat input capacity and fuel use of the combustion units at each facility will be necessary in order to develop the reports and determine initial applicability to the rule. Affected facilities will also need skills associated with vendor selection in order to identify service providers that can help them complete their compliance requirements, as necessary.

5.3.5 Description of the steps the Agency has Taken to Minimize the Significant Economic Impact on Small Entities

While EPA did make significant changes based on public comment, EPA is maintaining, but clarifying, the energy assessment requirement. Some changes to the energy assessment requirement that will reduce costs for small entities include a the following provisions: the energy assessment for facilities with affected boilers using less than 0.3 trillion Btu per year heat input will be one day in length maximum. The boiler system and energy use system accounting for at least 50 percent of the energy output will be evaluated to identify energy savings opportunities, within the limit of performing a one-day energy assessment; and the energy assessment for facilities with affected boilers using 0.3 to 1.0 trillion Btu per year will be 3 days in length maximum. The boiler system and any energy use system accounting for at least 33 percent of the energy output will be evaluated to identify energy savings opportunities, within the limit of performing a 3-day energy assessment. In addition, the final rule allows facilities to use a previously completed energy assessment to satisfy the energy assessment requirement.

As required by section 212 of SBREFA, EPA also is preparing a Small Entity Compliance Guide to help small entities comply with this rule. Small entities will be able to obtain a copy of the Small Entity Compliance guide at the following web site: http://www.epa.gov/ttn/atw/boiler/boilerpg.html.

5.4 Section 5 References

U.S. Bureau of Economic Analysis. 2010. “Implicit Price Deflators for Gross Domestic Product” (Table 1.1.9). <http://www.bea.gov/national/nipaweb/SelectTable.asp?Selected=N>.

U.S. Census Bureau. 2005a. *2002 Census of Governments, Volume 4, Number 3, Finances of County Governments: 2002 GC02(4)-3* (Table 12).Washington, DC: U.S. Government Printing Office.

U.S. Census Bureau. 2005b. *2002 Census of Governments, Volume 4, Number 4, Finances of Municipal and Township Governments: 2002 GC02(4)-4* (Table 13). Washington, DC: U.S. Government Printing Office.

U.S. Census Bureau. 2008. "Firm Size Data from the Statistics of U.S. Businesses: U.S. Detail Employment Sizes: 2002." <http://www.census.gov/csd/susb/download_susb02.htm>.

U.S. Small Business Administration. 2008. "Table of Small Business Size Standards Matched to North American Industry Classification System Codes." <http://www.sba.gov/services/contractingopportunities/sizestandardstopics/size/index.html>.

SECTION 6
AIR QUALITY MODELING OF EMISSIONS REDUCTIONS

6.1 Synopsis

This section describes the air quality modeling performed by EPA in support of the final boiler MACT rule. A national scale air quality modeling analysis was performed to estimate the impact of the sector emissions changes on future year: annual and 24-hour $PM_{2.5}$ concentrations, 8-hr maximum ozone, total mercury deposition, as well as visibility impairment. Air quality benefits are estimated with the Comprehensive Air Quality Model with Extensions (CAM_x) model. CAM_x simulates the numerous physical and chemical processes involved in the formation, transport, and destruction of ozone, particulate matter and air toxics. In addition to the CAM_x model, the modeling platform includes the emissions, meteorology, and initial and boundary condition data which are inputs to this model.

Emissions and air quality modeling decisions are made early in the analytical process. For this reason, it is important to note that the inventories used in the air quality modeling and the benefits modeling are different than the final boiler sector inventories presented in the RIA. At the time of proposal, we did not have the results of the ICR; those results have been incorporated into this final analysis as explained below. The boiler ICR does not have the emissions release point information such as stack height, exit velocity, exit temperature, etc. necessary for photochemical modeling so the ICR emissions data was matched with the National Emissions Inventory (NEI). Since States and local agencies have different criteria for emissions that get inventoried as a point source with stack information and area sources (no specific stack information) the ability to match ICR emissions to NEI varies from State to State depending on the level of information provided in the ICR and NEI.

Photochemical grid models use state of the science numerical algorithms to estimate pollutant formation, transport, and deposition over a variety of spatial scales that range from urban to continental. Emissions of precursor species are injected into the model where they react to form secondary species such as ozone and then transport around the modeling domain before ultimately being removed by deposition or chemical reaction. Photochemical model source apportionment tracks the formation and transport of primarily and secondarily formed pollutants from emissions sources and allows the estimation of contributions at receptors. This type of emissions apportionment is useful to understand what types of sources or regions are contributing to pollutants estimated by photochemical grid models.

The 2005-based CAM_x modeling platform was used for the air quality modeling for this rule. This platform represents a structured system of connected modeling-related tools and data that provide a consistent and transparent basis for assessing the air quality response to projected changes in emissions. The base year of data used to construct this platform includes emissions and meteorology for 2005. The platform is intended to support a variety of regulatory and research model applications and analyses. This modeling platform and analysis is described below. Additional information about the photochemical modeling is available as part of the modeling technical assessment document to support this source sector rule (USEPA, 2010).

6.2 Photochemical Model Background

CAM_x version 5.20 is a freely available computer model that simulates the formation and fate of photochemical oxidants, ozone, primary and secondary PM concentrations, and air toxics, over regional and urban spatial scales for given input sets of meteorological conditions and emissions. CAM_x includes numerous science modules that simulate the emission, production, decay, deposition and transport of organic and inorganic gas-phase and particle-phase pollutants in the atmosphere (Baker and Scheff, 2007; Nobel et al., 2001; Russell, 2008). CAM_x is applied with ISORROPIA inorganic chemistry (Nenes et al., 1999), a semi-volatile equilibrium scheme to partition condensable organic gases between gas and particle phase (Strader et al., 1999), Regional Acid Deposition Model (RADM) aqueous phase chemistry (Chang et al., 1987), and Carbon Bond 05 (CB05) gas-phase chemistry module (ENVIRON, 2008; Gery et al., 1989). Mercury oxidation pathways are represented for both the gas and aqueous phases in addition to aqueous phase reduction reactions (ENVIRON, 2008).

CAM_x contains a variety of ozone source apportionment tools, including the original ozone source apportionment tool (OSAT) and the anthropogenic pre-cursor culpability assessment (APCA) tool (ENVIRON, 2008). Ozone source apportionment tracers are treated using the standard model algorithms for vertical advection, vertical diffusion, and horizontal diffusion. Horizontal advective fluxes for each of the regular model species that make up nitrogen oxides (NO_x) and volatile organic compounds (VOC) are combined and normalized by a concentration based weighted mean. Separate ozone tracers are used in CAM_x to track ozone formation that happens under NO_x and VOC limited conditions.

Particulate matter source apportionment technology (PSAT) implemented in CAM_x estimates the contribution from specific emissions source groups to $PM_{2.5}$ and all forms of mercury using reactive tracers (ENVIRON, 2008; Wagstrom et al., 2008). The tracer species are estimated with source apportionment algorithms rather than by the host model routines. PSAT tracks contribution to $PM_{2.5}$ sulfate, nitrate, ammonium, secondary organic aerosol, and inert primarily emitted species. Non-linear processes like gas and aqueous phase chemistry are solved for bulk species and then apportioned to the tagged species. Emissions of nitrogen oxides are tracked through all intermediate nitrogen species to particulate nitrate ion. Ammonia emissions are tracked to particulate ammonium ion. This modeling assessment used the PSAT approach to estimate source contribution to $PM_{2.5}$ species and mercury and the APCA method to estimate source contribution to modeled ozone.

6.3 Model Domain and Grid Resolution

The modeling analyses were performed for a domain covering the continental United States, as shown in Figure 6-1. This domain has a parent horizontal grid of 36 km with two finer-scale 12 km grids over portions of the eastern and western U.S. The model extends vertically from the surface to 100 millibars (approximately 15 km) using a sigma-pressure coordinate system. Air quality conditions at the outer boundary of the 36 km domain were taken from a global model and vary in time and space. The 36 km grid was only used to establish the incoming air quality concentrations along the boundaries of the 12 km grids. Only the finer grid data were used in determining the impacts of the emission standard program changes. Table 6-1 provides some basic geographic information regarding the photochemical model domains.

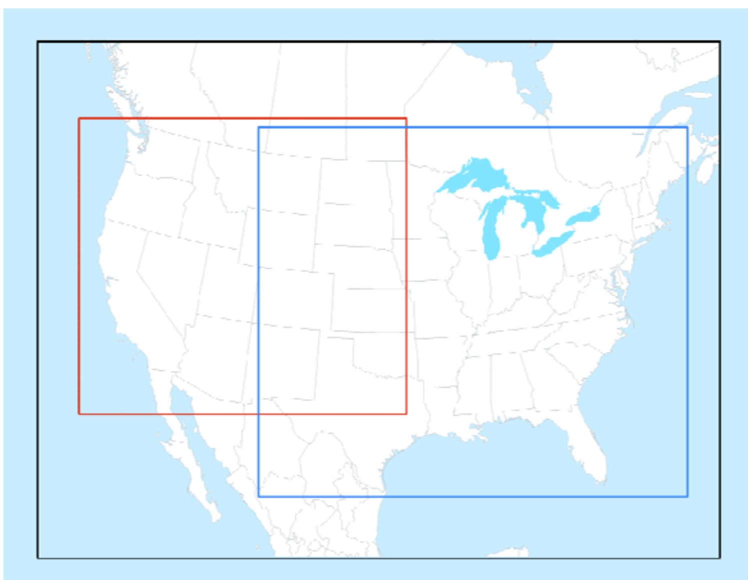

Figure 6-1. Map of the photochemical modeling domains. The black outer box denotes the 36 km national modeling domain; the red inner box is the 12 km western U.S. grid; and the blue inner box is the 12 km eastern U.S. grid.

Table 6-1. Geographic Elements of Domains Used in Photochemical Modeling

	Photochemical Modeling Configuration		
	National Grid	**Western U.S. Fine Grid**	**Eastern U.S. Fine Grid**
Map Projection	Lambert Conformal Projection		
Grid Resolution	36 km	12 km	12 km
Coordinate Center	97 deg W, 40 deg N		
True Latitudes	33 deg N and 45 deg N		
Dimensions	148 x 112 x 14	213 x 192 x 14	279 x 240 x 14
Vertical extent	14 Layers: Surface to 100 millibar level (see Table II-3)		

6.4 Emissions Input Data

6.4.1 2005 Baseline Emissions

The emissions data used in the 2005 base year are from the EPA's 2005-based v4.1 modeling platform. This platform is based on the 2005 National Emissions Inventory (NEI), version 2. Emissions were processed to photochemical model inputs with the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (Houyoux et al., 2000).

This platform includes criteria pollutants and precursors: particulate matter less than 10 microns (PM_{10}), $PM_{2.5}$, nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), volatile organic compounds (VOC), ammonia (NH_3) and hazardous air pollutants (HAP): hydrogen chloride, chlorine and mercury. Additionally, for some sectors, HAP emissions of benzene, formaldehyde, acetaldehyde and methanol are used from the inventory for chemical speciation VOC. For this rule, mercury emissions were added to the v4.1 platform to reflect the needs for the rule development will not be used for other rules. The mercury emissions included in this platform are primarily from the 2005 National Air Toxics Assessment (NATA) inventory, which was updated from the 2005 NEI v2 in order to incorporate updated data for particular source categories such as cement and hazardous waste incineration, and also revised from comments from state and local inventory providers as a result of NATA review.

This inventory was further modified to remove sources that were found to have shut down prior to 2005 and to update the gold mine emissions per information collected during the Gold Mine Ore and Production NESHAP. In addition, mercury emissions were revised for the boiler sector to allow for greater consistency with the Information Collection Request (ICR) data collected for this rule. In particular, we used the unit-specific ICR mercury emissions for all ICR facilities that could be mapped to the NATA Inventory.[1] We used the NEI to add important emissions release point information necessary for photochemical grid modeling such as geographic coordinates, stack coordinates, stack release height, exit temperature, exit velocity because the ICR lacks this information.

The replacement of the NATA mercury with the ICR mercury is described in more detail in the air quality modeling TSD. ICR emissions were not used directly for any other pollutants used in the v4.1 platform; however they informed numerous corrections and updates to the inventory including the removal of duplicates and facilities that had shut down prior to 2005, and the inclusion of control information.

The stationary inventory used in the v4.1 platform is separated into modeling sectors such as EGU point (ptipm), non-EGU point (ptnonipm), and stationary emissions not included in the point source inventories (nonpt). This nonpoint category is generally referred to as the "area" source inventory, and this category is not a direct representation of sources classified as area sources for the purposes of National Emissions Standards for Hazardous Air Pollutants (NESHAP) and Maximum Available Control Technology (MACT) standards.

6.4.2 Future Year Baseline Emissions

The 2016 baseline emissions are intended to represent the emissions associated with growth and controls in 2016. The projections used for this effort are unique to this project and are not associated with a particular modeling platform.

The EGU point source (ptipm) emissions estimates for the future year reference were created by the Integrated Planning Model (IPM) version 3.02 for criteria pollutants, hydrochloric acid, and mercury in 2015.[2] For the non-EGU point (ptnonipm) and nonpoint (nonpt) sectors, both control and growth factors were applied to a subset of the 2005 v4.1 platform data to create the 2016 reference case. The 2014 projection factors developed for the Transport Rule proposal (see http://www.epa.gov/ttn/chief/emch/index.html#transport) were further enhanced and updated for these 2016 baseline projections.

The projected inventory incorporates emissions projections for the proposed Transport Rule, cement kiln NESHAP, RICE NESHAP, gold mine NESHAP, changes to boiler emissions

[1] The "NEI_UNIQUE_ID" field was used to map the ICR facilities to the NATA inventory. We used 7032 units' Hg emissions out of 7,738 total units in the ICR. These 7032 units from the ICR sum to 4.66 tons. ICR emissions that were not included sum to 0.177 tons.

[2] The 2015 IPM run represents the average of 2014 to 2016.

based on the ICR database developed for this rule, and known consent decrees. A complete list of rules included in the future point source baseline inventory is shown in Table 6-2.

Table 6-2. Control Strategies and/or Growth Assumptions Included in the 2016 Projection

Projections Carried Forward from the proposed Transport Rule[a,b]	
Description	**Pollutants**
MACT rules, national, VOC: national applied by SCC, MACT	VOC
Consent Decrees and Settlements, including refinery consent decrees, and settlements for: (1) Alcoa, TX and (2) Premcor (formerly MOTIVA), DE	All
Municipal Waste Combustor Reductions—plant level	PM
Hazardous Waste Combustion	PM
Hospital/Medical/Infectious Waste Incinerator Regulations under Section 129d/11 1d	NO_X, PM, SO_2
Large Municipal Waste Combustors—growth applied to specific plants	All
MACT rules, plant-level, VOC: Auto Plants	VOC
MACT rules, plant-level, PM & SO_2: Lime Manufacturing	PM, SO_2
MACT rules, plant-level, PM: Taconite Ore	PM
Municipal Waste Landfills: project factor of 0.25 applied	All
Livestock Emissions Growth from year 2002 to 2016	NH_3, PM
Residential Wood Combustion Growth and Changeouts from year 2005 to year 2016	All
Gasoline Stage II growth and control from year 2005 to year 2016	VOC
Portable Fuel Container MSAT2 inventory growth and control from year 2005 to year 2016	VOC
Additional Projections Used In Boiler MACT modeling[c]	
Emission Reductions resulting from controls put on specific boiler units (not due to MACT) after 2005, identified through analysis of the control data gathered from the ICR from the ICI Boiler NESHAP.	NO_X, SO_2, HCL
NESHAP: Portland Cement (09/09/10)—plant level based on Industrial Sector Integrated Solutions (ISIS) policy emissions in 2013. The ISIS results are from the ISIS-Cement model runs for the NESHAP and NSPS analysis of July 28, 2010.	HG, NO_X, SO_2, PM, HCL
NESHAP: Gold Mine Ore Processing and Production Area Source Category (based on proposed rule 04-15-10)—finalized 12/2010	HG

(continued)

Table 6-2. Control Strategies and/or Growth Assumptions Included in the 2016 Projection (continued)

Projections Carried Forward from the proposed Transport Rule[a,b]	
New York SIP reductions	VOC, NO_X
Additional plant and unit closures	All
NESHAP: Reciprocating Internal Combustion Engines[d]	NO_X, CO, PM

[a] They were only changed in that the projection year was 2015 or 2016, rather than 2012 / 2014.

[b] We inadvertently did not apply closures that had been applied for the Transport Rule proposal; emissions from these plants sum to 3300 tons VOC, 178 tons $PM_{2.5}$, 1982 tons SO_2, 1639 tons NO_X, 6 tons NH_3 and 379 tons CO. At the state level, the largest impact is in West Virginia (717 tons NO_X, which is 2% of emissions in ptnonipm) and 1604 tons SO_2, which is 7% of the ptnonipm sector. When considering emissions from other sectors, the percentages will be much smaller. All other errors are under 500 tons (less than 1% of the ptnonipm sector).

[c] We inadvertently did not apply LaFarge and SaintGobain consent decrees, since one of the LaFarge facilities was already covered in the cement ISIS projections, the reductions missed were lower than estimated by the consent decree were on the order of 20,000 tons SO_2, 15,000 tons NO_X, 400 tons HCL, 200 tons $PM_{2.5}$.

[d] Note that SO_2 reductions are expected to occur to due fuel sulfur limits but were excluded from the projection. They were expected to reduce SO_2 by 27,000 tons, nationwide.

The 2016 onroad emissions reflect control program implementation through 2016 and include the Light-Duty Vehicle Tier 2 Rule, the Onroad Heavy-Duty Rule, and the Mobile Source Air Toxics (MSAT) final rule and the category 3 marine diesel engines Clean Air Act and International Maritime Organization standards which includes the establishment of emission control areas for these ships. Emission reductions and increases from the Renewable Fuel Standard version 2 (RFS2) are not included. The future baseline case nonroad mobile emissions reductions for these years include reductions to locomotives, various nonroad engines including diesel engines and various marine engine types, fuel sulfur content, and evaporative emissions standards.

6.4.3 Future Year Sector Contribution Approach

The 2016 reference scenario for the boilers affected by the rule includes 2005 emissions estimates with some emissions removed from the inventory because of shut downs. The length of time required to conduct emissions and photochemical modeling precluded the use of the final facility-specific emissions estimates based on controls implemented for this rule. A 2016 "control" or emissions adjustment scenario was developed by tracking the total contribution from potentially controllable boiler sector emissions from the 2016 baseline inventory. This total contribution estimate, essentially a "zero-out," of the sector creates a policy space where potential control impacts would be maximized at all locations. Since emissions reductions at controllable sources are not 100% (100% ~ total contribution), the boiler sector air quality contribution estimates from the 2016 source apportionment model simulation are adjusted based on nation-wide estimates of control percentages by pollutant to create a final 2016 "control" emissions scenario.

The 2016 estimated controllable emissions for the boiler sector are shown in Table 6-3. Boiler sector emissions are contained in several different general classes of emissions used for emissions modeling: non-point or area (nonpt), point EGU (ptipm), and point non-EGU (ptnonipm). These totals are the sum of emissions in the eastern and western U.S. modeling domains so the non-point (area) category contains some double-counting of emissions where the model domains overlap in the central United States (see Figure 6-2).

Table 6-3. Estimated Future Year (2016) Controllable Boiler Sector Emissions

	Sector	VOC	NO_X	SO_2	$PM_{2.5}$	NH_3	HG_0	HG_2	$PM_{2.5}$ HG
Total (TPY)	Non-point—Boiler (nonpt)	14,107	394,459	1,149,402	108,386	8,489	0	0	0
Total (TPY)	EGU Point—Boiler (ptipm)	57	0	54,337	826	0	0	0	0
Total (TPY)	Non-EGU Point—Boiler (ptnonipm)	15,451	215,809	492,676	28,838	706	1	2	1
Pct of Sector	Non-point—Boiler (nonpt)	0	19	82	9	5			
Pct of Sector	EGU Point—Boiler (ptipm)	0	0	1	0	0			
Pct of Sector	Non-EGU Point—Boiler (ptnonipm)	1	9	26	6	0	10	7	12

Figure 6-2 shows the locations of boilers in the NEI point source inventory used in the modeling analysis. Non-point boilers in the NEI do not have stack location information and are not shown. These boilers are spatially distributed in the modeling domain using spatial surrogates appropriate for this sector.

Boiler emissions in the non-point/area (nonpt) modeling sector are used as the basis of estimating air quality impacts and health benefits for the area source rule. These emissions are based on SCC codes shown in Table II-5. Boiler emissions in the point non-EGU (ptnonipm) and point EGU (ptipm) are used to estimate impacts of the major source rule. Facilities were identified for the major source rule based on meeting several criteria: (1) NEI facility ID and process level fuel type matched to a facility in the boiler ICR database, (2) NEI source had a boiler SCC code, and (3) unit design capacity was less than 25 MW.

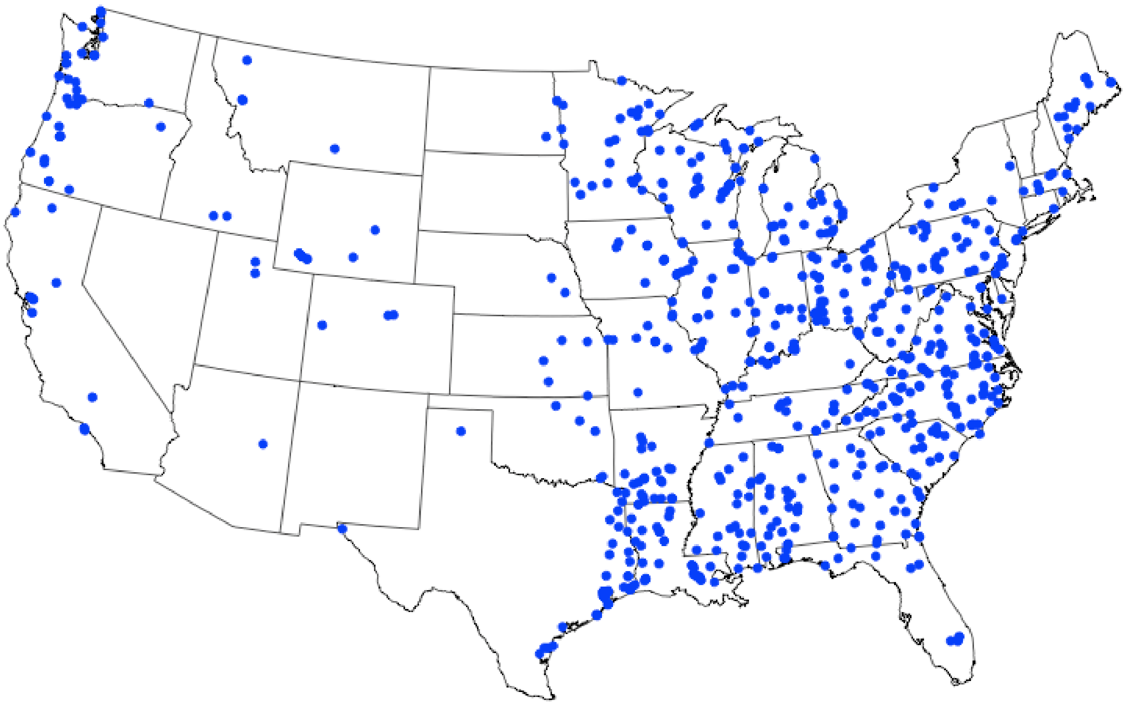

Figure 6-2. Locations of boilers in the NEI point inventory for the future baseline (2016)

Major source mercury emissions were identified as the units added from the boiler ICR database plus units in the NATA Hg inventory that were not in the ICR but were considered part of the Boiler MACT Universe. A percent emissions reduction was estimated based on the rule proposal unit-specific facility-fuel combination in the ICR database. Each facility/process matching the facility-fuel combinations that had emission reductions larger than 1% based on the proposed rule were tracked for source contribution.

6.5 Model Results

As part of the analysis for this rulemaking, the modeling system was used to calculate daily and annual $PM_{2.5}$ concentrations, 8-hr maximum ozone, annual total mercury deposition levels and visibility impairment. Model predictions are used to estimate future-year design values of $PM_{2.5}$ and ozone. The annual $PM_{2.5}$ design value[3] determines whether a monitor location is attaining the annual $PM_{2.5}$ NAAQS. Specifically, we compare a 2016 reference scenario, a scenario without the boiler sector controls, to a 2016 control scenario which includes the adjustments to the boiler sector. This is done by calculating the simulated air quality ratios

[3] The full details involved in calculating the annual $PM_{2.5}$ design value are provided in appendix N of 40 CFR part 50.

between any particular future year simulation and the 2005 base. These predicted ratios are then applied to ambient base year design values. The design value projection methodology used here followed EPA guidance for such analyses (USEPA, 2007). Additionally, the raw model outputs are also used in a relative sense as inputs to the health and welfare impact functions of the benefits analysis. Only model predictions for mercury deposition were analyzed using absolute model changes, although percent changes between the control case and two future baselines are also estimated.

The 36 km and both 12 km modeling domains were modeled for the entire year of 2005 and projected year 2016. Data from the entire year were utilized when looking at the estimation of $PM_{2.5}$, total mercury deposition, and visibility impacts from the regulation. Data from April through October is used to estimate ozone impacts. All air quality impacts are based on improvements in future year pollution based on emissions changes from this source sector.

6.5.1 Impacts of Sector on Total Mercury Deposition

This section summarizes the results of our modeling of total mercury deposition impacts in the future based on changes to boiler emissions. Available data indicate that the mercury emissions from these sources are a mixture of gaseous elemental mercury (25%), inorganic divalent mercury (reactive gas phase mercury) (50%), and particulate bound mercury (25%). Model results for the eastern and central United States indicate that estimated total mercury deposition (wet and dry forms) reductions from this sector would be 1,393 $\mu g/m^2$ (1.5% of total mercury deposition from all sources); approximately 51% in dry form and 49% in wet form. The chemical composition of this estimated reduction is approximately 60% reactive gas phase (HG_2) and 40% particulate. A reduction of 75 $\mu g/m^2$ (0.5% of total mercury deposition from all sources) is estimated for the western United States; approximately 56% in dry form and 44% in wet form. The chemical composition of the reductions in the western model domain is approximately 63% reactive gas phase (HG_2) and 37% particulate. These reductions are related to changes in emissions at major boiler sources using the ptnonipm sector as a surrogate.

6.5.2 Impacts of Sector on Future Annual $PM_{2.5}$ Levels

This section summarizes the results of our modeling of annual average $PM_{2.5}$ air quality impacts in the future due to estimated reductions in emissions from this sector. Specifically, we compare a 2016 reference scenario to a 2016 control scenario. The modeling assessment indicates a decrease up to 0.81 $\mu g/m^3$ in annual $PM_{2.5}$ design values is possible given an area's proximity to controlled sources and the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from major sources under the recommended solid fuel category option. The estimated mean reduction over all monitor locations is 0.15 $\mu g/m^3$ for major source reductions under the recommended solid fuel category. A decrease up to 0.66 $\mu g/m^3$ in annual $PM_{2.5}$ design values is possible given an area's proximity to controlled sources and the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from major sources under the alternative option. The estimated mean reduction over all monitor locations is 0.12 $\mu g/m^3$ for major source reductions under the alternative option. Area source reductions show a decrease up to 0.01 $\mu g/m^3$ in annual $PM_{2.5}$ design values is possible given an area's proximity to controlled area sources and the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions.

6.5.3 Impacts of Sector on Future 24-hour $PM_{2.5}$ Levels

This section summarizes the results of our modeling of 24-hr average $PM_{2.5}$ air quality impacts in the future due to reductions in emissions from this sector. Specifically, we compare a 2016 reference scenario to a 2016 control scenario. The modeling assessment indicates an estimated average decrease of 0.50 $\mu g/m^3$ in 24-hr average $PM_{2.5}$ design values over all monitor locations in the United States is possible given the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from major sources under the recommended solid fuel category option. An estimated average decrease of 0.39 $\mu g/m^3$ in 24-hr average $PM_{2.5}$ design values over all monitor locations in the United States is possible given the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from major sources under the alternative option. An estimated decrease up to 0.03 $\mu g/m^3$ in 24-hr average $PM_{2.5}$ design values at monitor locations in the United States is possible given an area's proximity to controlled sources and the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from area sources.

6.5.4 Impacts of Sector on Future Visibility Levels

Air quality modeling conducted for this final rule was used to project visibility conditions in 138 mandatory Class I federal areas across the U.S. in 2016 (USEPA, 2007). The level of visibility impairment in an area is based on the light-extinction coefficient and a unitless visibility index, called a "deciview," which is used in the valuation of visibility. The deciview metric provides a scale for perceived visual changes over the entire range of conditions, from clear to hazy. Under many scenic conditions, the average person can generally perceive a change of one deciview. Higher deciview values are indicative of worse visibility. Thus, an improvement in visibility is a decrease in deciview value.

The modeling assessment indicates an estimated average visibility improvement of 0.51 deciviews in annual 20% worst visibility days over all Class I area monitors based on controls for major sources under the recommended solid fuel category option. An estimated average visibility improvement of 0.42 deciviews in annual 20% worst visibility days over all Class I area monitors based on controls for major sources under the alternative option. An improvement in visibility up to 0.03 deciviews at Class I monitor locations in the United States is possible given an area's proximity to controlled sources and the amount of reduced sulfur dioxide and primary $PM_{2.5}$ emissions from area sources.

6.5.5 Impacts of Sector on Future Ozone Levels

This section summarizes the results of our modeling of 8-hr maximum ozone air quality impacts in the future due to reductions in emissions from this sector. Specifically, we compare a 2016 reference scenario to a 2016 control scenario. The modeling assessment indicates a decrease of less than 0.01 ppb in ozone design values is possible given an area's proximity to controlled sources and the amount of reduced VOC emissions under all major and area source options. The full details involved in calculating design value are given in appendix P of 40 CFR part 50. Projected air quality benefits are estimated using procedures outlined by United States Environmental Protection Agency modeling guidance (USEPA, 2007).

6.6 Section 6 References

Baker, K., Scheff, P., 2007. Photochemical model performance for $PM_{2.5}$ sulfate, nitrate, ammonium, and precursor species SO_2, HNO_3, and NH_3 at background monitor locations in the central and eastern United States. Atmospheric Environment 41, 6185-6195.

Chang, J.S., Brost, R.A., Isaksen, I.S.A., Madronich, S., Middleton, P., Stockwell, W.R., Walcek, C.J. 1987. A 3-dimensional eulerian acid deposition model—physical concepts and formulation. *J. Geophys. Res.-Atmos*. 92, 14681-14700.

ENVIRON, 2008. User's Guide Comprehensive Air Quality Model with Extensions. ENVIRON International Corporation, Novato.

Gery, M.W., Whitten, G.Z., Killus, J.P., Dodge, M.C., 1989. A photochemical kinetics mechanism for urban and regional scale computer modeling. *J. Geophys. Res.-Atmos*. 94, 12925-12956.

Houyoux, M.R., Vukovich, J.M., Coats, C.J., Wheeler, N.J.M., Kasibhatla, P.S., 2000. Emission inventory development and processing for the Seasonal Model for Regional Air Quality (SMRAQ) project. Journal of Geophysical Research-Atmospheres 105, 9079-9090.

Nenes, A., Pandis, S.N., Pilinis, C., 1999. Continued development and testing of a new thermodynamic aerosol module for urban and regional air quality models. Atmospheric Environment 33, 1553-1560.

Nobel, C.E., McDonald-Buller, E.C., Kimura, Y., Allen, D.T., 2001. Accounting for spatial variation of ozone productivity in NO_x emission trading. Environmental Science & Technology 35, 4397-4407.

Russell, A.G., 2008. EPA Supersites Program-related emissions-based particulate matter modeling: Initial applications and advances. J. Air Waste Manage. Assoc. 58, 289-302.

Strader, R., Lurmann, F., Pandis, S.N., 1999. Evaluation of secondary organic aerosol formation in winter. Atmospheric Environment 33, 4849-4863.USEPA, 2007. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze, RTP.

USEPA, 2010. Air Quality Modeling Technical Support Document: Boiler Source Sector Rules (EPA-454/R-10-006), Research Triangle Park, North Carolina.

Wagstrom, K.M., Pandis, S.N., Yarwood, G., Wilson, G.M., Morris, R.E., 2008. Development and application of a computationally efficient particulate matter apportionment algorithm in a three-dimensional chemical transport model. Atmospheric Environment 42, 5650-5659.

SECTION 7
BENEFITS OF EMISSIONS REDUCTIONS

7.1 Synopsis

In this section, we provide an estimate of the monetized benefits associated with reducing exposure to particulate matter (PM) and ozone for the final Boiler MACT and Boiler Area Source Rule. The $PM_{2.5}$ reductions are the result of emission limits on PM as well as emission limits on other pollutants, including hazardous air pollutants (HAPs). The total $PM_{2.5}$ reductions are the consequence of the technologies installed to meet these multiple limits. The latter are often referred to as "co-benefits." Ozone reductions are the result of reductions in emissions of VOCs, which are precursors to ozone formation. These benefit estimates include the number of cases of avoided morbidity and premature mortality among populations exposed to $PM_{2.5}$ and ozone, as well as the monetized value of those avoided cases. Because we were unable to monetize the direct benefits associated with reducing HAPs, the monetized benefits estimate is an underestimate of the total benefits. The extent of this underestimate, whether small or large, is unknown. Using a 3% discount rate, we estimate the total combined monetized benefits of the final Boiler MACT and Boiler Area Source Rule to be $22 billion to $54 billion in the implementation year (2014). Using a 7% discount rate, we estimate the total combined monetized benefits of the final Boiler MACT and Boiler Area Source Rule to be $20 billion to $49 billion in the implementation year. Higher or lower estimates of benefits are possible using other assumptions; examples of this are provided in Figure 7-1. All estimates are in 2008$ and include any energy disbenefits associated with the increased emissions from additional energy usage.

These monetized estimates reflect EPA's current interpretation of the scientific literature (U.S. EPA, 2009c). In addition, these estimates incorporate an array of improvements introduced since the proposal, including boiler sector-specific air quality modeling data, lowest measured level (LML) assessment, mercury deposition maps, ozone benefits, and energy disbenefits. Methodological and time limitations under the court-ordered schedule prevented EPA from monetizing the benefits from several important benefit categories, including direct benefits from reducing hazardous air pollutants, ecosystem effects, and visibility impairment. The direct benefits from reducing other air pollutants have not been monetized in this analysis, including reducing a combined 113,000 tons of carbon monoxide, 30,000 tons of HCl, 830 tons of HF, 2,900 pounds of mercury, 3,000 tons of other metals, and 23 grams of dioxins/furans (TEQ) each year. We assess the direct benefits of these emission reductions qualitatively in this analysis.

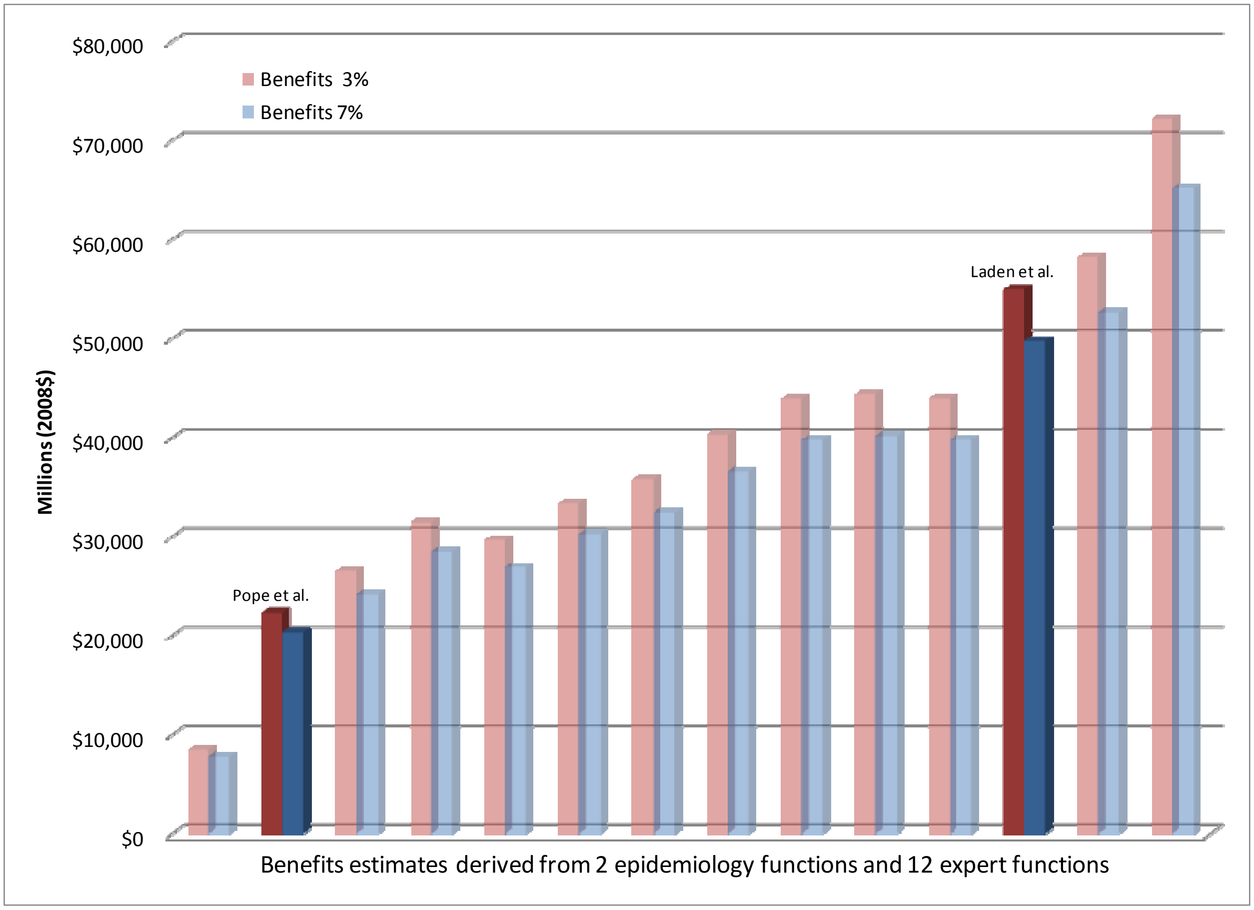

Figure 7-1. Total Monetized $PM_{2.5}$ and Ozone Benefits for the Final Boiler MACT and Boiler Area Source Rule in 2014[a]

[a] This graph shows the estimated benefits at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. (2002) study and the Laden et al. (2006) 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. These estimates do not include the direct benefits from reducing HAP emissions, but they do include the energy disbenefits associated with the increased emissions from additional energy usage. Due to methodology and time limitations under the court-ordered schedule, we were unable to monetize the benefits associated with several categories of benefits, including direct exposure to HAPs and SO_2, as well as ecosystem effects, and visibility effects. These benefits reflect existing boilers and new boilers anticipated to come online by 2014.

7.2 Calculating Benefits

The benefit categories associated with the emission reduction anticipated for these rules can be broadly categorized as those benefits directly attributable to reduced exposure to HAPs, the PM co-benefits associated with reducing HAPs (i.e., PM reduced by introducing technology designed to reduce HAPs), and those attributable to exposure to other pollutants. Several of the HAPs that would be reduced by these rules have been classified as known or probable human carcinogens.[1] As a result, one benefit of the proposed regulation is a reduction in the risk of cancer. Other benefit categories include potential reduced incidence of neurological effects and irritations of the lungs and skin, reduced mortality and other morbidity effects associated with PM and SO_2. In addition to health impacts occurring as a result of reductions in HAPs and other pollutant emissions, there are welfare impacts which can also be identified. In general, welfare impacts include effects on vegetation, visibility impairment, and acidification of water bodies. We were unable to monetize the direct benefits associated with reducing HAPs in this analysis. In Section 7.5.5 of this RIA, we provide a full qualitative discussion of the direct health benefits associated with the reductions in emissions of HAPs anticipated by these rules, including a full discussion of the complexity associated with monetizing HAP benefits. We also provide maps of reduced mercury deposition in that section. Therefore, all monetized benefits provided in this analysis only reflect improvements in ambient $PM_{2.5}$ and ozone concentrations. Thus, the monetized benefits estimate is an underestimate of the total benefits. The extent of this underestimate, whether small or large, is unknown. In addition to pollutants we do not directly monetize, these rulemakings are expected to reduce emissions of $PM_{2.5}$, SO_2, and VOCs. Because SO_2 is also a precursor to $PM_{2.5,}$ reducing SO_2 emissions will also reduce $PM_{2.5}$ formation, human exposure, and therefore reduce estimated incidence of $PM_{2.5}$-related health effects. The estimated PM reductions are the result of emission limits on PM as well as emission limits on other pollutants, including hazardous air pollutants for these rules. The total $PM_{2.5}$ reductions are the consequence of the technologies installed to meet these multiple limits. In addition, these rules are expected to result in reductions in VOCs, which will result in changes in ambient ozone concentrations.

In implementing these rules, emission controls may lead to reductions in ambient $PM_{2.5}$ below the National Ambient Air Quality Standards (NAAQS) for PM in some areas and assist other areas with attaining the PM NAAQS. Because the PM NAAQS RIAs also calculate PM benefits, there are important differences worth noting in the design and analytical objectives of each RIA. The NAAQS RIAs illustrate the potential costs and benefits of attaining a new air quality standard nationwide based on an array of emission control strategies for different sources. In short, NAAQS RIAs hypothesize, but do not predict, the control strategies that States may choose to enact when implementing a NAAQS. The setting of a NAAQS does not directly result in costs or benefits, and as such, the NAAQS RIAs are merely illustrative and are not intended to be added to the costs and benefits of other regulations that result in specific costs of control and

[1] As described in Section 7.5, formaldehyde, several PAHs, and acetaldehyde are classified as probable human carcinogens. Different nickel compounds are classified as human carcinogens and probable human carcinogens.

emission reductions. However, some costs and benefits estimated in this RIA account for the same air quality improvements as estimated in the illustrative $PM_{2.5}$ NAAQS RIA.

By contrast, the emission reductions for this rule are from a specific class of well-characterized sources. In general, EPA is more confident in the magnitude and location of the emission reductions for these rules. It is important to note that emission reductions anticipated from these rules do not result in emission increases elsewhere (other than potential energy disbenefits). Emission reductions achieved under these and other promulgated rules will ultimately be reflected in the baseline of future NAAQS analyses, which would reduce the incremental costs and benefits associated with attaining the NAAQS. EPA remains forward looking towards the next iteration of the 5-year review cycle for the NAAQS, and as a result does not issue updated RIAs for existing NAAQS that retroactively update the baseline for NAAQS implementation. For more information on the relationship between the NAAQS and rules such as analyzed here, please see Section 1.2.4 of the SO_2 NAAQS RIA (U.S. EPA, 2010h).

7.2.1 Methodology Improvements since Proposal

This benefits analysis for the final Boiler MACT and Area Source Rule incorporates an array of policy and technical improvements since the proposal analysis in 2010 (U.S. EPA, 2010c), including:

1. *Boiler sector-specific air quality modeling data*. The benefits estimates for this final analysis are derived from air quality data modeled using CAM_x that reflect the emissions from the boiler sector and their contribution to ambient $PM_{2.5}$ and ozone levels. These data provide a different and likely superior representation of the geographic distribution of emissions and associated ambient concentrations specifically from boilers than the generic benefit-per-ton estimates used in the proposal that reflected emissions for the entire non-EGU (non-electrical generating unit) category. For more information regarding the modeling inputs and assumptions, please see Section 6 of this RIA. For more information regarding the derivation of boiler sector-specific benefit-per-ton estimates and how they are superior to the estimates used in the proposal, please see Section 7.2.6 of this RIA.

2. *Lowest Measured Level (LML) assessment*. Consistent with the rationale outlined in the Cement NESHAP proposal RIA (U.S. EPA, 2009a), EPA has recently changed its approach to characterizing the uncertainty associated with benefits estimated at lower air quality levels. Specifically, EPA now estimates PM-related mortality without assuming an threshold at 10 $\mu g/m^3$ in the concentration-response function. Consistent with recent scientific advice, we are replacing the previous threshold sensitivity analysis with a new LML assessment. We discuss this assessment in more detail in Section 7.2.4 and provide the results of this LML assessment in Section 7.3.

3. *Mercury deposition*. The air quality modeling data provide an estimate of the reduction in mercury deposition associated with the mercury emission reductions anticipated as a result of these rules. We provide maps of the reduced mercury deposition in Section 7.5.4.1. EPA did not model mercury methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions.

4. *Ozone benefits*. The air quality modeling data provide an estimate of the change in ambient ozone concentrations associated with the VOC emission reductions anticipated as a result of the Boiler MACT. We provide a table of the ozone-related health benefits in Section 7.3.

5. *Energy disbenefits*. For this final analysis, we include an estimate of the increased CO_2 emissions associated with the additional electricity required to operate control devices. We provide the results of this analysis in Section 7.4.

6. *Improved characterization of uncertainty*. For this final analysis, we characterize uncertainty using four methods (Monte Carlo methods, LML assessment, alternate concentration-response functions, and qualitative descriptions). While the proposal incorporated some of these approaches, the Monte Carlo methods and LML assessment are an improvement for the final analysis. Confidence intervals reflecting the standard errors in the underlying epidemiology and economics literature are provided for incidence and valuation results in Tables 7-4 to 7-8.

7.2.2 Benefits Analysis Approach for $PM_{2.5}$ and Ozone

We follow a "damage-function" approach in calculating total benefits of the modeled changes in environmental quality. This approach estimates changes in individual health and welfare endpoints and assigns values to those changes assuming independence of the individual values. Total benefits are calculated simply as the sum of the values for all non-overlapping health and welfare endpoints. The "damage-function" approach is the standard method for assessing costs and benefits of environmental quality programs and has been used in several recent published analyses (Levy et al., 2009; Hubbell et al., 2009; Tagaris et al., 2009).

To assess economic value in a damage-function framework, the changes in environmental quality must be translated into effects on people or on the things that people value. For changes in $PM_{2.5}$ or ozone, a health impact analysis (HIA) must first be conducted to convert air quality changes into effects that can be assigned dollar values. For this RIA, the health impacts analysis is limited to those health effects that are directly linked to ambient levels of air pollution and specifically to those linked to $PM_{2.5}$ and ozone. We also provide qualitative discussions of the impact of changes in other environmental and ecological effects, including the benefits associated with decreasing deposition of sulfur to terrestrial and aquatic ecosystems, but we are unable to place an economic value on these changes due to time limitations under the court-ordered schedule.

We note at the outset that EPA rarely has the time or resources to perform extensive new research to measure directly either the health outcomes or their values for regulatory analyses. Thus, similar to Kunzli et al. (2001) and other recent health impact analyses, our estimates are based on the best available methods of benefits transfer. Benefits transfer is the science and art of adapting primary research from similar contexts to obtain the most accurate measure of benefits for the environmental quality change under analysis. Adjustments are made for the level of environmental quality change, the socio-demographic and economic characteristics of the affected population, and other factors to improve the accuracy and robustness of benefits estimates.

7.2.3 Health Impact Analysis (HIA)

The HIA quantifies the potential changes in the incidence of adverse health impacts resulting from estimated changes in human exposure to air pollution. HIAs are a well-established approach for estimating the retrospective or prospective change in adverse health impacts resulting from population-level changes in exposure to pollutants (Levy et al., 2009). Analysts have applied the HIA approach to estimate human health impacts resulting from hypothetical changes in pollutant levels (Hubbell et al., 2005; Davidson et al., 2007; Tagaris et al., 2009). For this analysis, we used the environmental Benefits Mapping and Analysis Program (BenMAP), which is a PC-based tool that can systematize health impact analyses by applying a database of key input parameters, including health impact functions and population projections.[2]

The HIA approach used in this analysis involves three basic steps: (1) utilizing CAM_x-generated projections of $PM_{2.5}$ and ozone air quality and estimating the change in the spatial distribution of the ambient air quality; (2) determining the subsequent change in population-level exposure; (3) calculating health impacts by applying concentration-response relationships drawn from the epidemiological literature (Hubbell et al., 2009) to this change in population exposure.

A typical health impact function might look as follows:

$$\Delta y = y_0 \cdot (e^{\beta \cdot \Delta x} - 1) \cdot Pop$$

where y_0 is the baseline incidence rate for the health endpoint being quantified (for example, a health impact function quantifying changes in mortality would use the baseline, or background,

[2] For this analysis, we used BenMAP version 3.0 (Abt Associates, 2008). This model is available for free download on the Internet at <http://www.epa.gov/air/benmap>.

mortality rate for the given population of interest); *Pop* is the population affected by the change in air quality; Δx is the change in air quality; and β is the effect coefficient drawn from the epidemiological study. For this analysis, we systematize the HIA calculation process using BenMAP's library of existing air quality monitoring data, population data and health impact functions. Figure 7-2 provides a simplified overview of this approach, and Figure 7-3 identifies the data inputs and outputs for the BenMAP model for a $PM_{2.5}$ analysis.

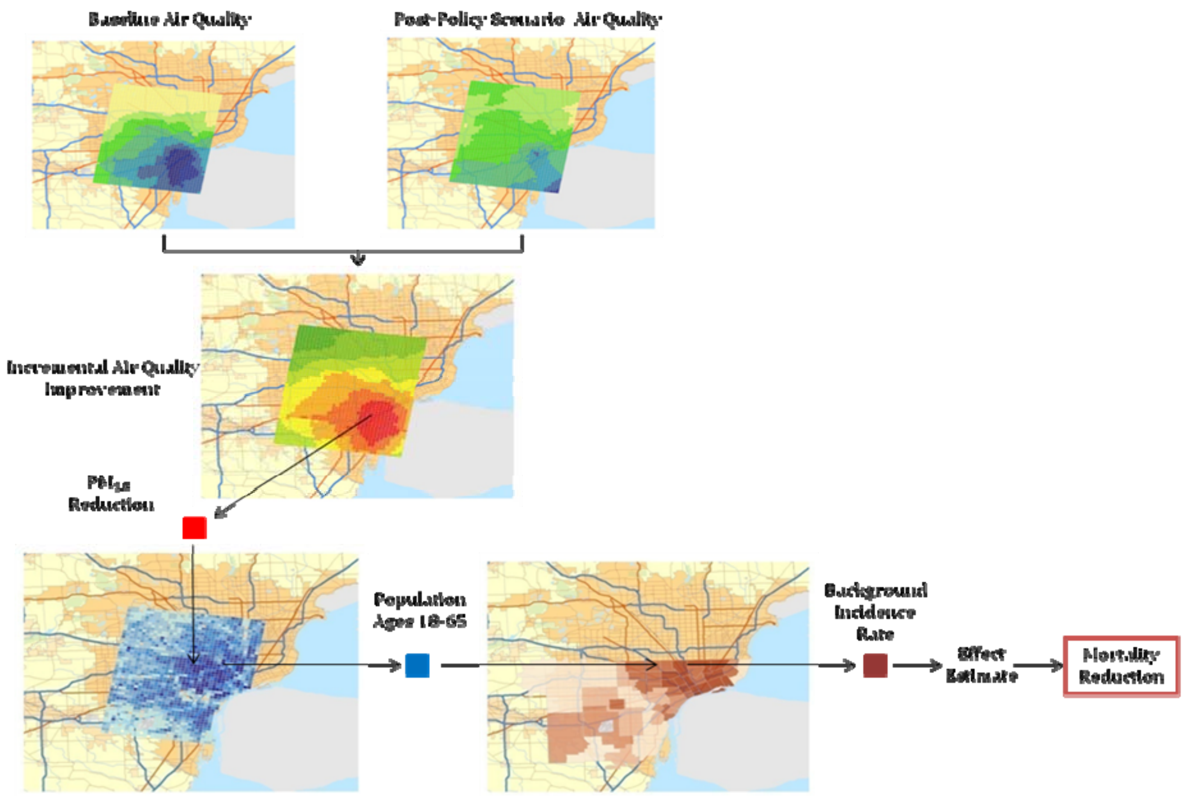

Figure 7-2. Illustration of BenMAP Approach

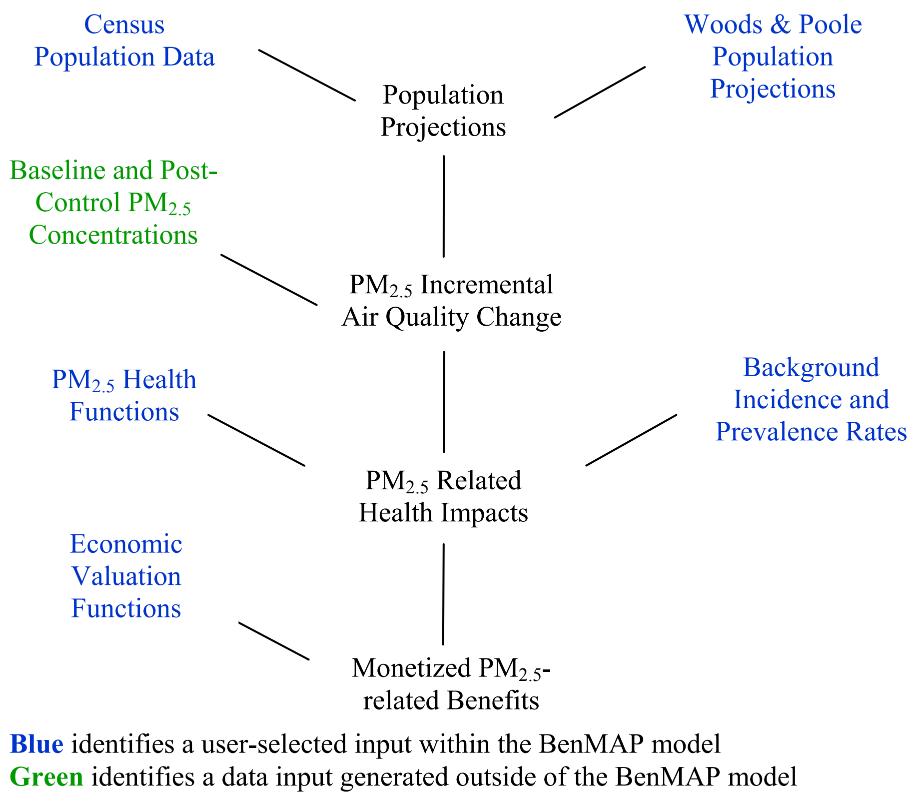

Figure 7-3. Data Inputs and Outputs for the BenMAP Model for a $PM_{2.5}$ Analysis

The benefits estimates in this analysis were derived using modified versions of the health impact functions used in the PM NAAQS Regulatory Impact Analysis (RIA) (U.S. EPA, 2006) and the Ozone NAAQS RIA (U.S. EPA, 2010a).[3] While many of the functions are identical to those used in the PM NAAQS RIA, we have updated a few of the underlying assumptions over the last few years. For a detailed description of the underlying functions, studies, baseline incidence rates, and population data used in this analysis, please refer to Chapter 5 of the recently proposed Transport Rule (U.S. EPA, 2010e). Table 7-1 identifies which human health and welfare endpoints are included in the monetized benefits and which endpoints remain unquantified. In summary, the estimate of monetized PM benefits includes premature mortality and eleven morbidity endpoints, and the estimate of monetized ozone benefits includes premature mortality and five morbidity endpoints.

[3] All of the RIAs cited in this analysis are available on EPA's website at http://www.epa.gov/ttn/ecas/ria.html.

Table 7-1. Human Health and Welfare Effects of Air Pollutants Affected

Pollutant/Effect	Quantified and Monetized	Unquantified
PM: health [a]	Premature mortality based on cohort study estimates [b] Premature mortality based on expert elicitation estimates Chronic bronchitis Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarctions) Lower and upper respiratory illness Minor restricted activity days Work loss days Asthma exacerbations (among asthmatic populations Respiratory symptoms (among asthmatic populations) Infant mortality	Low birth weight Pre-term births Pulmonary function Nonfatal cardiovascular outcomes other than myocardial infarctions Chronic respiratory diseases other than chronic bronchitis Non-asthma respiratory emergency room visits UVb exposure (+/–)[c]
PM: welfare		Visibility in Class I areas Household soiling Visibility in residential and non-class I areas UVb exposure (+/–)[c] Global climate impacts [c]
Ozone: health	Premature mortality based on short-term study estimates Hospital admissions: respiratory Emergency room visits for asthma Minor restricted activity days School loss days	Chronic respiratory damage Premature mortality due to long-term exposures Premature aging of the lungs Non-asthma respiratory emergency room visits UVb exposure (+/–)[c]
Ozone: welfare	Decreased outdoor worker productivity	Yields for: – Commercial forests – Fruits and vegetables, and – Other commercial and noncommercial crops Damage to urban ornamental plants Recreational demand from damaged forest aesthetics Ecosystem functions UVb exposure (+/–)[c]
SO_2: health		Respiratory hospital admissions Asthma emergency room visits Asthma exacerbation Acute respiratory symptoms Premature mortality Pulmonary function

(continued)

Table 7-1. Human Health and Welfare Effects of Air Pollutants Affected (continued)

Pollutant/Effect	Quantified and Monetized	Unquantified
SO_2: welfare		Commercial fishing and forestry from acidic deposition Recreation in terrestrial and aquatic ecosystems from acid deposition Increased mercury methylation
Mercury: health		Incidence of neurological disorders Incidence of learning disabilities Incidences in developmental delays Potential cardiovascular effects including: – Altered blood pressure regulation – Increased heart rate variability – Incidences of heart attack Potential reproductive effects
Mercury: environment		Impact on birds and mammals (e.g., reproductive effects, cardiovascular effects)
Mercury: welfare		Impacts to commercial., subsistence and recreational fishing
HAPs		Health effects associated with HAP exposure

[a] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.

[b] Cohort estimates are designed to examine the effects of long-term exposures to ambient pollution, but relative risk estimates may also incorporate some effects due to shorter term exposures (see Kunzli et al., 2001 for a discussion of this issue). While some of the effects of short-term exposure are likely to be captured by the cohort estimates, there may be additional premature mortality from short term PM exposure not captured in the cohort estimates included in the primary analysis.

[c] May result in benefits or disbenefits.

7.2.4 Estimating $PM_{2.5}$-related Premature Mortality

Consistent with all RIAs since the proposal RIA for the Portland Cement NESHAP (U.S. EPA, 2009a), the $PM_{2.5}$ 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 characterization of uncertainty.

- One estimate is based on the concentration-response (C-R) function developed from the extended analysis of American Cancer Society (ACS) cohort, as reported in Pope et al. (2002), a study that EPA has previously used to generate its primary benefits estimate. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 µg/m^3 as was done in recent (2006–2009) Office of Air and Radiation RIAs.

- 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, 2009c), 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. 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.

Therefore, there is no evidence to support a truncation of the CRF [concentration-response function]." In conjunction with the underlying scientific literature, this document provided a basis for reconsidering the application of thresholds in $PM_{2.5}$ concentration-response functions used in EPA's RIAs. For a summary of these scientific review statements and the panel members commenting on thresholds since 2002, please consult the Technical Support Document (TSD) Summary of Expert Opinions on the Existence of a Threshold (U.S. EPA, 2010d).

Consistent with the recent scientific advice summarized above, we are replacing the previous threshold sensitivity analysis with a new "Lowest Measured Level" (LML) assessment. This approach summarizes 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. In the results section, we identify on the figures the lowest air quality levels measured in each of the primary cohort studies that estimate PM-related mortality. This information allows readers to determine the portion of PM-related mortality benefits occurring above or below 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 the two epidemiological studies. 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.

Analyses of these cohorts using data from more recent years, during which time PM concentrations have fallen, continue to report strong associations with mortality. 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 cohort studies follow large 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 recent studies indicates that confidence in $PM_{2.5}$-related mortality effects down to at least 7.5 $\mu g/m^3$ is high.

In implementing these rules, emission controls may lead to reductions in ambient $PM_{2.5}$ below the PM NAAQS in some areas. While benefits occurring below the standard may be somewhat more uncertain than those occurring above the standard, EPA considers them to be legitimate components of the total benefits estimate. Furthermore, given that the epidemiological literature in most cases has not provided estimates based on threshold models, there would be additional uncertainties imposed by assuming thresholds or other non-linear concentration-functions for the purposes of benefits analysis.

7.2.5 Economic Valuation of Health Impacts

These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type (U.S. EPA, 2009c). Directly emitted PM, SO_2, and VOC are the dominant $PM_{2.5}$ precursors affected by this rule. Even though we assume that all fine particles have equivalent health effects, the benefit-per-ton estimates (described in detail in Section 7.2.6) vary between precursors because each ton of precursor reduced has a different propensity to form $PM_{2.5}$ and a different pattern of transport, resulting geographic distribution of exposure. When more people are exposed, the benefits per ton are greater. For example, SO_2 tends to have a lower benefit-per-ton estimate than direct $PM_{2.5}$ because sulfate particles formed from SO_2 emissions can transport many miles, meaning that higher exposures may occur over areas with low populations. On the other hand, to the extent that direct $PM_{2.5}$ emissions occur in high density population areas, exposures will tend to be higher there, leading to higher monetized health benefits for direct $PM_{2.5}$ than for SO_2 emissions. Economic Valuation of Health Impacts

After quantifying the change in adverse health impacts, the final step is to estimate the economic value of these avoided impacts. Please refer to Table 5-11 in the recently proposed Transport Rule (U.S. EPA, 2010e) for a detailed description of the underlying valuation functions and the monetized unit values for each endpoint incorporated into this analysis.[4] The monetized mortality benefits dominate the total benefits estimates.

As is the nature of RIAs, the assumptions and methods used to estimate air quality benefits evolve over time to reflect the Agency's most current interpretation of the scientific and economic literature. For a period of time (2004–2006), the Office of Air and Radiation (OAR) valued mortality risk reductions using a value-of-a-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

[4]To comply with Circular A-4, EPA provides monetized benefits using discount rates of 3% and 7% (OMB, 2003). These benefits are estimated for a specific analysis year (i.e., 2014), and most of the PM 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 benefits using a 7% discount rate are only approximately 10% less than the monetized benefits using a 3% discount rate.

$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 $5.5 million (2000$)[5] 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)[6] 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 $6.3 million (2000$).[7] 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.

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[5]After adjusting the VSL to account for a different currency year (2008$) and to account for income growth to 2015, the $5.5 million VSL is $7.9 million.

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

[7]In this analysis, we adjust the VSL to account for a different currency year (2008$) and to account for income growth to 2015. After applying these adjustments to the $6.3 million value, the VSL is $9.1 million.

7.2.6 Calculating Boiler Sector-specific Benefit-per-ton Estimates

Benefit per-ton (BPT) estimates can be used to quantify the health impacts and monetized human health benefits of an incremental change in air pollution precursor emissions. In situations when we are unable to specifically model a regulatory option because of data or resource constraints, this approach can provide a reliable estimate of the benefits of emission reduction scenarios. EPA has used the BPT technique in previous RIAs, including the recent Ozone NAAQS RIA (U.S. EPA, 2010a) and Federal Transport Rule RIA (U.S. EPA, 2010e). For this analysis, the emissions inventories used in the air quality modeling and benefits modeling are slightly different from the final boiler sector emission inventories reflected in the rules' emission memos. [8] These discrepancies exist because emissions and air quality modeling decisions are made early in the analytical process, and the sheer number of boilers (over 180,000 area boilers and 13,000 major boilers) made it impossible to reconcile the data completely. Part of the discrepancy is because the emissions inventory categorizes boilers as "point" and "non-point" instead of "major source" or "area source." We assume that the boilers in the point source inventory are appropriate surrogates for the major source boilers and that the boilers in the non-point source inventory are appropriate surrogates for the area source boilers. Furthermore, the emission inventories used for air quality modeling do not reflect emissions from new sources anticipated to come online by the analysis year. To address concerns about the discrepancies between these inventories, we utilized the air quality modeling to derive boiler sector-specific BPT estimates, which are then multiplied by the tons of emissions reduced for each regulatory option.

To derive the BPT estimates for this analysis, we:

1. *Quantified the $PM_{2.5}$ -related human health and monetized benefits of the SO_2 emission reductions for major source boilers*. We first quantified the health impacts and monetized benefits of total $PM_{2.5}$ mass formed from the SO_2 reductions, allowing us to isolate the PM air quality impacts from SO_2 reductions alone. This procedure allowed us to develop $PM_{2.5}$ BPT estimates that quantified the $PM_{2.5}$-related benefits of incremental changes in SO_2 emissions.

2. *Divided the health impacts and monetized benefits by the emission reduction.* This calculation yields BPT estimates for PM-related SO_2. The resulting BPT estimates

[8] Technical details regarding the emissions inventory used in the air quality modeling are available in the Air Quality Modeling TSD (U.S. EPA, 2010f). Technical details regarding the emission reductions estimated for this rule are available in these docket memos: "*Revised Development of Baseline Emission Factors for Boilers and Process Heaters at Commercial, Industrial, and Institutional Facilities*" and "*Revised Methodology for Estimating Cost and Emissions Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants.*"

were then multiplied by the projected SO_2 emission reductions to produce an estimate of the PM-related health impacts and monetized benefits.

This process was repeated for directly emitted $PM_{2.5}$ from major sources and for $PM_{2.5}$ and SO_2 emissions from area source boilers. This process was also repeated using the 2.5th percentile and 97.5th percentile benefits to provide confidence intervals for the BPT estimates.[9] To calculate the total benefits, we simply multiply the BPT estimate by the emission reductions of directly emitted $PM_{2.5}$ and SO_2 for each regulatory option. Deriving boiler sector-specific BPT estimates provides equivalent benefits results as scaling the air quality data directly to correspond to the inventory differences, but it provides greater flexibility to examine alternate regulatory scenarios.

The BPT estimates used in this analysis are different from the BPT estimates used in the proposal analysis. While these boiler sector-specific BPT estimates are methodologically consistent with the BPT estimates in Fann, Fulcher, and Hubbell (2009) that were used in the proposal analysis, the BPT estimates applied in this final analysis provide a different and likely superior representation of the health impacts and monetized benefits from boilers compared to the proposal. This is because the BPT used in the proposal lumped emissions from major boilers together with other emission sources in the non-EGU category and area boilers together with other emission sources in the area category. For example, the non-EGU category includes emissions from many different large stationary sources, including boilers, metal production, mineral products, chemical manufacturing, petroleum industry, pulp and paper production, and oil and gas production, and waste disposal, which all have different geographic distributions across the country. Because the geographic distribution of boilers is not likely to exactly match the average distribution of all of these sources, ambient air quality and the associated benefits for reducing boiler emissions are going to be different than for the entire non-EGU category. In addition to the location of the emission sources, the geographic differences also affect the benefits to due to geographic differences in local air chemistry, meteorology, population density, and baseline health incidence.

In addition, the air quality modeling for these rules reflected higher spatial resolution (12 km by 12 km nationally) than the previous BPT estimates and reflects an updated baseline emissions inventory.[10] We believe that these updates result in benefits estimates that are more

[9]These confidence intervals only reflect the standard errors within the epidemiology studies and valuation functions, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates.

[10]For more information on the changes in the emissions inventory, please see Table 2-2 of U.S. EPA, (2010g), which provides a list of the differences between the 2002 and 2005 base inventory. In addition to including consent decrees and several recent mobile source rules, the emissions platform used for this analysis also removed duplicates and plant closures and an updated version of IPM to project EGU emissions.

accurate than the proposal. For comparison, the BPT for directly emitted $PM_{2.5}$ in this analysis is lower for major and area sources than the proposal, whereas the BPT for SO_2 is higher in this analysis than the proposal. In addition, we have updated the analysis year used in this final analysis to be consistent with the implementation timeline, but this revision would not have a significant impact on the benefits results. In the proposal, the BPT estimates reflected emissions inventories, income growth, and population growth for 2015 because we did not have BPT estimates available for the proposal analysis year (2013). For this final analysis, the emissions inventories are for 2016, but income growth and population growth are for the final analysis year (2014). Because the projected emissions inventory does not assume growth in the boiler sector, the boiler benefits are not likely to change due to a 2016 inventory instead of a 2014 inventory. We provide the boiler-specific BPT estimates in Section 7.3. We also provide maps of the total ambient $PM_{2.5}$ impacts from the modeled point and non-point boilers in Figures 7-4 through 7-7.

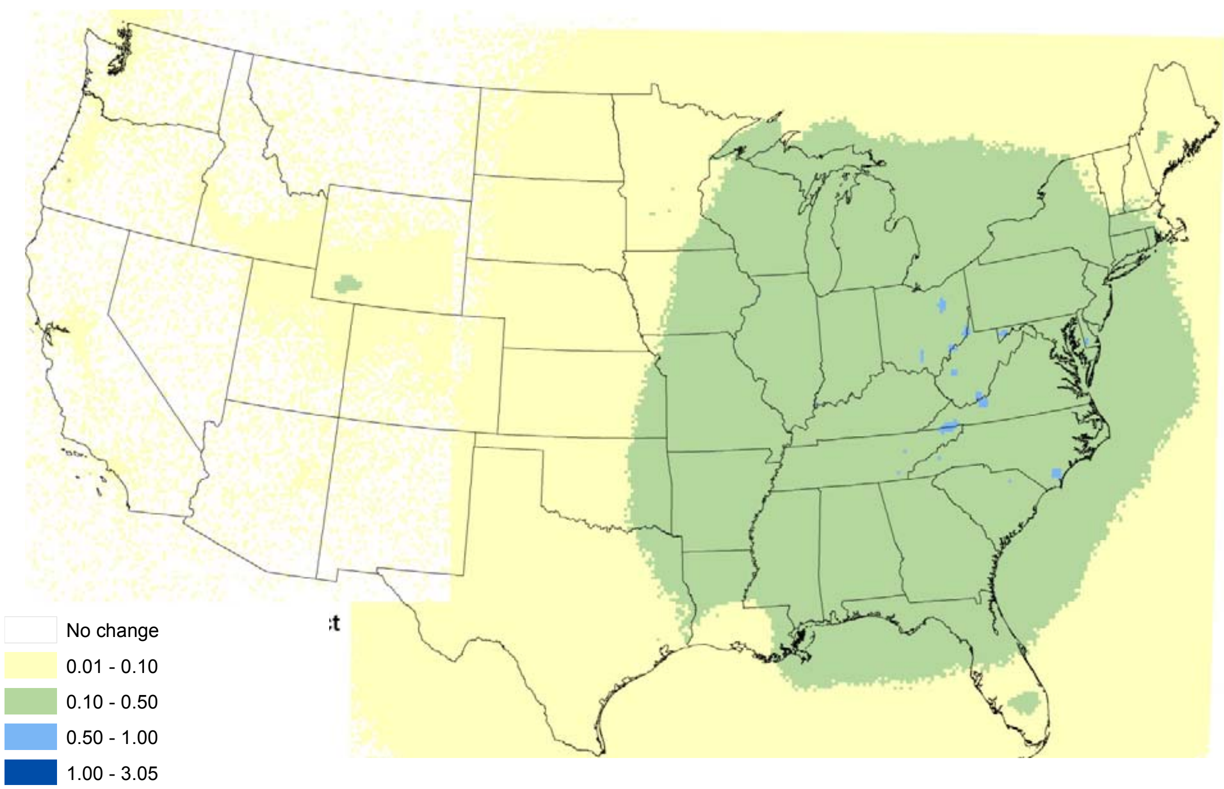

Figure 7-4. Change in Ambient $PM_{2.5}$ Levels from SO_2 Emissions from Point Source Boilers

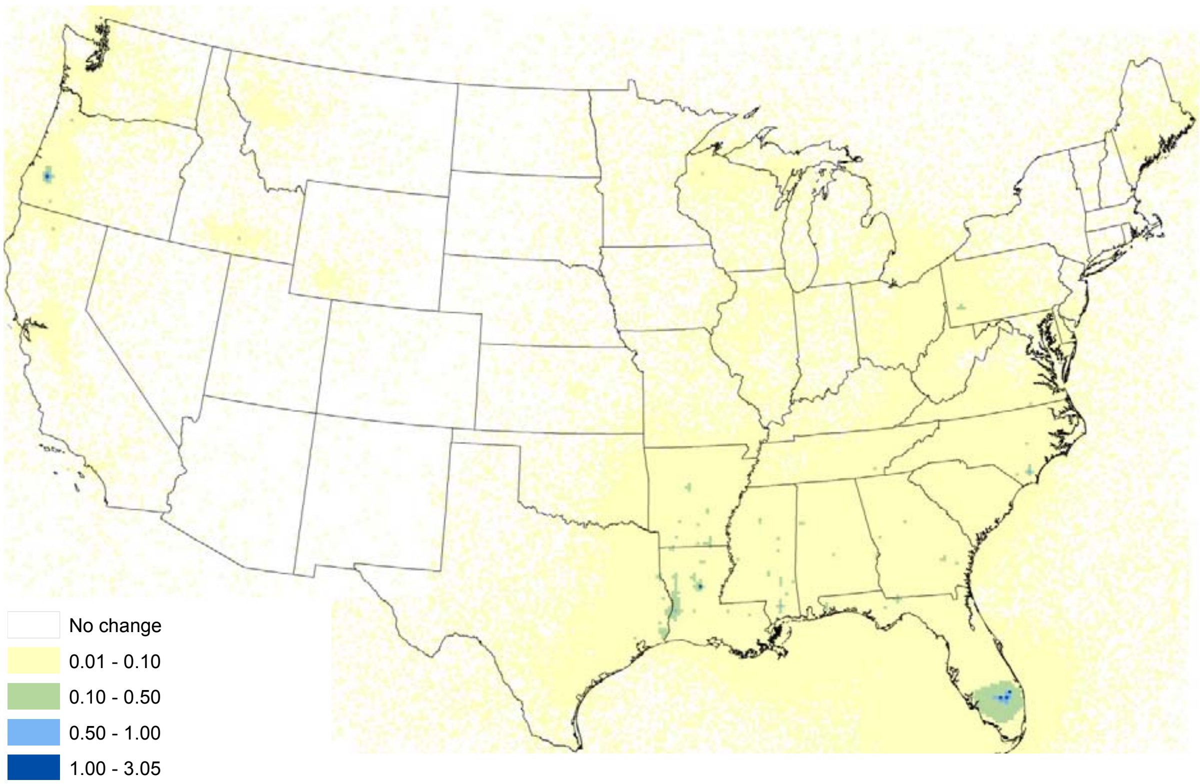

Figure 7-5. Change in Ambient $PM_{2.5}$ Levels from PM Emissions from Point Source Boilers

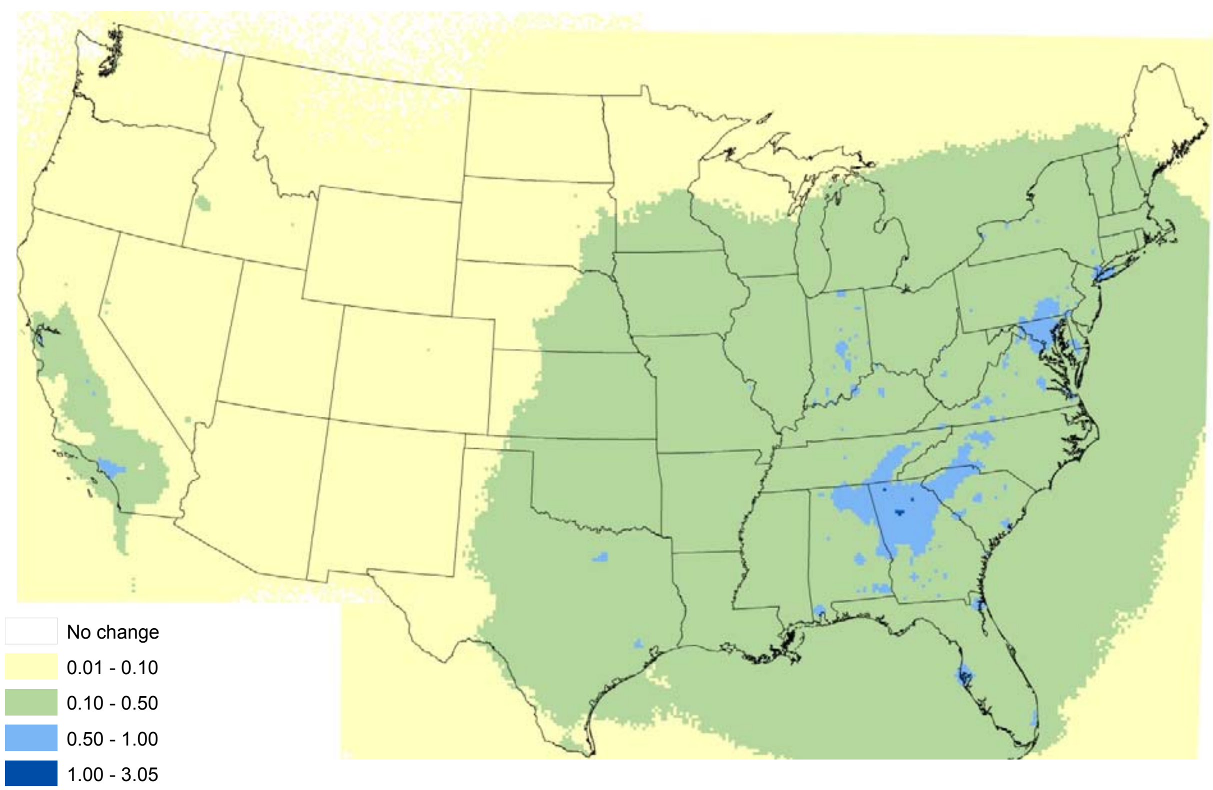

Figure 7-6. Change in Ambient $PM_{2.5}$ Levels from SO_2 Emissions from Non-point Source Boilers

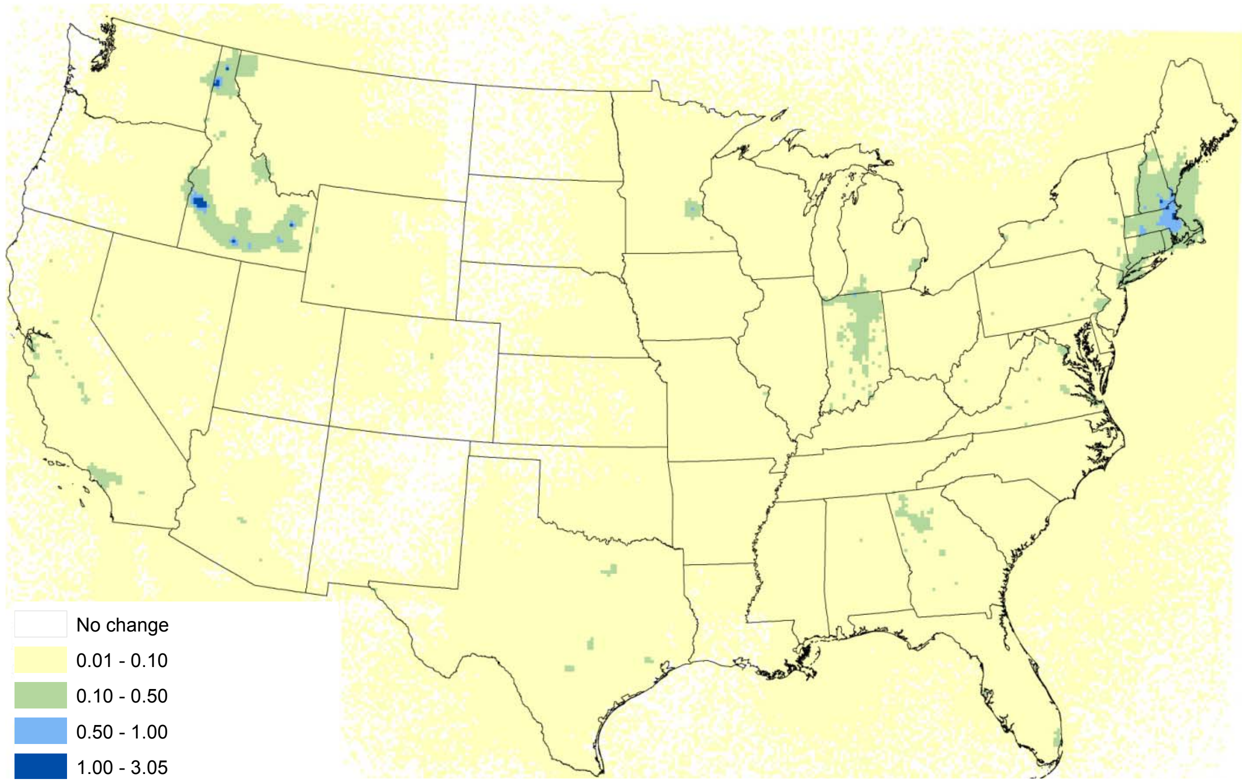

Figure 7-7. Change in Ambient $PM_{2.5}$ Levels from PM Emissions from Non-point Source Boilers

Although VOCs are also precursors to $PM_{2.5}$, we have not monetized their contribution to the $PM_{2.5}$ benefits in this analysis for several reasons. Analysis of organic carbon measurements suggest only a fraction of secondarily formed organic carbon aerosols are of anthropogenic origin. The current state of the science of secondary organic carbon formation indicates that anthropogenic VOC contribution to secondary organic carbon aerosols is often lower than the biogenic (natural) contribution. Given that a fraction of secondarily formed organic carbon aerosols from anthropogenic VOC emissions and the extremely small amount of VOC emissions from this sector relative to the entire VOC inventory, it is unlikely this sector has a large contribution to ambient secondary organic carbon aerosols. Photochemical models typically estimate secondary organic carbon aerosols from anthropogenic VOC emissions to be less than 0.1 $\mu g/m^3$. Given the resource requirements to apply source apportionment technology in the photochemical model for secondary organic carbon aerosols and that only a very small portion of secondary organic carbon aerosols (i.e., from anthropogenic sources) would be apportioned, this option was not employed to estimate the impact of this sector's VOC emissions on secondary organic carbon aerosols. Lastly, the contribution of VOC reductions to total monetized $PM_{2.5}$ benefits would likely be very small for these rules. For example, while not an appropriate source for this application, if the BPT for VOC emissions from industrial point sources and EGUs from Fann, Fulcher, and Hubbell (2009) were applied to the boiler rule, the VOC-related benefits would be less than $6 million for the Boiler MACT.

The differences between the VOC emissions inventories are comparatively small, and VOCs are only reduced by 20% for both of the Boiler MACT options. In addition, the complex non-linear chemistry of ozone formation introduces uncertainty to the development and application of a BPT estimate. Therefore, we used the scaled air quality modeling results directly to estimate the ozone benefits associated with VOC reductions. As the ozone-related benefits are very small, we do not believe that the differences in the VOC emissions inventory contribute much uncertainty to the overall benefits results. Because the VOC emission reductions for the Boiler Area Source Rule are less than 1%, we do not include the ozone-related benefits associated with that rule, as the benefits would be very small.

7.3 Health Benefits Results

The health benefits have increased since the proposal analysis for two reasons: (1) emission reductions of SO_2 have increased, and (2) the BPT for SO_2 has increased. The decreases in directly emitted $PM_{2.5}$ emissions and lower BPT for $PM_{2.5}$ since the proposal do not offset the increase in benefits from SO_2 emission reductions.

Tables 7-2 and 7-3 provide a summary of the monetized $PM_{2.5}$ benefits (including the indirect PM co-benefits) using the anchor points of Pope et al. (2002) and Laden et al. (2006) at discount rates of 3% and 7% for the final Boiler MACT and Boiler Area Source Rule, respectively. Tables 7-4 and 7-5 provide the reductions in health incidences as a result of the reduction in ambient $PM_{2.5}$ levels for the final Boiler MACT and Boiler Area Source Rule, respectively. Tables 7-6 and 7-7 provide the total monetized $PM_{2.5}$ benefits derived from Pope et al. (2002) and Laden et al. (2006) as well as the expert elicitation for the final Boiler MACT and Boiler Area Source Rule, respectively. Table 7-8 provides the estimated reductions in health incidences and the monetized benefits associated with estimated reductions in ambient ozone concentrations.

Table 7-2. Summary of Monetized Benefits Estimates for Final Boiler MACT in 2014 (millions of 2008$)[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 of 2008$ at 3%)	Total Monetized Benefits (millions of 2008$ at 7%)
Selected Option	Direct $PM_{2.5}$	29,007	$72,000	$180,000	$65,000	$160,000	$2,100 to $5,100	$1,900 to $4,600
	SO_2	439,901	$46,000	$110,000	$42,000	$100,000	$20,000 to $49,000	$18,000 to $45,000
						Total	**$22,000 to $54,000**	**$20,000 to $49,000**
Alternative Option	Direct $PM_{2.5}$	28,139	$72,000	$180,000	$65,000	$160,000	$2,000 to $5,000	$1,800 to $4,500
	SO_2	337,514	$46,000	$110,000	$42,000	$100,000	$15,000 to $38,000	$14,000 to $34,000
						Total	**$17,000 to $43,000**	**$16,000 to $39,000**

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures so numbers may not sum across columns. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The benefit per ton estimates vary because each ton of precursor reduced has a different propensity to become $PM_{2.5}$. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. These estimates do not include benefits from reducing HAP emissions, VOC emissions and ozone exposure, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section. These benefits reflect existing boilers and 47 new boilers anticipated to come online by 2014.

Table 7-3. Summary of Monetized Benefits Estimates for Final Boiler Area Source Rule in 2014 (millions of 2008$)[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 of 2008$ at 3%)	Total Monetized Benefits (millions of 2008$ at 7%)
Proposed MACT Approach	Direct $PM_{2.5}$	590	$120,000	$290,000	$110,000	$260,000	$69 to $170	$63 to $150
	SO_2	3,197	$41,000	$100,000	$37,000	$91,000	$130 to $320	$120 to $290
						Total	**$200 to $490**	**$180 to $440**
Final MACT/ GACT Approach	Direct $PM_{2.5}$	678	$120,000	$290,000	$110,000	$260,000	$79 to $190	$72 to $180
	SO_2	3,197	$41,000	$100,000	$37,000	$91,000	$130 to $320	$120 to $290
						Total	**$210 to $520**	**$190 to $470**

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures so numbers may not sum across columns. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The benefit per ton estimates vary because each ton of precursor reduced has a different propensity to become $PM_{2.5}$. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section.

Table 7-4. Summary of Estimated Reductions in Health Incidences from $PM_{2.5}$ for the Final Boiler MACT in 2014 (95th percentile confidence interval) [a]

	Selected Option	Alternative Option
Avoided Premature Mortality		
Pope et al. (2002)	2,500 (1,600 – 8,100)	2,000 (1,400 – 7,100)
Laden et al. (2006)	6,500 (6,200 – 19,000)	5,100 (5,500 – 16,000)
Woodruff (Infant mortality)	10 (0 – 58)	8 (0 – 51)
Avoided Morbidity		
Chronic Bronchitis	1,600 (340 – 6,000)	1,300 (300 – 5,200)
Acute Myocardial Infarction	4,000 (2,400 – 13,000)	3,100 (2,100 – 11,000)
Hospital Admissions, Respiratory	610 (520 – 1,800)	480 (460 – 1,600)
Hospital Admissions, Cardiovascular	1,300 (1,800 – 3,000)	1,000 (1,600 – 2,700)
Emergency Room Visits, Respiratory	2,400 (2,600 – 6,800)	1,900 (2,300 – 6,000)
Acute Bronchitis	3,700 (0 – 15,000)	2,900 (0 – 13,000)
Work Loss Days	310,000 (520,000 – 690,000)	250,000 (460,000 – 600,000)
Asthma Exacerbation	41,000 (5,800 – 250,000)	32,000 (5,000 – 220,000)
Minor Restricted Activity Days	1,900,000 (3,000,000 – 4,200,000)	1,500,000 (2,600,000 – 3,700,000)
Lower Respiratory Symptoms	44,000 (37,000 – 130,000)	35,000 (32,000 – 120,000)
Upper Respiratory Symptoms	34,000 (16,000 – 110,000)	26,000 (14,000 – 99,000)

[a] All estimates are for the analysis year (2014) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, VOC emissions and ozone exposure, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section. These confidence intervals only reflect the standard errors within the epidemiology studies, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and 47 new boilers anticipated to come online by 2014.

Table 7-5. Summary of Estimated Reductions in Health Incidences from $PM_{2.5}$ for the Final Boiler Area Source Rule in 2014 (95th percentile confidence interval)[a]

	Proposed MACT Approach	Final MACT/GACT Approach
Avoided Premature Mortality		
Pope et al. (2002)	23 (8 – 38)	24 (8 – 40)
Laden et al. (2006)	58 (29 – 87)	61 (31 – 91)
Woodruff (Infant mortality)	0 (0 – 0)	0 (0 – 0)
Avoided Morbidity		
Chronic Bronchitis	16 (2 – 30)	17 (2 – 31)
Acute Myocardial Infarction	38 (12 – 64)	40 (12 – 67)
Hospital Admissions, Respiratory	6 (3 – 9)	6 (3 – 9)
Hospital Admissions, Cardiovascular	12 (8 – 14)	13 (9 – 15)
Emergency Room Visits, Respiratory	20 (11 – 28)	21 (11 – 30)
Acute Bronchitis	37 (0 – 77)	38 (0 – 81)
Work Loss Days	3,100 (2,600 – 3,500)	3,200 (2,800 – 3,700)
Asthma Exacerbation	400 (29 – 1,200)	420 (31 – 1,300)
Minor Restricted Activity Days	18,000 (15,000 – 21,000)	19,000 (16,000 – 22,000)
Lower Respiratory Symptoms	430 (190 – 680)	460 (200 – 710)
Upper Respiratory Symptoms	330 (83 – 580)	350 (87 – 610)

[a] All estimates are for the analysis year (2014) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section. These confidence intervals only reflect the standard errors within the epidemiology studies, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and 6,779 new boilers anticipated to come online by 2014.

Table 7-6. Summary of Monetized Benefits Estimates from $PM_{2.5}$ for the Final Boiler MACT in 2014 (95th percentile confidence interval)[a]

	Selected Option		Alternative Option	
	3%	7%	3%	7%
Based on Epidemiology Literature				
Pope et al. (2002)	$22,000 ($1,900 – $68,000)	$20,000 ($1,600 – $62,000)	$17,000 ($1,500 – $53,000)	$16,000 ($1,300 – $49,000)
Laden et al. (2006)	$54,000 ($4,900 – $160,000)	$49,000 ($4,300 – $140,000)	$43,000 ($3,800 – $120,000)	$39,000 ($3,400 – $110,000)
Based on Expert Elicitation				
Expert A	$58,000 ($3,400 – $190,000)	$52,000 ($3,000 – $170,000)	$45,000 ($2,700 – $150,000)	$41,000 ($2,400 – $140,000)
Expert B	$44,000 ($1,700 – $180,000)	$39,000 ($1,500 – $160,000)	$34,000 ($1,300 – $140,000)	$31,000 ($1,200 – $130,000)
Expert C	$44,000 ($2,600 – $170,000)	$40,000 ($2,300 – $150,000)	$35,000 ($2,100 – $130,000)	$31,000 ($1,800 – $120,000)
Expert D	$31,000 ($2,100 – $100,000)	$28,000 ($1,800 – $91,000)	$24,000 ($1,600 – $78,000)	$22,000 ($1,400 – $71,000)
Expert E	$72,000 ($6,200 – $210,000)	$65,000 ($5,500 – $190,000)	$56,000 ($4,900 – $170,000)	$51,000 ($4,400 – $150,000)
Expert F	$40,000 ($3,900 – $120,000)	$36,000 ($3,500 – $110,000)	$31,000 ($3,100 – $92,000)	$28,000 ($2,700 – $84,000)
Expert G	$26,000 ($250 – $95,000)	$24,000 ($160 – $86,000)	$21,000 ($190 – $74,000)	$19,000 ($120 – $68,000)
Expert H	$33,000 ($300 – $130,000)	$30,000 ($210 – $120,000)	$26,000 ($240 – $100,000)	$24,000 ($160 – $92,000)
Expert I	$44,000 ($2,500 – $140,000)	$39,000 ($2,200 – $130,000)	$34,000 ($1,900 – $110,000)	$31,000 ($1,700 – $100,000)
Expert J	$36,000 ($2,700 – $140,000)	$32,000 ($2,400 – $120,000)	$28,000 ($2,100 – $110,000)	$25,000 ($1,900 – $97,000)
Expert K	$8,400 ($250 – $54,000)	$7,800 ($160 – $50,000)	$6,600 ($190 – $43,000)	$6,100 ($120 – $39,000)
Expert L	$29,000 ($1,200 – $110,000)	$27,000 ($1,000 – $100,000)	$23,000 ($930 – $89,000)	$21,000 ($790 – $81,000)

[a] All estimates are for the analysis year (2014) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section. These confidence intervals only reflect the standard errors within the epidemiology studies and valuation functions, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and 47 new boilers anticipated to come online by 2014.

Table 7-7. Summary of Monetized Benefits Estimates from $PM_{2.5}$ for the Final Boiler Area Source Rule in 2014 (95th percentile confidence interval)[a]

	Proposed MACT Approach		Final MACT/GACT Approach	
	3%	7%	3%	7%
Based on Epidemiology Literature				
Pope et al. (2002)	$200 ($17 – $610)	$180 ($15 – $560)	$210 ($18 – $650)	$190 ($16 – $590)
Laden et al. (2006)	$490 ($44 – $1,400)	$440 ($39 – $1,300)	$520 ($46 – $1,500)	$470 ($41 – $1,400)
Based on Expert Elicitation				
Expert A	$520 ($30 – $1,700)	$470 ($27 – $1,500)	$550 ($32 – $1,800)	$490 ($28 – $1,600)
Expert B	$390 ($15 – $1,600)	$360 ($14 – $1,500)	$410 ($16 – $1,700)	$370 ($14 – $1,500)
Expert C	$400 ($24 – $1,500)	$360 ($21 – $1,400)	$420 ($25 – $1,600)	$380 ($22 – $1,400)
Expert D	$280 ($19 – $900)	$250 ($17 – $820)	$300 ($20 – $950)	$270 ($17 – $860)
Expert E	$640 ($56 – $1,900)	$580 ($50 – $1,700)	$680 ($59 – $2,000)	$610 ($52 – $1,800)
Expert F	$360 ($35 – $1,100)	$330 ($31 – $960)	$380 ($37 – $1,100)	$340 ($33 – $1,000)
Expert G	$240 ($2.1 – $850)	$220 ($1.6 – $780)	$250 ($2.2 – $900)	$230 ($1.6 – $820)
Expert H	$300 ($2.6 – $1,200)	$270 ($2.0 – $1,000)	$310 ($2.7 – $1,200)	$280 ($2.1 – $1,100)
Expert I	$390 ($22 – $1,300)	$350 ($20 – $1,200)	$410 ($23 – $1,400)	$370 ($21 – $1,200)
Expert J	$320 ($24 – $1,200)	$290 ($22 – $1,100)	$340 ($25 – $1,300)	$300 ($23 – $1,200)
Expert K	$77 ($2.1 – $490)	$71 ($1.6 – $450)	$81 ($2.2 – $520)	$75 ($1.6 – $480)
Expert L	$270 ($11 – $1,000)	$240 ($10 – $930)	$280 ($12 – $1,100)	$250 ($10 – $970)

[a] All estimates are for the analysis year (2014) and are rounded to whole numbers with two significant figures. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates do not include benefits from reducing HAP emissions, nor energy disbenefits associated with the increased emissions from additional energy usage described in the next section. These confidence intervals only reflect the standard errors within the epidemiology studies and valuation functions, but they do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates. These benefits reflect existing boilers and 6,779 new boilers anticipated to come online by 2014.

Table 7-8. Summary of Monetized Benefits Estimates from Ozone for the Final Boiler MACT in 2014 (95th percentile confidence interval)[a]

Avoided Premature Mortality		Incidence	Valuation (millions of 2008$)
NMMAPS	Bell et al. (2004)	0 (0 – 1)	$3.3 ($0.27 – $9.8)
	Schwartz (2005)	1 (0 – 1)	$5.0 ($0.41 – $15)
	Huang and Bell (2005)	1 (0 – 1)	$5.5 ($0.46 – $16)
Meta-analyses	Bell et al. (2005)	1 (1 – 2)	$11 ($0.94 – $31)
	Ito et al. (2005)	2 (1 – 2)	$15 ($1.4 – $41)
	Levy et al. (2005)	2 (1 – 2)	$15 ($1.4 – $41)
Avoided Morbidity			
Adult Hospital Admissions, Respiratory		3 (0 – 5)	$0.07 ($0.01 – $0.12)
Infant Hospital Admissions, Respiratory		2 (1 – 4)	$0.03 ($0.01 – $0.04)
Emergency Room Visits, Respiratory		2 (0 – 5)	< $0.01 ($0.00 – $0.01)
School Loss Days		810 (330 – 1,200)	$0.08 ($0.03 – $0.11)
Worker Productivity		N/A	$0.02 ($0.02 – $0.02)
Minor Restricted Activity Days		2,300 (1,100 – 3,600)	$0.15 ($0.06 – $0.28)

[a] All estimates are for the analysis year (2014) and are rounded to two significant figures. Health effects associated with ozone exposure are assumed to occur within the analysis year. Therefore, the monetized benefits are the same for any discount rate. These confidence intervals reflect the standard errors within the epidemiology studies and valuation functions. These benefits reflect existing boilers and 47 new boilers anticipated to come online by 2014.

Figures 7-8 and 7-9 illustrate the relative breakdown of the estimated monetized health benefits associated with changes in $PM_{2.5}$ and ozone, respectively. Figure 7-10 shows the total combined monetized benefits for the final Boiler MACT and Area Source Rule at discount rates of 3% and 7%. Figures 7-11 and 7-12 provide a breakdown of the estimated monetized $PM_{2.5}$ benefits by precursor pollutant for the final Boiler MACT and Boiler Area Source Rule, respectively. Figures 7-13 and 7-14 provide a breakdown of the monetized $PM_{2.5}$ benefits by subcategory for the final Boiler MACT and Boiler Area Source Rule, respectively.

This analysis shows that the majority of the population is exposed to PM levels at or above the lowest LML of the cohort studies (Figures 7-15 and 7-16), increasing our confidence in the PM mortality analysis. Because we used BPT estimates, we are unable to provide an estimate of the mortality impacts that occur at various PM levels. Figure 7-15 shows a bar chart of the percentage of the adult population exposed to each $PM_{2.5}$ level in the baseline. Figure 7-16 shows a cumulative distribution function of the same data. Both figures identify the LML for each of the major cohort studies.

Using the Pope et al. (2002) study, approximately 79% 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, 34% of the population is exposed to annual mean $PM_{2.5}$ levels at or 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.

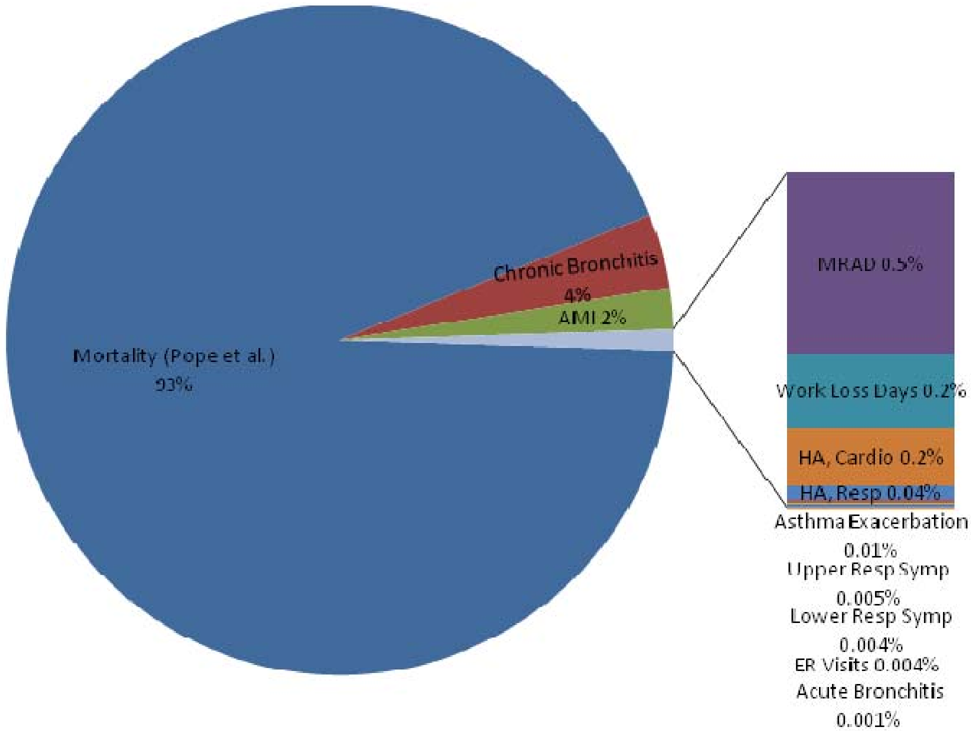

Figure 7-8. Breakdown of Monetized $PM_{2.5}$ Health Benefits Estimates using Mortality Function from Pope et al. (2002)[a]

[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 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.

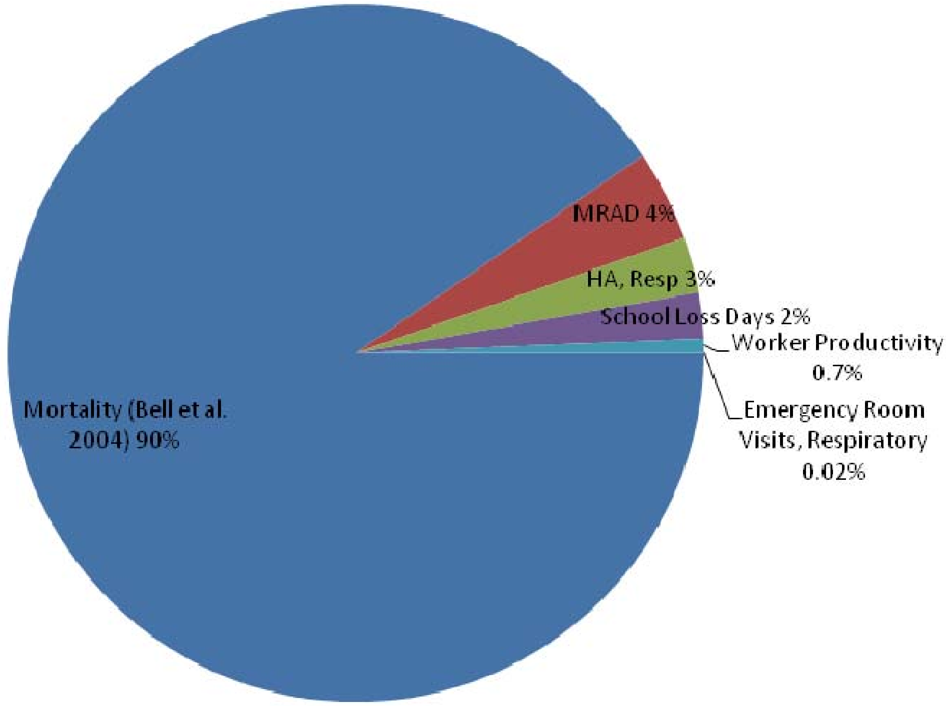

Figure 7-9. Breakdown of Monetized Ozone Health Benefits Estimates using Mortality Function from Bell et al. (2004)[a]

[a] This pie chart breakdown is illustrative, using the results based on Bell et al. (2004) as an example. Using the Levy et al. (2005) function for premature mortality, the percentage of total monetized benefits due to mortality would be 98%.

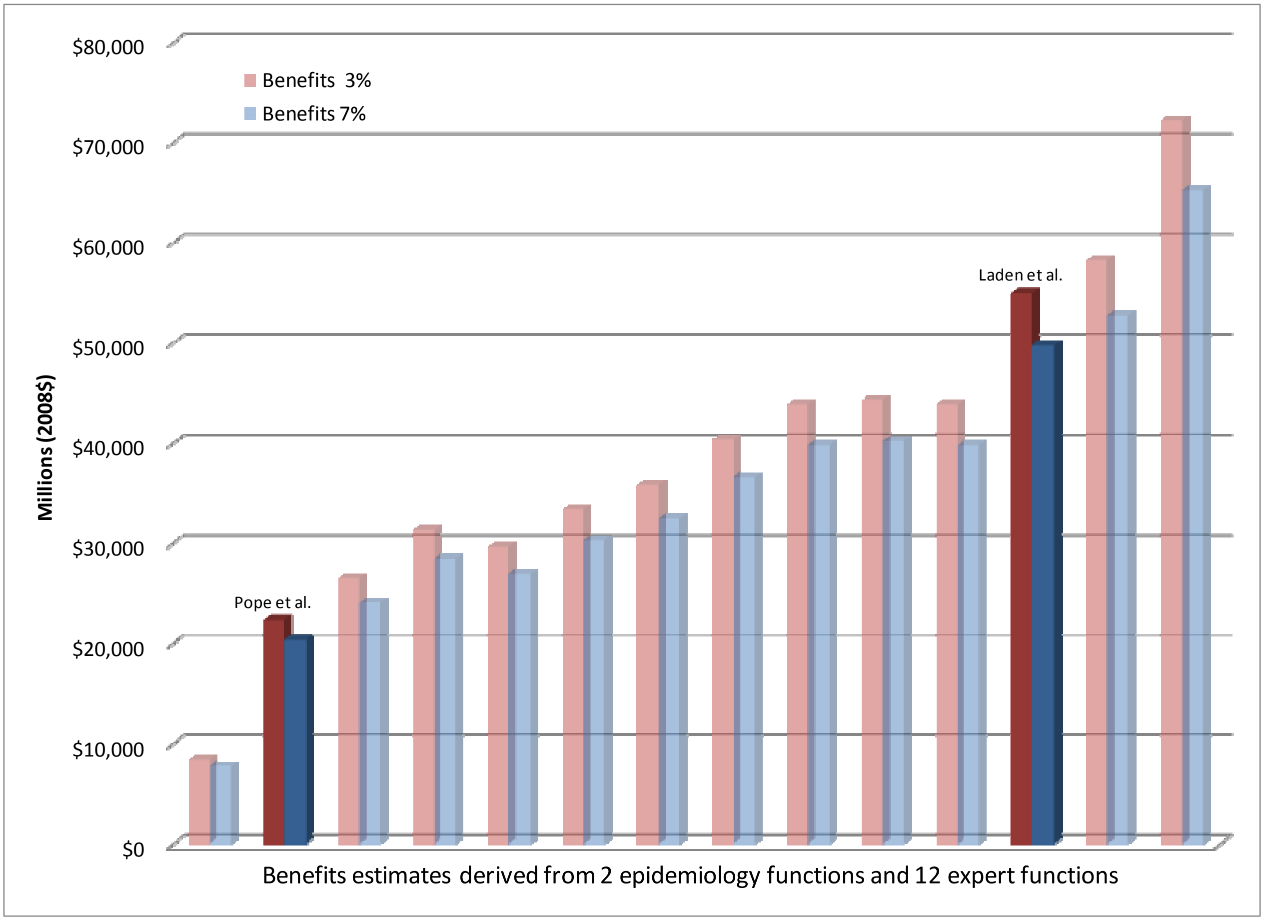

Figure 7-10. Total Monetized $PM_{2.5}$ and Ozone Benefits Estimates for the Final Boiler MACT and Boiler Area Source Rule in 2014[a]

[a] This graph shows the estimated benefits at discount rates of 3% and 7% using effect coefficients derived from the Pope et al. (2002) study and the Laden et al. (2006) 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. These estimates do not include benefits from reducing HAP emissions, but they do include the energy disbenefits associated with the increased emissions from additional energy usage. Due to methodology and time limitations under the court-ordered schedule, we were unable to monetize the benefits associated with several categories of benefits, including direct exposure to HAPs and SO_2, as well as ecosystem effects, and visibility effects. These benefits reflect existing boilers and new boilers anticipated to come online by 2014.

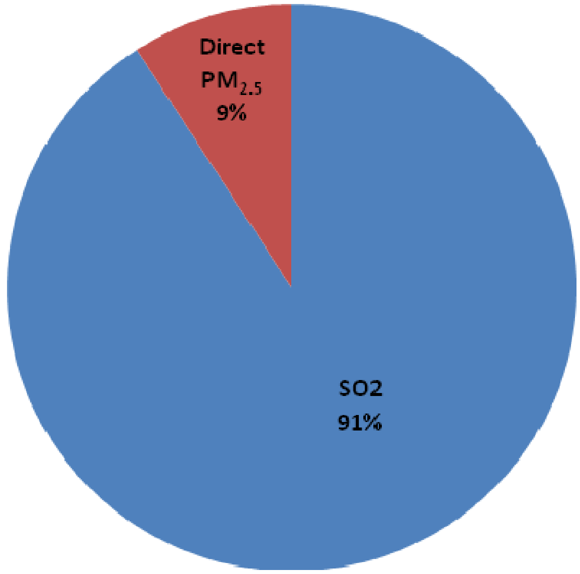

Figure 7-11. Breakdown of Monetized $PM_{2.5}$ Benefits Estimates by Precursor for the Final Boiler MACT in 2014[a]

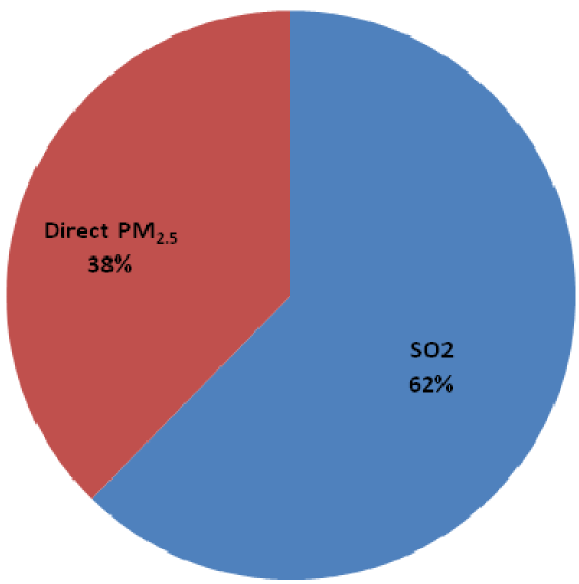

Figure 7-12. Breakdown of Monetized $PM_{2.5}$ Benefits Estimates by Precursor for the Final Boiler Area Source Rule in 2014[a]

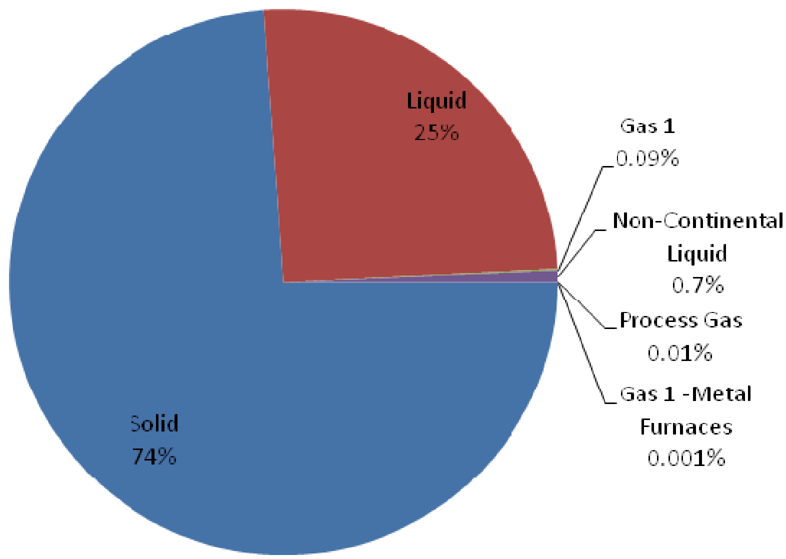

Figure 7-13. Breakdown of Monetized $PM_{2.5}$ Benefits Estimates by Subcategory for the Final Boiler MACT in 2014[a]

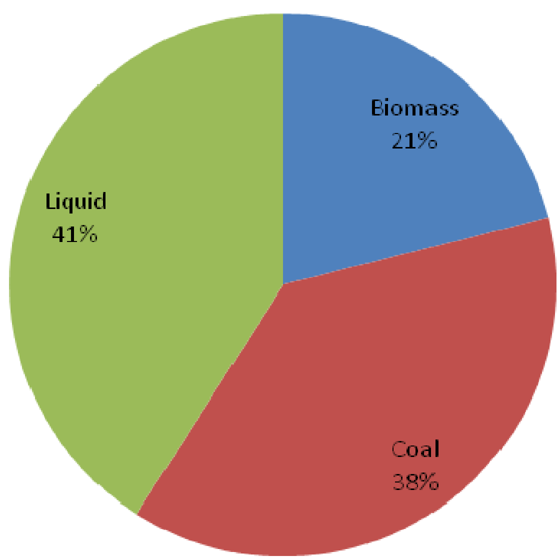

Figure 7-14. Breakdown of Monetized $PM_{2.5}$ Benefits Estimates by Subcategory for the Final Boiler Area Source Rule in 2014[a]

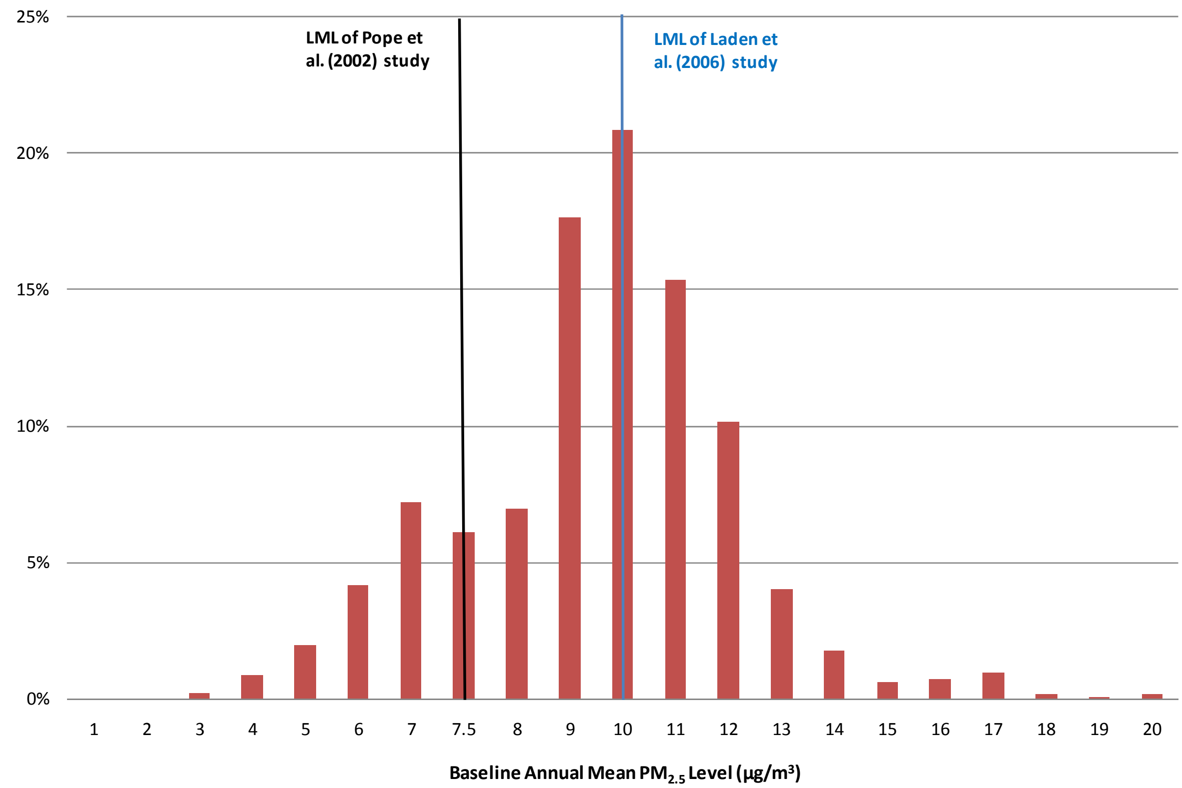

Figure 7-15. Percentage of Population Exposed to Baseline Air Quality Levels for Final Boiler MACT and Boiler Area Source Rule[a]

[a] Approximately 79% of the population is exposed to baseline exposure to annual mean $PM_{2.5}$ levels at or above 7.5 µg/m^3, which is the lowest air quality level considered in the ACS cohort study by Pope et al. (2002).

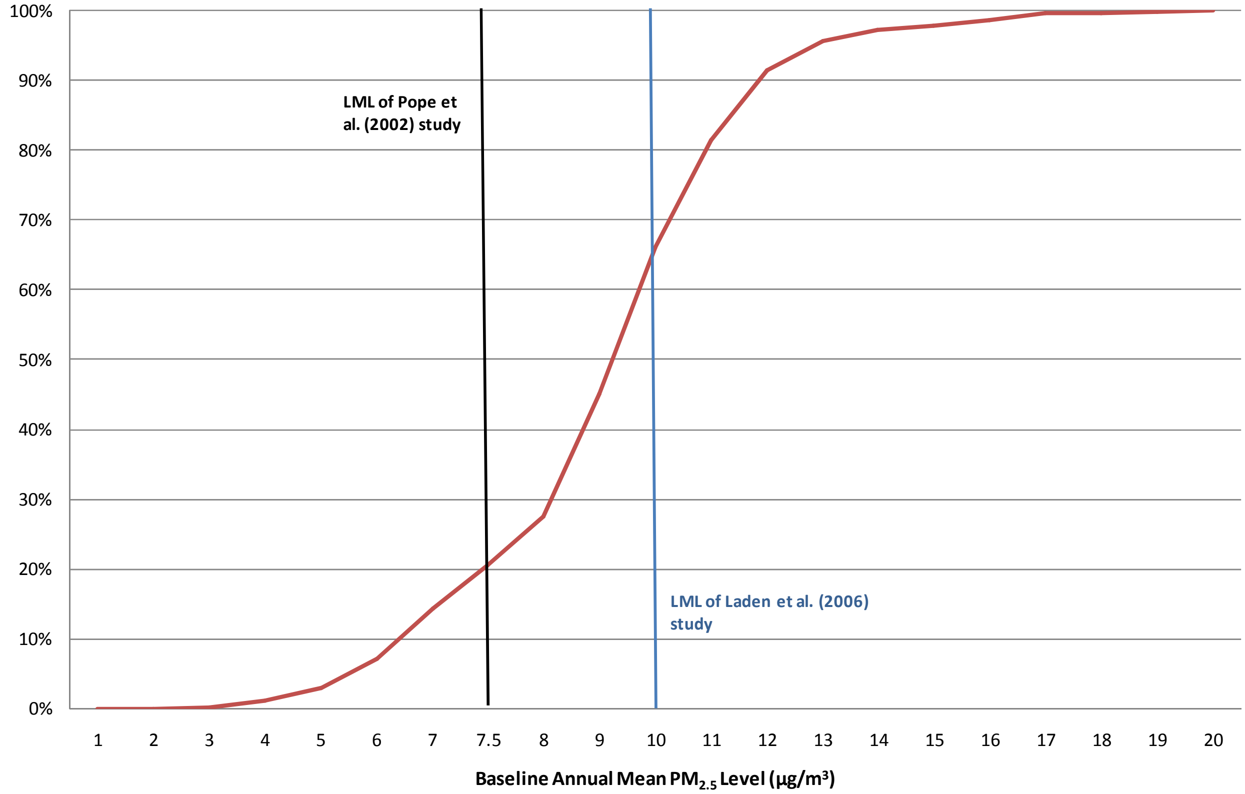

Figure 7-16. Cumulative Percentage of Population Exposed to Baseline Air Quality Levels for Final Boiler MACT and Boiler Area Source Rule[a]

[a] Approximately 79% of the population is exposed baseline exposure to annual mean $PM_{2.5}$ levels at or above 7.5 µg/m^3, which is the lowest air quality level considered in the ACS cohort study by Pope et al. (2002).

7.4 Energy Disbenefits

In this section, we provide an estimate of the energy disbenefits associated with the increased emissions from additional energy usage.[11] Electricity usage associated with the operation of control devices is anticipated to increase emissions of pollutants from electric utility boilers (EGU boilers) that supply electricity to the non-EGU boiler facilities. We estimate emission increases of 910,000 tpy CO_2 for major boilers and 22,000 tpy CO_2 for area boilers.

7.4.1 Social Cost of Carbon and Greenhouse Gas Disbenefits

EPA has assigned a dollar value to reductions in carbon dioxide (CO_2) emissions using recent estimates of the "social cost of carbon" (SCC). The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is

[11] As we use the term "energy disbenefits" in this analysis, we are not referring to the cost of purchasing additional electricity or fuel.

intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change. The SCC estimates used in this analysis were developed through an interagency process that included EPA and other executive branch entities, and concluded in February, 2010. EPA first used these SCC estimates in the benefits analysis for the final joint EPA/DOT Rulemaking to establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; see the rule's preamble for discussion about application of SCC (75 FR 25324; 5/7/10). The SCC Technical Support Document (SCC TSD) provides a complete discussion of the methods used to develop these SCC estimates.[12]

The interagency group selected four SCC values for use in regulatory analyses, which we have applied in this analysis: \$5, \$21, \$35, and \$65 per metric ton of CO_2 emissions[13] in 2010, in 2007 dollars. The first three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent, respectively. SCCs at several discount rates are included because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context. The fourth value is the 95th percentile of the SCC from all three models at a 3 percent discount rate. It is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. Low probability, high impact events are incorporated into all of the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages.

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that the interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual

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

[13]The interagency group decided that these estimates apply only to CO_2 emissions. Given that warming profiles and impacts other than temperature change (e.g., ocean acidification) vary across GHGs, the group concluded "transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases" (SCC TSD, pg 13).

growth rate. This helps to ensure that the estimates are internally consistent with other modeling assumptions. The SCC estimates for the analysis years of 2014, in 2005 dollars are provided in Table 7-9.

Table 7-9. Social Cost of Carbon (SCC) Estimates (per tonne of CO_2) for 2014[a]

Discount Rate and Statistic	SCC estimate (2008$)
5% (Average)	$5.7
3% (Average)	$24.2
2.5% (Average)	$39.1
3% (95th percentile)	$73.9

[a] The SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC, 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

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

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

Applying the global SCC estimates to the estimated increases in CO_2 emissions for the range of policy scenarios, we estimate the dollar value of the climate-related disbenefits captured by the models for each analysis year. For internal consistency, the annual disbenefits are discounted back to NPV terms using the same discount rate as each SCC estimate (i.e., 5%, 3%, and 2.5%) rather than 3% and 7%.[14] These estimates are provided in Table 7-10.

Table 7-10. Monetized SCC-Derived Disbenefits of CO_2 Emission Increases in 2014 (millions of 2008$)[a]

Discount Rate and Statistic	Selected Option (Major)	Alternative Option (Major)	Proposed MACT Approach (Area)	Final MACT/GACT Approach (Area)
Tons of CO_2	911,048	1,524,572	24,936	22,191
5% (Average)	$5.2	$8.7	$0.1	$0.1
3% (Average)	$22	$37	$0.6	$0.5
2.5% (Average)	$36	$60	$1.0	$0.9
3% (95th percentile)	$67	$113	$1.8	$1.6

[a] The SCC values are dollar-year and emissions-year specific. SCC values represent only a partial accounting of climate impacts.

7.5 Unquantified or Nonmonetized Benefits

The monetized benefits estimated in this RIA only reflect the portion of benefits attributable to the health impacts associated with exposure to 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 direct health benefits from reducing HAPs have not been monetized in this analysis. In addition to being a $PM_{2.5}$ precursor, SO_2 emissions also contribute to adverse effects from acidic deposition in aquatic and terrestrial ecosystems, increase mercury methylation, as well as visibility impairment. In addition to health effects, ozone is associated with adverse vegetation effects to forests and crops.

7.5.1 Other SO_2 Benefits

In addition to being a precursor to $PM_{2.5}$, SO_2 emissions are also associated with a variety of respiratory health effects. Unfortunately, we were unable to estimate the health benefits

[14] It is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

associated with reduced SO_2 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 SO_2 for nearby populations. Therefore, this analysis only quantifies and monetizes the $PM_{2.5}$ benefits associated with the reductions in SO_2 emissions.

Following an extensive evaluation of health evidence from epidemiologic and laboratory studies, the *Integrated Science Assessment (ISA) for Sulfur Dioxide* concluded that there is a causal relationship between respiratory health effects and short-term exposure to SO_2 (U.S. EPA, 2008a). According to summary of the ISA in EPA's risk and exposure assessment (REA) for the SO_2 NAAQS "the immediate effect of SO_2 on the respiratory system in humans is bronchoconstriction" (U.S. EPA, 2009b). In addition, the REA summarized from the ISA that "asthmatics are more sensitive to the effects of SO_2 likely resulting from preexisting inflammation associated with this disease." A clear concentration-response relationship has been demonstrated in laboratory studies following exposures to SO_2 at concentrations between 20 and 100 ppb, both in terms of increasing severity of effect and percentage of asthmatics adversely affected (U.S. EPA, 2009b). Based on our review of this information, we identified four short-term morbidity endpoints that the SO_2 ISA identified as a "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 SO_2 ISA. The SO_2 ISA also concluded that the relationship between short-term SO_2 exposure and premature mortality was "suggestive of a causal relationship" because it is difficult to attribute the mortality risk effects to SO_2 alone. Although the SO_2 ISA stated that studies are generally consistent in reporting a relationship between SO_2 exposure and mortality, there was a lack of robustness of the observed associations to adjustment for pollutants.

SO_2 emissions also contribute to adverse welfare effects from acidic deposition, visibility impairment, and enhanced mercury methylation (U.S. EPA, 2008c). Deposition of sulfur 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)

7.5.2 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 methodological and time limitations under the court-ordered schedule, 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, 2010b) 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.

7.5.3 Visibility Benefits

Reducing SO_2 and PM emissions would improve the level of visibility throughout the United States (U.S. EPA, 2009c). 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. In fact, particulate sulfate is the largest contributor to regional haze in the eastern U.S. (i.e., 40% or more annually and 75% during summer). In the western U.S., particulate sulfate contributes to 20–50% of regional haze (U.S. EPA, 2009c). 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. Due to time limitations under the court-ordered schedule, we were unable to estimate the monetized benefits associated with visibility improvements. Previous analyses (U.S. EPA, 2006; U.S. EPA, 2010e) show that visibility benefits are a significant welfare benefit category. As shown in Section 6.5.4 of this RIA, an average visibility improvement of 0.51 deciviews in annual 20% worst visibility days over all Class I area monitors is anticipated as a result of these rules.

7.5.4 Ozone Vegetation Benefits

Exposure to ozone has been associated with a wide array of vegetation and ecosystem effects in the published literature (U.S. EPA, 2010a). Sensitivity to ozone is highly variable across species, with over 65 plan species identified as "ozone-sensitive," many of which occur in state and national parks and forests. These effects include those that damage or impair the intended use of the plant or ecosystem. Such effects are considered adverse to the public welfare and can include reduced growth and/or biomass production in sensitive plant species, including forest trees, reduced crop yields, visible foliar injury, reduced plant vigor (e.g., increased susceptibility to harsh weather, disease, insect pest infestation, and competition), species composition shift, and changes in ecosystems and associated ecosystem services.

7.5.5 Direct HAP Benefits

Americans are exposed to ambient concentrations of air toxics at levels which have the potential to cause adverse health effects.[15] 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 that are of

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

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.[16] NATA for 2002 includes four steps:

1. Compiling a national emissions inventory of air toxics emissions from outdoor sources
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,[17] subchronic,[18] or acute[19] 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.[20] Figures 7-17 and 7-18 depict estimated county-level carcinogenic risk and noncancer respiratory hazard from the assessment. Results from the 2002 NATA suggest that acrolein is the primary driver for noncancer respiratory risk.[21] Large reductions in HAP emissions may not necessarily translate into significant reductions in health risk because toxicity varies by pollutant and whether or not there are exposures at or above levels of concern is not known. For example, acetaldehyde mass emissions are more than double acrolein emissions on a national basis, according to EPA's 2005 National Emissions Inventory (NEI). However, the Integrated Risk Information System (IRIS) reference concentration (RfC) for acrolein is considerably lower than that for acetaldehyde, suggesting that acrolein could be potentially more toxic than acetaldehyde. Thus, it is important to

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

[17]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).

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

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

[20]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/

[21] Details about the overall confidence of certainty ranking of the individual pieces of NATA assessments including both quantitative (e.g., model-to-monitor ratios) and qualitative (e.g., quality of data, review of emission inventories) judgments can be found at http://www.epa.gov/ttn/atw/nata/roy/page16.html.

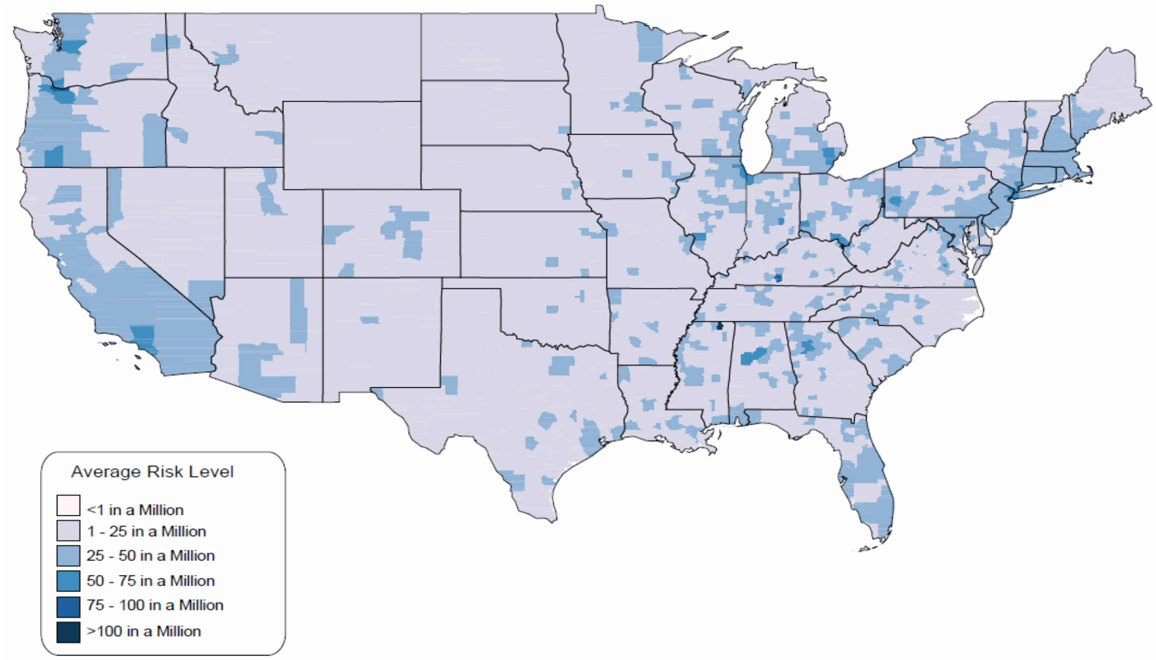

Figure 7-17. Estimated County Level Carcinogenic Risk from HAP exposure from outdoor sources (2002 NATA)

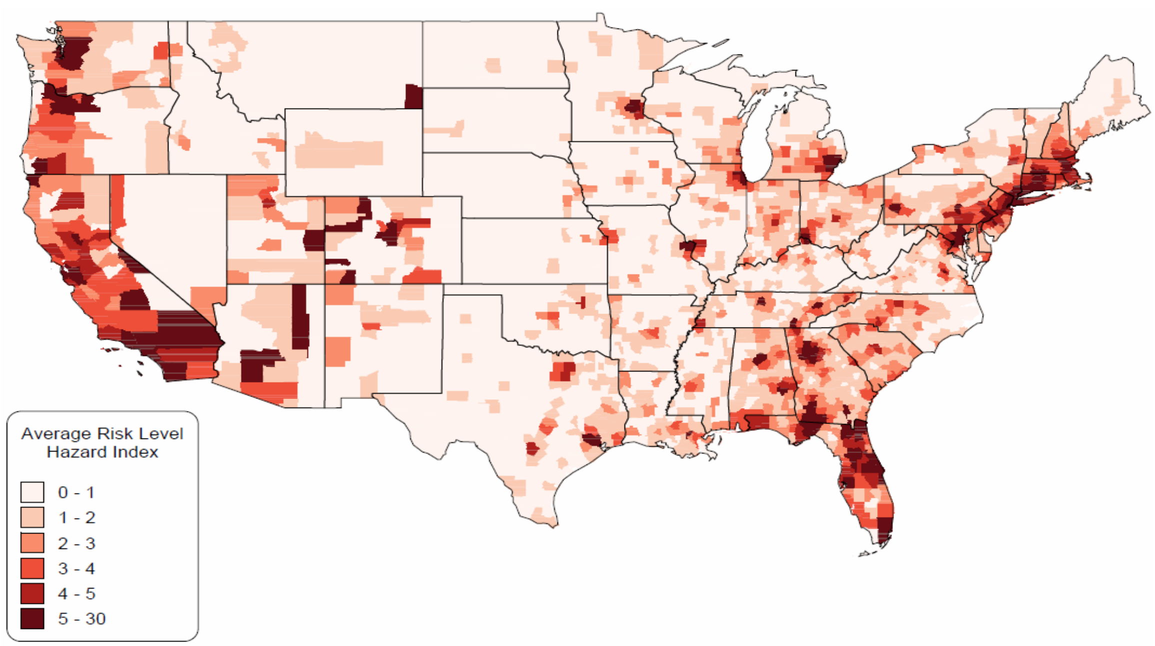

Figure 7-18. Estimated County Level Noncancer (Respiratory) Risk from HAP exposure from outdoor sources (2002 NATA)

account for the toxicity and exposure, as well as the mass of the targeted emissions when designing reduction strategies to maximize health benefits.

Due to methodology and time limitations under the court-ordered schedule, we were unable to estimate the benefits associated with the hazardous air pollutants that would be reduced as a result of these rules. In a few previous analyses of the benefits of reductions in HAPs, EPA has quantified the benefits of potential reductions in the incidences of cancer and non-cancer risk (e.g., U.S. EPA, 1995). In those analyses, EPA relied on unit risk factors (URF) developed through risk assessment procedures.[22] These URFs are designed to be conservative, and as such, are more likely to represent the high end of the distribution of risk rather than a best or most likely estimate of risk. As the purpose of a benefit analysis is to describe the benefits most likely to occur from a reduction in pollution, use of high-end, conservative risk estimates would overestimate the benefits of the regulation. While we used high-end risk estimates in past analyses, advice from the EPA's Science Advisory Board (SAB) recommended that we avoid using high-end estimates in benefit analyses (U.S. EPA, 2002). Since this time, EPA has continued to develop better methods for analyzing the benefits of reductions in HAPs.

In the Second Prospective 812 Analysis, EPA conducted a case study analysis of the health effects associated with reducing exposure to benzene in Houston from implementation of the Clean Air Act (IEc, 2009). While reviewing the draft report, EPA's Advisory Council on Clean Air Compliance Analysis concluded that "the challenges for assessing progress in health improvement as a result of reductions in emissions of hazardous air pollutants (HAPs) are daunting...due to a lack of exposure-response functions, uncertainties in emissions inventories and background levels, the difficulty of extrapolating risk estimates to low doses and the challenges of tracking health progress for diseases, such as cancer, that have long latency periods" (U.S. EPA-SAB, 2008).

In 2009, EPA convened a workshop to address the inherent complexities, limitations, and uncertainties in current methods to quantify the benefits of reducing HAPs. Recommendations from this workshop included identifying research priorities, focusing on susceptible and vulnerable populations, and improving dose-response relationships (Gwinn et al., 2011).

In summary, monetization of the benefits of reductions in cancer incidences requires several important inputs, including central estimates of cancer risks, estimates of exposure to

[22]The unit risk factor is a quantitative estimate of the carcinogenic potency of a pollutant, often expressed as the probability of contracting cancer from a 70-year lifetime continuous exposure to a concentration of one $\mu g/m^3$ of a pollutant.

carcinogenic HAPs, and estimates of the value of an avoided case of cancer (fatal and non-fatal). Due to methodology and time limitations under the court-ordered schedule, we do not have sufficient information on emissions from specific sources and thus are unable to model changes in population exposures to ambient concentrations of HAPs. For this reason, we did not attempt to quantify or monetized the health benefits of reductions in HAPs in this analysis.[23] Instead, we provide a qualitative analysis of the health effects associated with the HAPs anticipated to be reduced by these rules. EPA remains committed to improving methods for estimating HAP benefits by continuing to explore additional concepts of benefits, including changes in the distribution of risk.

Available emissions data show that boilers emit several different HAPs, either contained within the fuel burned or formed during the combustion process. Although numerous HAPs may be emitted from boilers, a few HAPs account for the majority of the total mass of HAPs emissions. See Table 7-11 for the list of the major HAPs for each fuel type. These rules are anticipated to reduce a combined 113,000 tons of carbon monoxide, 30,000 tons of HCl, 830 tons of HF, 2,900 pounds of mercury, 3,000 tons of other metals, and 23 grams of dioxins/furans (TEQ) each year. We discuss the health effects associated with these top HAPs as well as the HAPs for which we have emission reduction estimates.

Table 7-11. Top HAPs by Mass from Boilers by Fuel Type

Coal	Gas	Biomass	Oil
68% HCl	44% Formaldehyde	32% Acetaldehyde	28% Nickel
5% HF	25% PAH	28% HCl	19% Manganese
	3% Toluene	25% Formaldehyde	

7.5.5.1 Mercury

Mercury is a highly neurotoxic contaminant that enters the food web as a methylated compound, methylmercury (U.S. EPA, 2008c). The contaminant is concentrated in higher trophic levels, including fish eaten by humans. Experimental evidence has established that only inconsequential amounts of methylmercury can be produced in the absence of sulfate (U.S. EPA,

[23]Due to time limitations under the court-ordered schedule for this rule, we were unable to model mercury methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions. However, it is important to emphasize, that we generally have more data and accepted methods to estimate mercury benefits than we have for other HAPs.

2008c). Current evidence indicates that in watersheds where mercury is present, increased sulfate deposition very likely results in methylmercury accumulation in fish (Drevnick et al., 2007; Munthe et al., 2007). The NO_x SO_X Ecological ISA concluded that evidence is sufficient to infer a casual relationship between sulfur deposition and increased mercury methylation in wetlands and aquatic environments (U.S. EPA, 2008c).

In addition to the role of sulfate deposition on methylation, these rules would also reduce mercury emissions. Mercury is emitted to the air from various man-made and natural sources. These emissions transport through the atmosphere and eventually deposit to land or water bodies. This deposition can occur locally, regionally, or globally, depending on the form of mercury emitted and other factors such as the weather. The form of mercury emitted varies depending on the source type and other factors. Available data indicate that the mercury emissions from these sources are a mixture of gaseous elemental mercury (25%), inorganic divalent mercury (reactive gas phase mercury) (50%), and particulate bound mercury (25%) (U.S. EPA, 2010f). Gaseous elemental mercury can be transported very long distances, even globally, to regions far from the emissions source (becoming part of the global “pool”) before deposition occurs. Inorganic divalent and particulate bound mercury have a shorter atmospheric lifetime and can deposit to land or water bodies closer to the emissions source. Furthermore, elemental mercury in the atmosphere can undergo transformation into divalent mercury, providing a significant pathway for deposition of emitted elemental mercury.

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

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

Several studies suggest that the methylmercury content of fish may reduce cardio-protective effects of fish consumption. Some of these studies also suggest that methylmercury may cause adverse effects to the cardiovascular system. For example, the NRC (2000) review of the literature concerning methylmercury health effects took note of two epidemiological studies that found an association between dietary exposure to methylmercury and cardiovascular effects.[24] In a study of 1,833 males in Finland aged 42 to 60 years, Solonen et al. (1995) observed a relationship between methylmercury exposure via fish consumption and acute myocardial infarction (AMI or heart attacks), death from coronary heart disease or cardiovascular disease.[25] The NRC also noted a study of 917 seven-year old children in the Faroe Islands, whose initial exposure to methylmercury was *in utero* although postnatal exposures may have occurred as well. At seven years of age, these children exhibited an increase in blood pressure and a decrease in heart rate variability.[26] Based on these and other studies, NRC concluded in 2000 that, "Although the data base is not as extensive as it is for other end points (i.e., neurologic effects) the cardiovascular system appears to be a target for methylmercury toxicity in humans and

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

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

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

animals."[27] NRC also stated that "additional studies are needed to better characterize the effect of methylmercury exposure on blood pressure and cardiovascular function at various stages of life."

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

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

Baseline emissions for major and area source boilers in the U.S. are about 11 tons of mercury in the air.[28] Based on the EPA's National Emission Inventory, about 103 tons of mercury were emitted from all anthropogenic sources in the U.S. in 2005. Moreover, the United Nations has estimated that about 2,100 tons of mercury were emitted worldwide by anthropogenic sources in 2005. We believe that total mercury emissions in the U.S. and globally in 2008 were about the same magnitude in 2005. Therefore, we estimate that in 2008, these sources emitted about 11% of the total anthropogenic mercury emissions in the U.S. and about 0.5% of the global emissions.

Overall, the major and area source rules would reduce mercury emissions by about 1.5 tons (2,900 pounds, or a 13% reduction) per year from current levels, and therefore, contribute to reductions in mercury exposures and health effects. Due to time limitations under the court-ordered schedule for this rule, we were unable to model mercury methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions. However, we were able to model the change in mercury deposition using CAM_x for the final Boiler MACT and Boiler Area Source Rule.[29] These modeling results indicate significantly reduced total mercury

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

[28] See "*Revised Development of Baseline Emission Factors for Boilers and Process Heaters at Commercial, Industrial, and Institutional Facilities,*" which available in the docket.

[29] See Section 6 of this RIA and U.S. EPA (2010f) for more information on the air quality modeling conducted for these rules.

deposition (wet and dry forms) in some areas, including reducing total deposition from all sources by an average of 1.4% in the East and 0.5% in the West in the analysis year. This modeling indicates that mercury deposition reductions tend to be greatest nearest the sources. Figure 7-19 shows the percentage reduction in total mercury deposition as a result of the final Boiler MACT and Boiler Area Source Rule in the Eastern U.S., and Figure 7-20 shows the percentage reduction in mercury deposition in the Western U.S. based on the air quality modeling conducted for these rules.

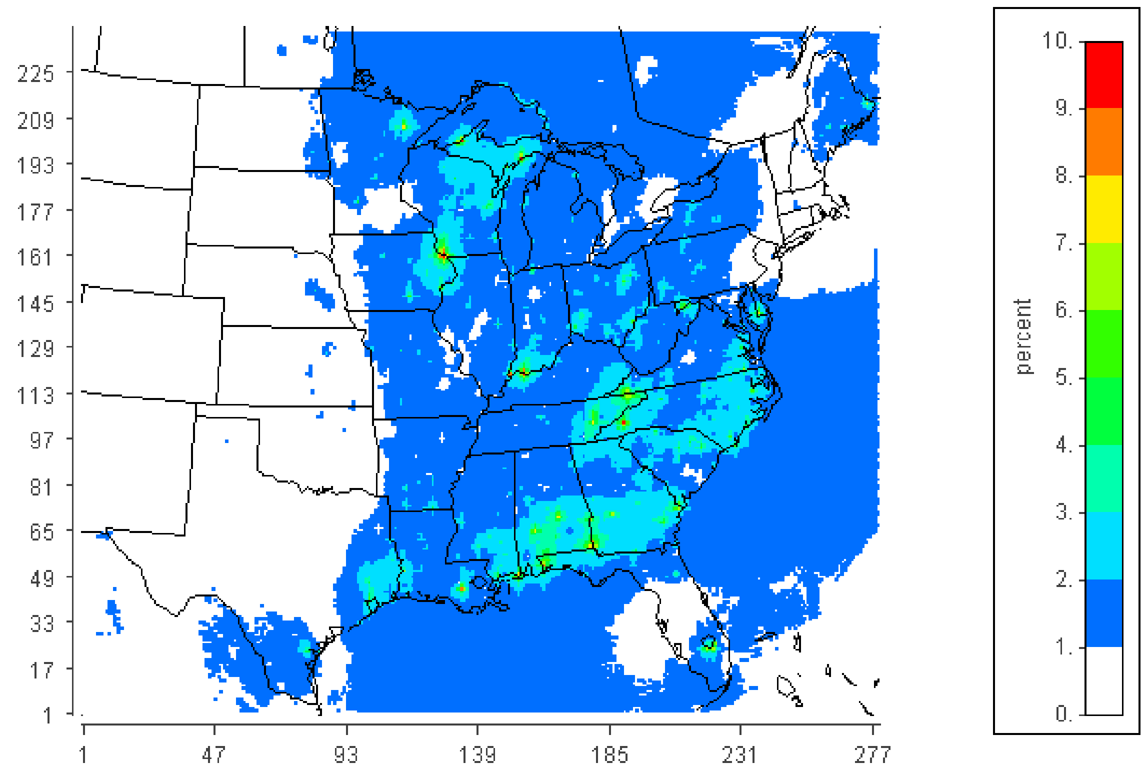

Figure 7-19. Percentage Reduction in Total Mercury Deposition in the Eastern U.S.

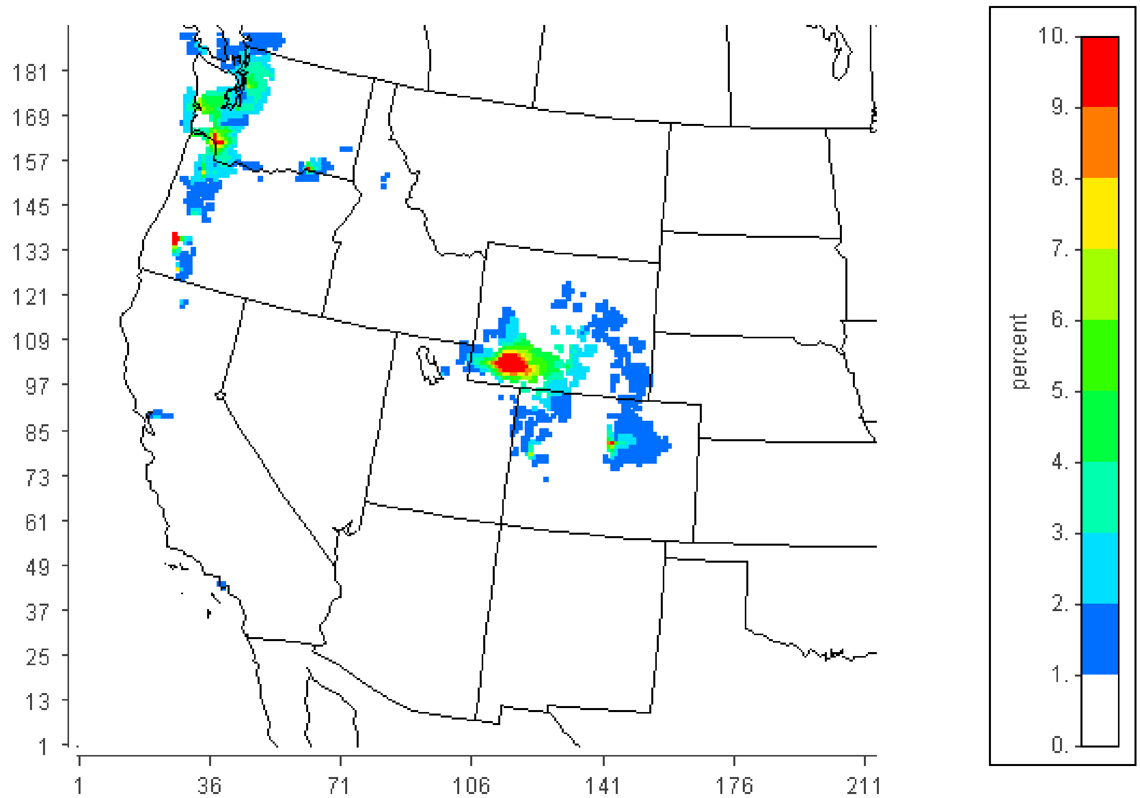

Figure 7-20. Percentage Reduction in Total Mercury Deposition in the Western U.S.

7.5.5.2 Hydrogen Chloride (HCl)[30]

Hydrogen chloride gas is intensely irritating to the mucous membranes of the nose, throat, and respiratory tract. Brief exposure to 35 ppm causes throat irritation, and levels of 50 to 100 ppm are barely tolerable for 1 hour. The greatest impact is on the upper respiratory tract; exposure to high concentrations can rapidly lead to swelling and spasm of the throat and suffocation. Most seriously exposed persons have immediate onset of rapid breathing, blue coloring of the skin, and narrowing of the bronchioles. Patients who have massive exposures may develop an accumulation of fluid in the lungs. Exposure to hydrogen chloride can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma. Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed. Hydrogen chloride has not been classified for carcinogenic effects.

[30] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). Medical Management Guidelines for Hydrogen Chloride (HCl). CAS#: 7647-01-0. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/Mhmi/mmg173.html>.

7.5.5.3 Chlorine Gas (Cl_2)[31]

Chlorine gas is irritating and corrosive to the eyes, skin, and respiratory tract. Exposure to chlorine may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.

7.5.5.4 Hydrogen Cyanide (HCN)[32]

Hydrogen cyanide is highly toxic by all routes of exposure and may cause abrupt onset of profound central nervous system, cardiovascular, and respiratory effects, leading to death within minutes. Exposure to lower concentrations of hydrogen cyanide may produce eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death. Hydrogen cyanide acts as a cellular asphyxiant. By binding to mitochondrial cytochrome oxidase, it prevents the utilization of oxygen in cellular metabolism. The central nervous system and myocardium are particularly sensitive to the toxic effects of cyanide.

7.5.5.5 Hydrogen Fluoride (HF)[33]

Acute (short-term) inhalation exposure to gaseous hydrogen fluoride can cause severe respiratory damage in humans, including severe irritation and pulmonary edema. Chronic (long-term) exposure to fluoride at low levels has a beneficial effect of dental cavity prevention and may also be useful for the treatment of osteoporosis. Exposure to higher levels of fluoride may cause dental fluorosis. One study reported menstrual irregularities in women occupationally exposed to fluoride. The EPA has not classified hydrogen fluoride for carcinogenicity.

7.5.5.6 Toluene[34]

Toluene is found in evaporative as well as exhaust emissions from motor vehicles. Under the 2005 Guidelines for Carcinogen Risk Assessment, there is inadequate information to assess

[31] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Medical Management Guidelines for Chlorine (CAS 7782-50-5; UN 1017). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at http://www.atsdr.cdc.gov/MHMI/mmg172.html#bookmark02.

[32] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Medical Management Guidelines for Hydrogen Cyanide (HCN) (CAS#: 7782-50-5). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at http://www.atsdr.cdc.gov/Mhmi/mmg8.html#bookmark02.

[33] All health effects language for this section came from: U.S. EPA, "National Emission Standards for Hazardous Air Pollutants for Industrial/Commercial/Institutional Boilers and Process Heaters; Proposed Rule," 68 Federal Register 8 (January 13, 2003). pp. 1664-1665. Available on the internet at http://www.epa.gov/ttn/atw/boiler/fr13ja03.pdf

[34] All health effects language for this section came from: U.S. EPA. 2005. "Full IRIS Summary for Toluene (CASRN 108-88-3)" Environmental Protection Agency, Integrated Risk Information System (IRIS), Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. Available on the Internet at <http://www.epa.gov/iris/subst/0118.htm>.

the carcinogenic potential of toluene because studies of humans chronically exposed to toluene are inconclusive, toluene was not carcinogenic in adequate inhalation cancer bioassays of rats and mice exposed for life, and increased incidences of mammary cancer and leukemia were reported in a lifetime rat oral bioassay.

The central nervous system (CNS) is the primary target for toluene toxicity in both humans and animals for acute and chronic exposures. CNS dysfunction (which is often reversible) and narcosis have been frequently observed in humans acutely exposed to low or moderate levels of toluene by inhalation; symptoms include fatigue, sleepiness, headaches, and nausea. Central nervous system depression has been reported to occur in chronic abusers exposed to high levels of toluene. Symptoms include ataxia, tremors, cerebral atrophy, nystagmus (involuntary eye movements), and impaired speech, hearing, and vision. Chronic inhalation exposure of humans to toluene also causes irritation of the upper respiratory tract, eye irritation, dizziness, headaches, and difficulty with sleep.

Human studies have also reported developmental effects, such as CNS dysfunction, attention deficits, and minor craniofacial and limb anomalies, in the children of women who abused toluene during pregnancy. A substantial database examining the effects of toluene in subchronic and chronic occupationally exposed humans exists. The weight of evidence from these studies indicates neurological effects (i.e., impaired color vision, impaired hearing, decreased performance in neurobehavioral analysis, changes in motor and sensory nerve conduction velocity, headache, and dizziness) as the most sensitive endpoint.

7.5.5.7 Formaldehyde

Since 1987, EPA has classified formaldehyde as a probable human carcinogen based on evidence in humans and in rats, mice, hamsters, and monkeys.[35] EPA is currently reviewing 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.[36,37] In an analysis of the lymphohematopoietic cancer mortality from an extended follow-up of these workers, NCI

[35]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.
[36]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.
[37]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.

confirmed an association between lymphohematopoietic cancer risk and peak exposures.[38] 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.[39] 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.[40]

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.[41,42,43] 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.[44,45,46,47] These findings are not supportive of interpreting the CIIT model results as providing a conservative (health protective) estimate of human risk.[48] 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

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[38] 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.

[39] Pinkerton, L. E. 2004. Mortality among a cohort of garment workers exposed to formaldehyde: an update. Occup. Environ. Med. 61: 193-200.

[40] 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.

[41] 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.

[42] 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.

[43] 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.

[44] 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, 2006

[45] Subramaniam, R; Chen, C; Crump, K; et al. (2006) Uncertainties in biologically-based modeling of formaldehyde-induced cancer risk: identification of key issues. Risk Anal 28(4):907-923.

[46] 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

[47] Crump, K; Chen, C; Fox, J; et al. (2006) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495.

[48] Crump, K; Chen, C; Fox, J; et al. (2006) Sensitivity analysis of biologically motivated model for formaldehyde-induced respiratory cancer in humans. Ann Occup Hyg 52:481-495.

to the compound's tumorigenicity was found not to hold under variations of modeling assumptions.[49]

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."[50] 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.[51, 52]

7.5.5.8 Polycyclic Aromatic Hydrocarbons (PAHs)

At least seven PAH compounds are classified by EPA as probable human carcinogens based on animal data, including benzo(a)anthracene,[53] benzo(b)fluoranthene,[54]

[49]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

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

[51]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

[52]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.

[53]U.S. EPA (1997). Integrated Risk Information System File of benzo(a)anthracene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0454.htm.

[54]U.S. EPA (1997). Integrated Risk Information System File of benzo(b)fluoranthene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0453.htm.

benzo(k)fluoranthene,[55] benzo(a)pyrene,[56] chrysene,[57] dibenz(a,h)anthracene,[58] and indeno(1,2,3-cd)pyrene.[59] Recent studies have found that maternal exposures to PAHs in a population of pregnant women were associated with several adverse birth outcomes, including low birth weight and reduced length at birth, as well as impaired cognitive development at age three.[60, 61] EPA has not yet evaluated these recent studies.

7.5.5.9 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.[62] 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.[63, 64] 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.[65] In short-term (4 week) rat studies, degeneration of olfactory

55 U.S. EPA (1997). Integrated Risk Information System File of benzo(k)fluoranthene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0452.htm.

56 U.S. EPA (1998). Integrated Risk Information System File of benzo(a)pyrene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0136.htm.

57 U.S. EPA (1997). Integrated Risk Information System File of chrysene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0455.htm

58 U.S. EPA (1997). Integrated Risk Information System File of dibenz(a,h)anthracene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0456.htm.

59 U.S. EPA (1997). Integrated Risk Information System File of indeno(1,2,3-cd)pyrene. Research and Development, National Center for Environmental Assessment, Washington, DC. This material is available electronically at http://www.epa.gov/ncea/iris/subst/0457.htm.

60 Perera, F.P.; Rauh, V.; Tsai, W-Y.; et al. (2002) Effect of transplacental exposure to environmental pollutants on birth outcomes in a multiethnic population. Environ Health Perspect. 111: 201-205.

61 Perera, F.P.; Rauh, V.; Whyatt, R.M.; Tsai, W.Y.; Tang, D.; Diaz, D.; Hoepner, L.; Barr, D.; Tu, Y.H.; Camann, D.; Kinney, P. (2006) Effect of prenatal exposure to airborne polycyclic aromatic hydrocarbons on neurodevelopment in the first 3 years of life among inner-city children. Environ Health Perspect 114: 1287-1292.

62 U.S. EPA (1988). 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.

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

64 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.

65 U.S. EPA (1988). Integrated Risk Information System File of Acetaldehyde. This material is available electronically at http://www.epa.gov/iris/subst/0290.htm.

epithelium was observed at various concentration levels of acetaldehyde exposure.[66] 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.[67] The agency is currently conducting a reassessment of the health hazards from inhalation exposure to acetaldehyde.

7.5.5.10 Nickel[68]

Nickel is an essential element in some animal species, and it has been suggested it may be essential for human nutrition. Nickel dermatitis, consisting of itching of the fingers, hand and forearms, is the most common effect in humans from chronic (long-term) skin contact with nickel. Respiratory effects have also been reported in humans from inhalation exposure to nickel. No information is available regarding the reproductive or developmental effects of nickel in humans, but animal studies have reported such effects. Human and animal studies have reported an increased risk of lung and nasal cancers from exposure to nickel refinery dusts and nickel subsulfide. Animal studies of soluble nickel compounds (i.e., nickel carbonyl) have reported lung tumors. The EPA has classified nickel refinery subsulfide as Group A, human carcinogens and nickel carbonyl as a Group B2, probable human carcinogen.

7.5.5.11 Manganese[69]

Health effects in humans have been associated with both deficiencies and excess intakes of manganese. Chronic (long-term) exposure to low levels of manganese in the diet is considered to be nutritionally essential in humans, with a recommended daily allowance of 2 to 5 milligrams per day. Chronic exposure to high levels of manganese by inhalation in humans results primarily in CNS effects. Visual reaction time, hand steadiness, and eye-hand coordination were affected in chronically exposed workers. Manganism, characterized by feelings of weakness and lethargy, tremors, a masklike face, and psychological disturbances, may result from chronic exposure to higher levels. Impotence and loss of libido have been noted in male workers afflicted with

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[66] 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.

[67] 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.

[68] All health effects language for this section came from: U.S. EPA, "National Emission Standards for Hazardous Air Pollutants for Industrial/Commercial/Institutional Boilers and Process Heaters; Proposed Rule," 68 Federal Register 8 (January 13, 2003). pp. 1664-1665. Available on the internet at http://www.epa.gov/ttn/atw/boiler/fr13ja03.pdf

[69] All health effects language for this section came from: U.S. EPA, "National Emission Standards for Hazardous Air Pollutants for Industrial/Commercial/Institutional Boilers and Process Heaters; Proposed Rule," 68 Federal Register 8 (January 13, 2003). pp. 1664-1665. Available on the internet at http://www.epa.gov/ttn/atw/boiler/fr13ja03.pdf

manganism attributed to inhalation exposures. The EPA has classified manganese in Group D, not classifiable as to carcinogenicity in humans.

7.5.5.12 Dioxins (Chlorinated dibenzodioxins (CDDs) [70]

A number of effects have been observed in people exposed to 2,3,7,8-TCDD levels that are at least 10 times higher than background levels. The most obvious health effect in people exposure to relatively large amounts of 2,3,7,8-TCDD is chloracne. Chloracne is a severe skin disease with acne-like lesions that occur mainly on the face and upper body. Other skin effects noted in people exposed to high doses of 2,3,7,8-TCDD include skin rashes, discoloration, and excessive body hair. Changes in blood and urine that may indicate liver damage also are seen in people. Alterations in the ability of the liver to metabolize (or breakdown) hemoglobin, lipids, sugar, and protein have been reported in people exposed to relatively high concentrations of 2,3,7,8-TCDD. Most of the effects are considered mild and were reversible. However, in some people these effects may last for many years. Slight increases in the risk of diabetes and abnormal glucose tolerance have been observed in some studies of people exposed to 2,3,7,8-TCDD. We do not have enough information to know if exposure to 2,3,7,8-TCDD would result in reproductive or developmental effects in people, but animal studies suggest that this is a potential health concern.

In certain animal species, 2,3,7,8-TCDD is especially harmful and can cause death after a single exposure. Exposure to lower levels can cause a variety of effects in animals, such as weight loss, liver damage, and disruption of the endocrine system. In many species of animals, 2,3,7,8-TCDD weakens the immune system and causes a decrease in the system's ability to fight bacteria and viruses at relatively low levels (approximately 10 times higher than human background body burdens). In other animal studies, exposure to 2,3,7,8-TCDD has caused reproductive damage and birth defects. Some animal species exposed to CDDs during pregnancy had miscarriages and the offspring of animals exposed to 2,3,7,8-TCDD during pregnancy often had severe birth defects including skeletal deformities, kidney defects, and weakened immune responses. In some studies, effects were observed at body burdens 10 times higher than human background levels.

[70] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 1999. ToxFAQs for Chlorinated Dibenzo-p-dioxins (CDDs) (CAS#: 2,3,7,8-TCDD 1746-01-6). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at http://www.atsdr.cdc.gov/tfacts104.html.

7.5.5.13 Furans (Chlorinated dibenzofurans (CDFs))[71]

Most of the information on the adverse health effects comes from studies in people who were accidentally exposed to food contaminated with CDFs. The amounts that these people were exposed to were much higher than are likely from environmental exposures or from a normal diet. Skin and eye irritations, especially severe acne, darkened skin color, and swollen eyelids with discharge, were the most obvious health effects of the CDF poisoning. CDF poisoning also caused vomiting and diarrhea, anemia, more frequent lung infections, numbness, effects on the nervous system, and mild changes in the liver. Children born to exposed mothers had skin irritation and more difficulty learning, but it is unknown if this effect was permanent or caused by CDFs alone or CDFs and polychlorinated biphenyls in combination.

Many of the same effects that occurred in people accidentally exposed also occurred in laboratory animals that ate CDFs. Animals also had severe weight loss, and their stomachs, livers, kidneys, and immune systems were seriously injured. Some animals had birth defects and testicular damage, and in severe cases, some animals died. These effects in animals were seen when they were fed large amounts of CDFs over a short time, or small amounts over several weeks or months. Nothing is known about the possible health effects in animals from eating CDFs over a lifetime.

7.5.5.14 Other Air Toxics

In addition to the compounds described above, other compounds in gaseous hydrocarbon and PM emissions would be affected by these rules, including metal and organic HAPs. Information regarding the health effects of these compounds can be found in EPA's IRIS database.[72]

7.6 Limitations and Uncertainties

The National Research Council (NRC) (2002) concluded that EPA's general methodology for calculating the benefits of reducing air pollution is reasonable and informative in spite of inherent uncertainties. To address these inherent uncertainties, NRC highlighted the need to conduct rigorous quantitative analysis of uncertainty and to present benefits estimates to decisionmakers in ways that foster an appropriate appreciation of their inherent uncertainty. In response to these comments, EPA's Office of Air and Radiation (OAR) is developing a

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[71] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 1995. ToxFAQs™ for Chlorodibenzofurans (CDFs). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/tfacts32.html>.

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

comprehensive strategy for characterizing the aggregate impact of uncertainty in key modeling elements on both health incidence and benefits estimates. Components of that strategy include emissions modeling, air quality modeling, health effects incidence estimation, and valuation.

In this analysis, we use three methods to assess uncertainty quantitatively: Monte Carlo analysis, LML assessment, and alternate concentration-response functions for PM- and ozone-related mortality. We also provide a qualitative assessment for those aspects that we are unable to address quantitatively in this analysis. Each of these analyses is described in the following sections.

This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, health effect estimates from epidemiology studies, and economic data for monetizing benefits. Each of these inputs may be uncertain and would affect the benefits estimate. When the uncertainties from each stage of the analysis are compounded, small uncertainties can have large effects on the total quantified benefits. In this analysis, we are unable to quantify the cumulative effect of all of these uncertainties, but we provide the following analyses to characterize many of the largest sources of uncertainty.

7.6.1 Monte Carlo Analysis

Similar to other recent RIAs, we used Monte Carlo methods for characterizing random sampling error associated with the concentration response functions and economic valuation functions. Monte Carlo simulation uses random sampling from distributions of parameters to characterize the effects of uncertainty on output variables, such as incidence of morbidity. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and monetized benefits. The reported standard errors in the epidemiological studies determined the distributions for individual effect estimates, as shown in Tables 7-4 and 7-5. The confidence intervals around the monetized benefits in Tables 7-6 and 7-7 incorporate the epidemiology standard errors as well as the distribution of the valuation function. These confidence intervals do not reflect other sources of uncertainty inherent within the boiler-specific BPT estimates, nor do they reflect 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 benefits estimates.

7.6.2 LML Assessment for $PM_{2.5}$

$PM_{2.5}$ 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. We have more confidence in the mortality impacts among populations exposed to levels of $PM_{2.5}$ above the lowest LML of the large cohort studies, and our confidence in the results diminish as we model that are lower than the LML. 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 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. In Section 7.3, we provide the results of the LML assessment in Figures 7-15 and 7-16.

7.6.3 Alternate Concentration-response Functions for PM Mortality

$PM_{2.5}$ mortality benefits are the largest benefit category that we monetized in this analysis. To better understand the concentration-response relationship between $PM_{2.5}$ exposure and premature mortality, EPA conducted an expert elicitation in 2006 (Roman et al., 2008; IEc, 2006). In general, the results of the expert elicitation support the conclusion that the benefits of $PM_{2.5}$ control are very likely to be substantial. In previous RIAs, EPA presented benefits estimates using concentration response functions derived from the $PM_{2.5}$ Expert Elicitation as a range from the lowest expert value (Expert K) to the highest expert value (Expert E). However, this approach did not indicate the agency's judgment on what the best estimate of PM benefits may be, and EPA's Science Advisory Board described this presentation as misleading. Therefore, we began to present the cohort-based studies (Pope et al., 2002; and Laden et al., 2006) as our core estimates in the proposal RIA for the Portland Cement NESHAP (U.S. EPA, 2009a). 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 the two epidemiology-based estimates (Roman et al., 2008).

In this analysis, we present the results derived from the expert elicitation as indicative of the uncertainty associated with a major component of the health impact functions, and we provide the independent estimates derived from each of the twelve experts to better characterize the degree of variability in the expert responses. In this section, we provide the results using the concentration-response functions derived from the expert elicitation in both tabular (Tables 7-7 and 7-8) and graphical form (Figure 7-10). Please note that these results 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.

7.6.4 Alternate Concentration-response Functions for Ozone Mortality

While particulate matter is the criteria pollutant most clearly associated with premature mortality, recent research suggests that short-term repeated ozone exposure also likely contributes to premature death. In 2008 the National Research Council (NRC) of the National Academy of Science (NAS) (NRC, 2008) issued a series of recommendations to the EPA regarding the quantification and valuation of ozone-related short-term mortality. Chief among these was that "…short-term exposure to ambient ozone is likely to contribute to premature deaths" and the committee recommended that "ozone-related mortality be included in future estimates of the health benefits of reducing ozone exposures…" The NAS also recommended that "…the greatest emphasis be placed on the multicity and NMMAPS studies without exclusion of the meta-analyses" (NRC, 2008).

In view of the findings of the NAS panel, we include used estimates of short-term ozone mortality from the Bell et al. (2004) NMMAPS analysis, the Schwartz (2005) multi-city study, the Huang and Bell (2005) multi-city study as well as effect estimates from the three meta-analyses (Bell et al., 2005; Levy et al., 2005; Ito et al., 2005).

7.6.5 Qualitative Assessment of Uncertainty and Other Analysis Limitations

Although we strive to incorporate as many quantitative assessments of uncertainty, there are several aspects for which we are only able to address qualitatively. These aspects are important factors to consider when evaluating the relative benefits of the attainment strategies for each of the alternative standards:

Above we present the estimates of the total monetized 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 benefits estimates are subject to a number of assumptions and uncertainties. For example, the key assumptions underlying the estimates for premature mortality, which typically account for at least 90% of the total monetized benefits, include the following:

1. 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 the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type.

2. 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 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.

3. To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized 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 $PM_{2.5}$ benefits, please consult the $PM_{2.5}$ NAAQS RIA (Table 5.5).

It is important to note that the monetized benefit-per-ton estimates used here reflect specific geographic patterns of emissions reductions and specific air quality and benefits modeling assumptions. For example, these estimates assume that emissions are reduced equally across all boilers and that the geographic distribution of boiler emissions will remain constant through the analysis year. As we did not model fuel subcategories, we assume that each fuel type is equally represented in the emissions and geographic distribution. Use of these $/ton values to estimate benefits associated with a specific fuel type (e.g., for reducing emissions from liquid fuel) may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling of that fuel subcategory. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on national emission reduction assumptions and therefore represent an average benefits-per-ton over the entire United States. The benefits- per-ton for variable emission reductions in specific locations may be very different from the estimates presented here. Despite our inability to fully characterize and quantify these relatively small uncertainties, we believe that, on net, the air quality impacts and associated monetized benefits are representative of the magnitude of benefits anticipated from these rules.

As previously described, we strive to monetize as many of the benefits anticipated from these rules as possible, but the monetized benefits estimated in this RIA inevitably only reflect the portion of benefits. Specifically, only the benefits attributable to the health impacts associated with exposure to ambient fine particles and ozone have been monetized in this analysis. Methodological and time limitations under the court-ordered schedule for this rule prevented EPA from quantifying or monetizing the benefits from several important benefit categories, including benefits from reducing toxic emissions, ecosystem effects, and visibility impairment. Data limitations include limited monitoring for HAPs, incomplete emissions inventories for HAPs, and limited photochemical air quality modeling for non-mercury HAPs. Resource limitations include limited staff and extramural funding in conjunction with a heavy regulatory workload, which led EPA to not model these endpoints. Methodological limitations include an absence of concentration-response functions for many HAP health effects, with issues such as exposure misclassification, small number of cases, confounding, and extrapolation of toxicological effects down to ambient levels. Despite our inability to monetize all of the benefit categories, the total combined monetized benefits still exceed the costs by a substantial margin.

This RIA does not include the type of detailed uncertainty assessment found in the PM NAAQS RIA (U.S. EPA, 2006). However, the results of the Monte Carlo analyses of the health and welfare benefits presented in Chapter 5 of the PM RIA can provide some evidence of the uncertainty surrounding the benefits results presented in this analysis.

7.7 Section 7 References

Abt Associates, Inc. 2008. *Environmental Benefits and Mapping Program (Version 3.0)*. Bethesda, MD. Prepared for U.S. Environmental Protection Agency—Office of Air Quality Planning and Standards. Research Triangle Park, NC. Available on the Internet at <http://www.epa.gov/air/benmap>.

Bell, M.L., et al. 2004. "Ozone and short-term mortality in 95 US urban communities, 1987–2000." *Journal of the American Medical Association.* 292(19): p. 2372-8.

Bell, M.L., F. Dominici, and J.M. Samet. 2005. "A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study." *Epidemiology*. 16(4): p. 436-45.

Davidson, K., A. Hallberg, D. McCubbin, and B.J. Hubbell. 2007. "Analysis of $PM_{2.5}$ Using the Environmental Benefits Mapping and Analysis Program (BenMAP)." *J Toxicol Environ Health*. 70: p. 332-46.

Drevnick, P.E., D.E. Canfield, P.R. Gorski, A.L.C. Shinneman, D.R. Engstrom, D.C.G. Muir, G.R. Smith, P.J. Garrison, L.B. Cleckner, J.P. Hurley, R.B. Noble, R.R. Otter, and J.T. Oris. 2007. "Deposition and cycling of sulfur controls mercury accumulation in Isle Royale fish." *Environmental Science and Technology*. 41(21): p. 7266-72.

Fann, N., C.M. Fulcher, and B.J. Hubbell. 2009. "The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution." *Air Qual Atmos Health*. 2: p. 169-76.

Gwinn, M.R., J. Craig, D.A. Axelrad, R. Cook, C. Dockins, N. Fann, R. Fegley, D.E. Guinnup, G. Helfand, B. Hubbell, S.L. Mazur, T. Palma, R.L. Smith, J. Vandenberg, and B. Sonawane. 2011. "Meeting report: Estimating the benefits of reducing hazardous air pollutants—summary of 2009 workshop and future considerations." *Environ Health Perspect*. Jan; 119(1): p. 125-30.

Huang, Y. and Dominici F. Bell M. 2005. "Bayesian Hierarchical Distributed Lag Models for Summer Ozone Exposure and Cardio-Respiratory Mortality." *Environmetrics*, 16: p. 547-62.

Hubbell, B.J., N. Fann, and J.I. Levy. 2009. "Methodological Considerations in Developing Local-Scale Health Impact Assessments: Balancing National, Regional and Local Data." *Air Qual Atmos Health*. 2: p. 99–110.

Hubbell, B.J., A. Hallberg, D. McCubbin, and E. Post. 2005. "Health-Related Benefits of Attaining the 8-Hr Ozone Standard." *Environ Health Perspect*. 113: p. 73-82.

Industrial Economics, Inc (IEc). 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>.

Industrial Economics, Inc (IEc). 2009. *Section 812 Prospective Study of the Benefits and Costs of the Clean Air Act: Air Toxics Case Study—Health Benefits of Benzene Reductions in Houston, 1990–2020. Final Report*, July 14, 2009. Available on the Internet at <http://www.epa.gov/air/sect812/dec09/812CAAA_Benzene_Houston_Final_Report_July_2009.pdf>.

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

Ito, K., S.F. De Leon, and M. Lippmann. 2005. "Associations between ozone and daily mortality: analysis and meta-analysis." *Epidemiology*. 16(4): p. 446-57.

Kochi, I., B. Hubbell, and R. Kramer. 2006. "An Empirical Bayes Approach to Combining Estimates of the Value of Statistical Life for Environmental Policy Analysis." *Environmental and Resource Economics*. 34: p. 385-406.

Kunzli, N., S. Medina, R. Kaiser, P. Quenel, F. Horak Jr, and M. Studnicka. 2001. "Assessment of Deaths Attributable to Air Pollution: Should We Use Risk Estimates Based on Time Series or on Cohort Studies?" *American Journal of Epidemiology*. 153(11): p. 1050-55.

Laden, F., J. Schwartz, F.E. Speizer, and D.W. Dockery. 2006. "Reduction in Fine Particulate Air Pollution and Mortality." *American Journal of Respiratory and Critical Care Medicine*. 173: p. 667-672.

Levy, J.I., L.K. Baxter, and J. Schwartz. 2009. "Uncertainty and variability in health-related damages from coal-fired power plants in the United States." *Risk Anal.* 29(7): p. 1000-14.

Levy, J.I., S.M. Chemerynski, and J.A. Sarnat. 2005. "Ozone exposure and mortality: an empiric bayes metaregression analysis." *Epidemiology*. 16(4): p. 458-68.

Mrozek, J.R., and L.O. Taylor. 2002. "What Determines the Value of Life? A Meta-Analysis." *Journal of Policy Analysis and Management*. 21(2): p. 253-270.

Munthe, J., R. A. Bodaly, B. A. Branfireun, C. T. Driscoll, C. C. Gilmour, R. Harris, M. Horvat, M. Lucotte, and O. Malm. 2007. "Recovery of mercury-contaminated fisheries." *AMBIO: A Journal of the Human Environment* 36: p. 33-44.

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

National Research Council (NRC). 2008. Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution. National Academies Press. Washington, DC.

National Research Council (NRC). 2009. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* National Academies Press. Washington, DC.

National Research Council. 2000. *Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology.* Washington, DC: National Academies Press.

Office of Management and Budget (OMB). 2003. *Circular A-4: Regulatory Analysis*. Washington, DC. Available on the internet at http://www.whitehouse.gov/omb/circulars/a004/a-4.html.

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution." *Journal of the American Medical Association*. 287: p. 1132-41.

Roman, H.A., K.D. Walker, T.L. Walsh, L. Conner, H.M. Richmond, J. Hubbell, and P.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): p. 2268-74.

Salonen, J.T., K. Seppanen, Nyyssonen et al. 1995. "Intake of Mercury From Fish Lipid Peroxidation, and the Risk of Myocardial Infarction and Coronary, Cardiovascular and Any Death in Eastern Finnish Men." *Circulation*. 91(3): p. 645-55.

Schwartz, J. 2005. “How sensitive is the association between ozone and daily deaths to control for temperature?” *Am J Respir Crit Care Med*. 171(6): p. 627-31.

Scudder, B.C., L.C. Chasar, D.A. Wentz, N.J. Bauch, M.E. Brigham, P.W. Moran, and D.P. Krabbenhoft. 2009. *Mercury in fish, bed sediment, and water from streams across the United States, 1998–2005: U.S. Geological Survey Scientific Investigations Report*. *2009–5109*, 74 p., Reston, VA: U.S. Geological Survey.

Sisler, J.F. 1996. *Spatial and seasonal patterns and long-term variability of the composition of the haze in the United States: an analysis of data from the IMPROVE network*. CIRA Report, ISSN 0737-5352-32, Colorado State University.

Tagaris, E., K.J. Liao, A.J. Delucia, et al. 2009. “Potential impact of climate change on air-pollution related human health effects.” *Environ. Sci. Technol*. 43: p. 4979-88.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2002. *Workshop on the Benefits of Reductions in Exposure to Hazardous Air Pollutants: Developing Best Estimates of Dose-Response Functions An SAB Workshop Report of an EPA/SAB Workshop (Final Report).* EPA-SAB-EC-WKSHP-02-001. January. Available on the Internet at <http://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/34355712EC011A358525719A005BF6F6/$File/ecwkshp02001%2Bappa-g.pdf>.

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>.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2007. *SAB Advisory on EPA’s Issues in Valuing Mortality Risk Reductio*n. EPA-SAB-08-001. October. Available at <http://yosemite.epa.gov/sab/sabproduct.nsf/4128007E7876B8F0852573760058A978/$File/sab-08-001.pdf >.

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2008. *Benefits of Reducing Benzene Emissions in Houston, 1990–2020*. EPA-COUNCIL-08-001. July. Available at <http://yosemite.epa.gov/sab/sabproduct.nsf/D4D7EC9DAEDA8A548525748600728A83/$File/EPA-COUNCIL-08-001-unsigned.pdf>.

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

U.S. Environmental Protection Agency—Science Advisory Board (U.S. EPA-SAB). 2009b. *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>.

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>.

U.S. Environmental Protection Agency (U.S. EPA). 1995. *Regulatory Impact Analysis for the Petroleum Refinery NESHAP. Revised Draft for Promulgation*. Office of Air Quality Planning and Standards, Research Triangle Park, N.C. Available on the Internet at <http://www.reg-markets.org/admin/authorpdfs/page.php?id=705>.

U.S. Environmental Protection Agency (U.S. EPA). 2000. *Guidelines for Preparing Economic Analyses*. EPA 240-R-00-003. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. September. Available at <http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/cover.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2006. *Regulatory Impact Analysis, 2006 National Ambient Air Quality Standards for Particulate Matter, Chapter 5*. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/Chapter%205--Benefits.pdf >.

U.S. Environmental Protection Agency (U.S. EPA). 2008a. *Integrated Science Assessment for Sulfur Oxides—Health Criteria* (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. September. Available at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843>.

U.S. Environmental Protection Agency (U.S. EPA). 2008b. *Guidelines for Preparing Economic Analyses: External Review Draft.* National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC. September. Available at <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0516-01.pdf/$file/EE-0516-01.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2008c. *Integrated Science Assessment for Oxides of Nitrogen and Sulfur–Ecological Criteria National* (Final Report). National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-08/139. December. Available at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485>.

U.S. Environmental Protection Agency (U.S. EPA). 2009a. *Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry*. Office of Air Quality Planning and Standards, Research Triangle Park, NC. April. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/portlandcementria_4-20-09.pdf >.

U.S. Environmental Protection Agency (U.S. EPA). 2009b. *Risk and Exposure Assessment to Support the Review of the SO_2 Primary National Ambient Air Quality Standards: Final Report.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. August. Available on the Internet at <http://www.epa.gov/ttn/naaqs/standards/so2/data/Risk%20and%20Exposure%20Assessment%20to%20Support%20the%20Review%20of%20the%20SO2%20Primary%20National%20Ambient%20Air%20Quality%20Standards-%20Final%20Report.pdf>.

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

U.S. Environmental Protection Agency (U.S. EPA). 2010a. *Regulatory Impact Analysis, National Ambient Air Quality Standards for Ozone*, Office of Air Quality Planning and Standards, Research Triangle Park, NC. October. Available on the Internet at < http://www.epa.gov/ttn/ecas/regdata/RIAs/s1-supplemental_analysis_full.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2010b. *Integrated Science Assessment for Carbon Monoxide*. National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-09/019F. January. Available at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=218686>.

U.S. Environmental Protection Agency (U.S. EPA). 2010c. *Regulatory Impact Analysis for Regulatory Impact Analysis: National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and Institutional Boilers and Process Heaters.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. April. Available at <http://www.epa.gov/airquality/combustion/docs/boilerria20100429.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2010d. *Summary of Expert Opinions on the Existence of a Threshold in the Concentration-Response Function for $PM_{2.5}$-related Mortality: Technical Support Document*. Compiled by Office of Air Quality Planning and Standards, Research Triangle Park, NC. July. Available at < http://www.epa.gov/ttn/ecas/regdata/Benefits/thresholdstsd.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2010e. *Regulatory Impact Analysis for the Proposed Federal Transport Rule.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. July. Available at <http://www.epa.gov/ttn/ecas/regdata/RIAs/proposaltrria_final.pdf>.

U.S. Environmental Protection Agency. (U.S. EPA). 2010f. *Air Quality Modeling Technical Support Document: Boiler Source Sector Rules* (EPA-454/R-10-006), Research Triangle Park, North Carolina. December. Available at <http://www.epa.gov/scram001/reportsindex.htm>.

U.S. Environmental Protection Agency. (U.S. EPA). 2010g. *Technical Support Document: Preparation of Emissions Inventories for the Version 4, 2005-based Platform.* Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, North Carolina. July. Available at <ftp://ftp.epa.gov/EmisInventory/2005v4/2005_emissions_tsd_07jul2010.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). 2010h. *Regulatory Impact Analysis for the SO_2 NAAQS.* Office of Air Quality Planning and Standards, Research Triangle Park, NC. June. Available at < http://www.epa.gov/ttn/ecas/regdata/RIAs/fso2ria100602full.pdf>.

Viscusi, V.K., and J.E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." *Journal of Risk and Uncertainty*. 27(1): p. 5-76.

SECTION 8
COMPARISON OF MONETIZED BENEFITS AND COSTS

8.1 Boiler MACT

Because we were unable to monetize the benefits associated with reducing HAPs, all monetized benefits reflect improvements in ambient $PM_{2.5}$ and ozone concentrations. This results in an underestimate of the monetized benefits. Using a 3% discount rate, we estimate the total monetized benefits of the major source rule to be $22 billion to $54 billion in the implementation year (2014) (Table 8-1). Using a 7% discount rate, we estimate the total monetized benefits to be $20 billion to $49 billion. The annualized costs are $1.5 billion at a 7% interest rate. The net benefits are $21 billion to $53 billion at a 3% discount rate for the benefits and $19 million to $48 billion at a 7% discount rate. All estimates are in 2008$. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 112,000 tons of carbon monoxide, 30,000 tons of HCl, 820 tons of HF, 2,800 pounds of mercury, 2,700 tons of other metals, and 23 grams of dioxins/furans (TEQ) each year.

8.2 Boiler Area Source Rule

Because we were unable to monetize the benefits associated with reducing HAPs, all monetized benefits reflect improvements in ambient $PM_{2.5}$ and ozone concentrations. This results in an underestimate of the monetized benefits. Using a 3% discount rate, we estimate the total monetized benefits of the area source rule to be $210 million to $520 million in the implementation year (2014) (Table 8-2). Using a 7% discount rate, we estimate the total monetized benefits to be $190 million to $470 million. The annualized costs are $490 million at a 7% interest rate. The net benefits are −$280 million to $30 million at a 3% discount rate for the benefits and −$300 million to −$20 million at a 7% discount rate. All estimates are in 2008$. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 1,100 tons of carbon monoxide, 340 tons of HCl, 8 tons of HF, 90 pounds of mercury, 320 tons of other metals, and less than 1 gram of dioxins/furans (TEQ) each year.

Table 8-1. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the Boiler MACT in 2014 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Selected						
Total Monetized Benefits[b]	$22,000	to	$54,000	$20,000	to	$49,000
Total Social Costs[c]		$1,500			$1,500	
Net Benefits	$20,500	to	$52,500	$18,500	to	$47,500
Non-monetized Benefits	112,000 tons of carbon monoxide					
	30,000 tons of HCl					
	820 tons of HF					
	2,800 pounds of mercury					
	2,700 tons of other metals					
	23 grams of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					
Alternative						
Total Monetized Benefits[b]	$18,000	to	$43,000	$16,000	to	$39,000
Total Social Costs[b]		$1,900			$1,900	
Net Benefits	$16,100	to	$41,100	$14,100	to	$37,100
Non-monetized Benefits	112,000 tons of carbon monoxide					
	22,000 tons of HCl					
	620 tons of HF					
	2,400 pounds of mercury					
	2,600 tons of other metals					
	23 grams of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures. These results include units anticipated to come online and the lowest cost disposal assumption.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors such as SO_2, as well as reducing exposure to ozone through reductions of VOCs. 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 the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates include energy disbenefits associated with the increased emissions from additional energy usage valued at $22 million for the selected option and $37 million for the alternative option. Ozone benefits are valued at $3.6 to $15 million for both options.

[c] The methodology used to estimate social costs for one year in the multimarket model using surplus changes results in the same social costs for both discount rates.

Table 8-2 Summary of the Monetized Benefits, Social Costs, and Net Benefits for the Boiler Area Source Rule in 2014 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Final MACT/GACT Approach						
Total Monetized Benefits[b]	$210	to	$520	$190	to	$470
Total Social Costs[c]		$490			$490	
Net Benefits	−$280	to	$30	−$300	to	−$20
Non-monetized Benefits	1,100 tons of carbon monoxide					
	340 tons of HCl					
	8 tons of HF					
	90 pounds of mercury					
	320 tons of other metals					
	<1 gram of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					
Proposed MACT Approach						
Total Monetized Benefits[b]	$200	to	$490	$180	to	$440
Total Social Costs[c]		$850			$850	
Net Benefits	−$650	to	−$360	−$670	to	−$410
Non-monetized Benefits	1,100 tons of carbon monoxide					
	340 tons of HCl					
	8 tons of HF					
	90 pounds of mercury					
	320 tons of other metals					
	<1 gram of dioxins/furans (TEQ)					
	Health effects from SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					

[a] All estimates are for the implementation year (2014), and are rounded to two significant figures. These results include units anticipated to come online and the lowest cost disposal assumption.

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to $PM_{2.5}$ through reductions of directly emitted $PM_{2.5}$ and $PM_{2.5}$ precursors such as SO_2. 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 the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. These estimates include energy disbenefits associated with the increased emissions from additional energy usage valued at less than $1 million.

[c] The methodology used to estimate social costs for one year in the multimarket model using surplus changes results in the same social costs for both discount rates.

Figures 8-1 and 8-2 show the full range of net benefits estimates (i.e., annual benefits minus annualized costs) quantified in terms of $PM_{2.5}$ benefits for the implementation year (2014).

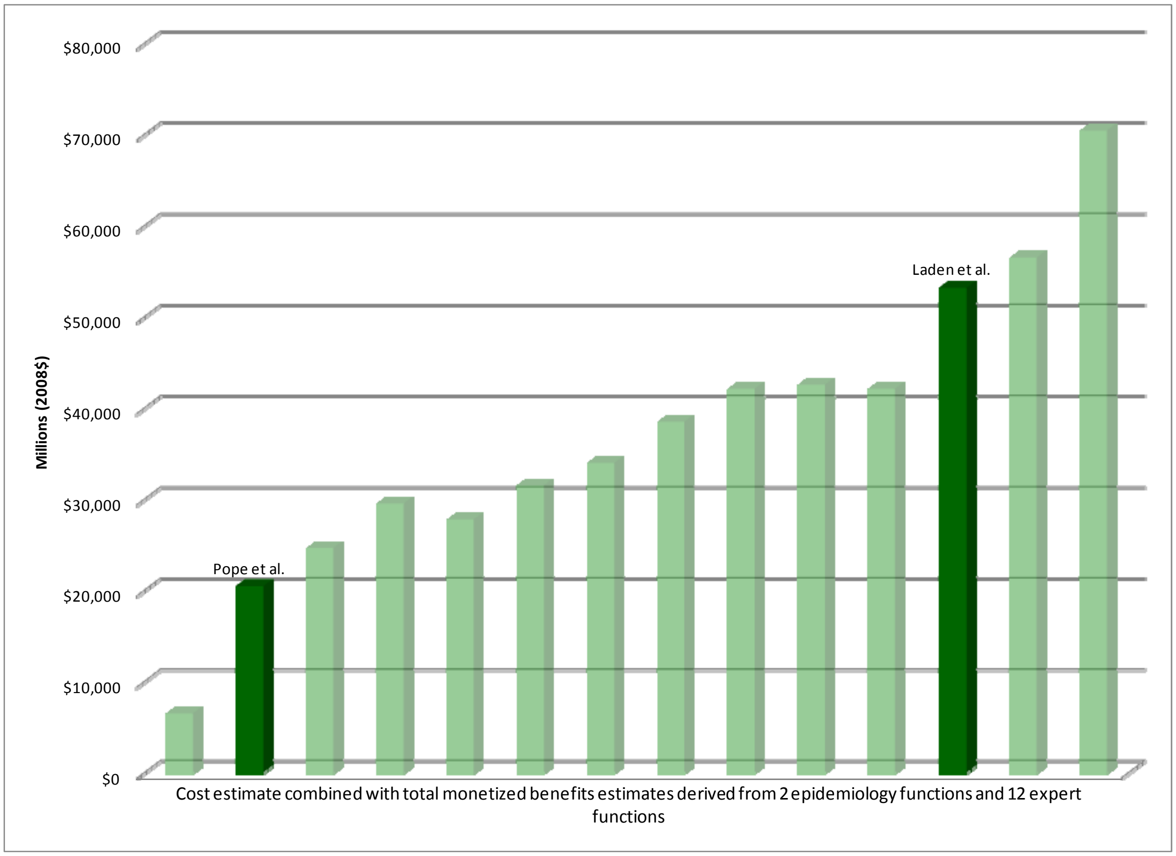

Figure 8-1. Net Benefits for the Final Major and Area Source Boiler Rules at 3% Discount Rate[a]

[a] Net benefits are quantified in terms of $PM_{2.5}$ benefits for the implementation year (2014). This graph shows 14 benefits estimates combined with the cost estimate. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles.

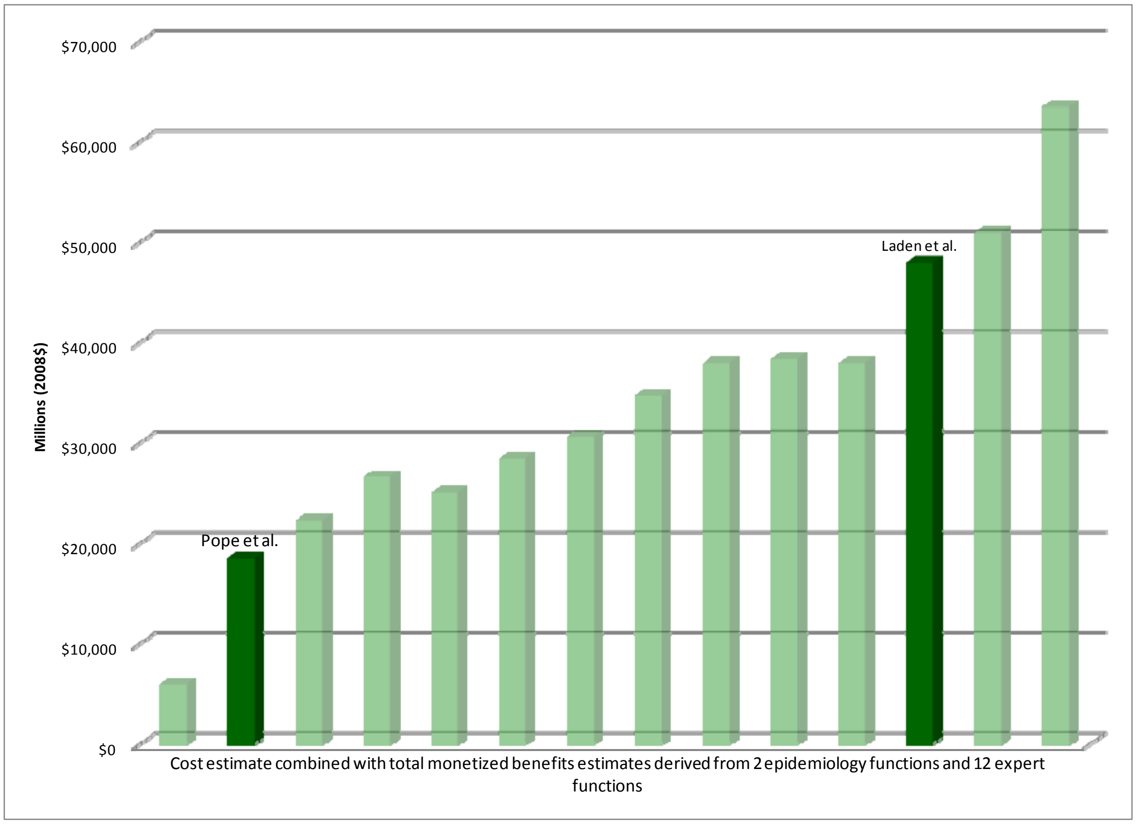

Figure 8-2. Net Benefits for the Final Major and Area Source Boiler Rules at 7% Discount Rate[a]

[a] Net benefits are quantified in terms of $PM_{2.5}$ benefits for the implementation year (2014). This graph shows 14 benefits estimates combined with the cost estimate. These models assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality because the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles.

8.3 Section 8 References

Laden, F., J. Schwartz, F.E. Speizer, and D.W. Dockery. 2006. "Reduction in Fine Particulate Air Pollution and Mortality." *American Journal of Respiratory and Critical Care Medicine* 173:667-672.

Pope, C.A., III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution." *Journal of the American Medical Association* 287:1132-1141.

APPENDIX A
OAQPS MULTIMARKET MODEL TO ASSESS THE ECONOMIC IMPACTS OF ENVIRONMENTAL REGULATION

A.1 Introduction

An economic impact analysis (EIA) provides information about a policy's effects (i.e., social costs); emphasis is also placed on how the costs are distributed among stakeholders (EPA, 2000). In addition, large-scale policies require additional analysis to better understand how costs are passed across the economy. Although several tools are available to estimate social costs, current EPA guidelines suggest that multimarket models "…are best used when potential economic impacts and equity effects on related markets might be considerable" and modeling using a computable general equilibrium model is not available or practical (EPA, 2000, p. 146). Other guides for environmental economists offer similar advice (Berck and Hoffmann, 2002; Just, Hueth, and Schmitz, 2004).

Multimarket models focus on "short-run" time horizons and measure a policy's near term or transition costs (EPA, 1999). Recent studies suggest short-run analyses can complement full dynamic general equilibrium analysis.

The multimarket model described in this appendix is a new addition to the Office of Air Quality Planning and Standards' (OAQPS's) economic model tool kit; it is designed to be used as a transparent tool that can respond quickly to requests about how stakeholders in 100 U.S. industries might respond to new environmental policy. Next, we provide an overview of the model, data, and parameters.

A.2 Multimarket Model

The multimarket model contains the following features:

- Industry sectors and benchmark data set
  - 100 industry sectors
  - a single benchmark year (2010)
  - estimates of industry carbon dioxide (CO_2) emissions
  - estimates of industry employment
- Economic behavior
  - industries respond to regulatory costs by changing production rates
  - market prices rise to reflect higher energy and other nonenergy material costs
  - customers respond to these price increases and consumption falls
- Model scope

- 100 sectors are linked with each other based on their use of energy and other nonenergy materials. For example, the construction industry is linked with the petroleum, cement, and steel industries and is influenced by price changes that occur in each sector. The links allow EPA to account for indirect effects the regulation has on related markets.
  - Links come from input-output information used from OAQPS's computable general equilibrium model (EMPAX)
  - production adjustments influence employment levels
  - international trade (imports/exports) behavior considered
- Model time horizon ("short-run")
  - fixed production resources (e.g., capital) leads to an upward-sloping industry supply function
  - firms cannot alter input mixes; there is no substitution among intermediate production inputs
  - price of labor (i.e., wage) is fixed
  - investment and government expenditures are fixed

A.2.1 Industry Sectors and Benchmark Data Set

The multimarket model includes 100 industries. For the benchmark year, the model uses information from OAQPS's computable general equilibrium model's balanced social accounting matrix (SAM) and the following accounting identity holds:

$$\text{Output} + \text{Imports} = \text{Consumption} + \text{Investment} + \text{Government} + \text{Exports} \qquad (A.1)$$

If we abstract and treat each industry as a national market, the identity represents the prepolicy market-clearing condition, or benchmark "equilibrium"; supply equals demand in each market. In Table A-1, we identify the 100 industries for the multimarket model; Table A-2 provides the 2010 benchmark data set. Since the benchmark data are reported in value terms, we also use the common "Harberger convention" and choose units where are all prices are one in the benchmark equilibrium (Shoven and Whalley, 1995).

Table A-1. Industry Sectors Included in Multimarket Model

Industry Label	Description	Representative NAICS[a]
Energy Industries		
COL	Coal	2121
CRU	Crude Oil Extraction	211111 (exc. nat gas)
ELE	Electric Generation	2211
GAS	Natural Gas	211112 2212 4862
OIL	Refined Petroleum	324
Nonmanufacturing		
AGR	Agricultural	11
MIN	Mining	21 less others
CNS	Construction	23
Manufactured Goods		
Food, beverages, and textiles		
ANM	Animal Foods	3111
GRN	Grain Milling	3112
SGR	Sugar	3113
FRU	Fruits and Vegetables	3114
MIL	Dairy Products	3115
MEA	Meat Products	3116
SEA	Seafood	3117
BAK	Baked Goods	3118
OFD	Other Food Products	3119
BEV	Beverages and Tobacco	312
TEX	Textile Mills	313
TPM	Textile Product Mills	314
WAP	Wearing Apparel	315
LEA	Leather	316
Lumber, paper, and printing		
SAW	Sawmills	3211
PLY	Plywood and Veneer	3212
LUM	Other Lumber	3219
PAP	Pulp and Paper Mills	3221
CPP	Converted Paper Products	3222
PRN	Printing	323
Chemicals		
CHM	Chemicals and Gases	3251
RSN	Resins	3252
FRT	Fertilizer	3253
MED	Drugs and Medicine	3254
PAI	Paints and Adhesives	3255
SOP	Soap	3256
OCM	Other Chemicals	3259

(continued)

Table A-1. Industry Sectors Included in Multimarket Model (continued)

Industry Label	Description	Representative NAICS[a]
Plastics and Rubber		
PLS	Plastic	3261
RUB	Rubber	3262
Nonmetallic Minerals		
CLY	Clay	3271
GLS	Glass	3272
CEM	Cement	3273
LIM	Lime and Gypsum	3274
ONM	Other Non-Metallic Minerals	3279
Primary Metals		
I_S	Iron and Steel	3311 3312 33151
ALU	Aluminum	3313 331521 331524
OPM	Other Primary Metals	3314 331522 331525 331528
Fabricated Metals		
FRG	Forging and Stamping	3321
CUT	Cutlery	3322
FMP	Fabricated Metals	3323
BOI	Boilers and Tanks	3324
HRD	Hardware	3325
WIR	Springs and Wires	3326
MSP	Machine Shops	3327
EGV	Engraving	3328
OFM	Other Fabricated Metals	3329
Machinery and Equipment		
CEQ	Construction and Agricultural Equipment	3331
IEQ	Industrial Equipment	3332
SEQ	Service Industry Equipment	3333
HVC	HVAC Equipment	3334
MEQ	Metalworking Equipment	3335
EEQ	Engines	3336
GEQ	General Equipment	3339
Electronic Equipment		
CPU	Computers	3341
CMQ	Communication Equipment	3342
TVQ	TV Equipment	3343
SMI	Semiconductor Equipment	3344
INS	Instruments	3345
MGT	Magnetic Recording Equipment	3346
LGT	Lighting	3351
APP	Appliances	3352

(continued)

Table A-1. Industry Sectors Included in Multimarket Model (continued)

Industry Label	Description	Representative NAICS[a]
Electronic Equipment (continued)		
ELQ	Electric Equipment	3353
OEQ	Other Electric Equipment	3359
Transportation Equipment		
M_V	Motor Vehicles	3361
TKB	Truck Bodies	3362
MVP	Motor Vehicle Parts	3363
ARC	Aircraft	3364
R_R	Rail Cars	3365
SHP	Ships	3366
OTQ	Other Transport Equipment	3369
Other		
FUR	Furniture	337
MSC	Miscellaneous Manufacturing	339
Services		
Wholesale and Retail Trade		
WHL	Wholesale Trade	42
RTL	Retail Trade	44–45
Transportation Services		
ATP	Air Transportation	481
RTP	Railroad Transportation	482
WTP	Water Transportation	483
TTP	Freight Truck Transportation	484
PIP	Pipeline Transport	486
OTP	Other Transportation Services	485 487 488
Other Services		
INF	Information	51
FIN	Finance and Insurance	52
REL	Real Estate	53
PFS	Professional Services	54
MNG	Management	55
ADM	Administrative Services	56
EDU	Education	61
HLT	Health Care	62
ART	Arts	71
ACM	Accommodations	72
OSV	Other Services	81
PUB	Public Services	92

[a] NAICS = North American Industry Classification System. Industry assignments are based on data used in the EMPAX-modeling system, which relies on the commodity code system used in IMPLAN.

Table A-2. 2010 Benchmark Data Set (billion 2006$)

Industry Label	Industry Description	Output	Imports	Consumption	Investment and Government	Exports
ACM	Accommodations	$828	$6	$816	$17	$1
ADM	Administrative Services	$795	$37	$771	$61	Less than $1
AGR	Agricultural	$314	$53	$333	$5	$29
ALU	Aluminum	$65	$17	$70	$4	$8
ANM	Animal Foods	$45	Less than $1	$36	Less than $1	$9
APP	Appliances	$25	$19	$35	$6	$3
ARC	Aircraft	$217	$60	$58	$120	$98
ART	Arts	$252	Less than $1	$246	$3	$3
ATP	Air Transportation	$154	$28	$91	$32	$59
BAK	Baked Goods	$61	$3	$61	$2	Less than $1
BEV	Beverages and Tobacco	$133	$54	$186	Less than $1	$1
BOI	Boilers and Tanks	$27	$2	$19	$9	$2
CEM	Cement	$52	Less than $1	$47	$3	$2
CEQ	Construction and Agricultural Equipment	$70	$24	$47	$33	$14
CHM	Chemicals and Gases	$284	$75	$300	$10	$49
CLY	Clay	$8	$4	$10	$1	$2
CMQ	Communication Equipment	$73	$40	$47	$56	$11
CNS	Construction	$983	$77	$594	$465	Less than $1
COL	Coal	$44	$2	$42	Less than $1	$4
CPP	Converted Paper Products	$52	$2	$43	$6	$6
CPU	Computers	$145	$76	$132	$52	$37
CRU	Crude Oil Extraction	$67	$189	$255	Less than $1	Less than $1
CUT	Cutlery	$11	$5	$9	$5	$2
EDU	Education	$970	Less than $1	$257	$701	$13
EEQ	Engines	$36	$14	$30	$6	$13
EGV	Engraving	$21	Less than $1	$9	$5	$7
ELE	Electric Generation	$317	Less than $1	$287	$31	Less than $1
ELQ	Electric Equipment	$33	$16	$23	$17	$10
FIN	Finance and Insurance	$2,015	$106	$1,972	$43	$106
FMP	Fabricated Metals	$66	$1	$58	$7	$2
FRG	Forging and Stamping	$20	Less than $1	$17	$1	$2
FRT	Fertilizer	$42	$5	$33	$4	$10

(continued)

Table A-2. 2010 Benchmark Data Set (billion 2006$) (continued)

Industry Label	Industry Description	Output	Imports	Consumption	Investment and Government	Exports
FRU	Fruits and Vegetables	$74	$12	$76	$4	$5
FUR	Furniture	$66	$38	$84	$17	$2
GAS	Natural Gas	$139	$32	$160	$6	$6
GEQ	General Equipment	$54	$32	$47	$25	$14
GLS	Glass	$30	Less than $1	$18	$2	$10
GRN	Grain Milling	$77	$9	$74	$2	$10
HLT	Health Care	$1,863	Less than $1	$1,823	$20	$20
HRD	Hardware	$8	$4	$5	$4	$3
HVC	HVAC Equipment	$34	$9	$26	$10	$6
I_S	Iron and Steel	$125	$42	$143	$10	$13
IEQ	Industrial Equipment	$26	$14	$16	$14	$11
INF	Information	$1,305	$77	$1,217	$154	$11
INS	Instruments	$112	$44	$71	$65	$20
LEA	Leather	$4	$26	$29	Less than $1	$1
LGT	Lighting	$12	$11	$16	$5	$1
LIM	Lime and Gypsum	$7	Less than $1	$1	Less than $1	$5
LUM	Other Lumber	$41	$2	$32	$9	$2
M_V	Motor Vehicles	$272	$190	$313	$106	$43
MEA	Meat Products	$174	$9	$169	$5	$10
MED	Drugs and Medicine	$258	$102	$316	$18	$27
MEQ	Metalworking Equipment	$24	$11	$16	$14	$4
MGT	Magnetic Recording Equipment	$15	$2	$13	$2	$2
MIL	Dairy Products	$87	$3	$84	$4	$2
MIN	Mining	$53	$2	$30	$15	$11
MNG	Management	$469	Less than $1	$378	Less than $1	$92
MSC	Miscellaneous Manufacturing	$178	$129	$189	$73	$46
MSP	Machine Shops	$38	$2	$32	$5	$2
MVP	Motor Vehicle Parts	$220	$75	$226	$17	$52
OCM	Other Chemicals	$45	$2	$23	$9	$15
OEQ	Other Electric Equipment	$31	$16	$28	$7	$11
OFD	Other Food Products	$92	$7	$90	$2	$7
OFM	Other Fabricated Metals	$56	$28	$50	$22	$12

(continued)

Table A-2. 2010 Benchmark Data Set (billion 2006$) (continued)

Industry Label	Industry Description	Output	Imports	Consumption	Investment and Government	Exports
OIL	Refined Petroleum	$415	$106	$462	$12	$47
ONM	Other Non-Metallic Minerals	$13	$5	$15	$1	$2
OPM	Other Primary Metals	$40	$27	$52	$2	$12
OSV	Other Services	$2,321	Less than $1	$1,479	$598	$244
OTP	Other Transportation Services	$245	Less than $1	$202	$22	$22
OTQ	Other Transport Equip	$23	$10	$14	$13	$5
PAI	Paints and Adhesives	$36	$1	$28	$3	$6
PAP	Pulp and Paper Mills	$131	$21	$133	$5	$14
PFS	Professional Services	$2,103	$84	$1,715	$461	$10
PIP	Pipeline Transport	$37	$83	$20	$98	$1
PLS	Plastic	$145	$14	$139	$4	$15
PLY	Plywood and Veneer	$19	$8	$25	$1	$1
PRN	Printing	$51	$1	$34	$11	$6
PUB	Public Services	$1,099	$22	$355	$766	Less than $1
R_R	Rail Cars	$11	$2	$6	$6	$2
REL	Real Estate	$2,719	$2	$2,559	$131	$31
RSN	Resins	$107	$23	$98	$6	$26
RTL	Retail Trade	$1,440	$53	$1,412	$82	Less than $1
RTP	Railroad Transportation	$70	Less than $1	$42	$18	$11
RUB	Rubber	$38	$20	$36	$15	$6
SAW	Sawmills	$29	$9	$36	$1	$1
SEA	Seafood	$13	$3	$14	$1	$1
SEQ	Service Industry Equipment	$29	$23	$22	$24	$6
SGR	Sugar	$34	$6	$36	$2	$3
SHP	Ships	$36	$6	$13	$29	Less than $1
SMI	Semiconductor Equipment	$141	$69	$157	$12	$41
SOP	Soap	$82	$5	$74	$3	$9
TEX	Textile Mills	$29	$9	$31	$1	$6
TKB	Truck Bodies	$58	$12	$34	$32	$5
TPM	Textile Product Mills	$27	$19	$37	$7	$2
TTP	Freight Truck Transportation	$301	Less than $1	$211	$39	$51

(continued)

Table A-2. 2010 Benchmark Data Set (billion 2006$) (continued)

Industry Label	Industry Description	Output	Imports	Consumption	Investment and Government	Exports
TVQ	TV Equipment	$19	$37	$50	$3	$3
WAP	Wearing Apparel	$25	$94	$117	$1	Less than $1
WHL	Wholesale Trade	$1,309	$22	$1,021	$172	$138
WIR	Springs and Wires	$5		$2	$1	$3
WTP	Water Transportation	$45		$14	$12	$19

A.2.1.2 Employment Data

The model includes employment forecasts for each of the 100 sectors. Employment estimates are based on data from three sources: the AEO 2009 estimates of employment (AEO supplemental Table 126 and indicators of Macroeconomic Activity), and Global Insights, Inc., and the Bureau of Labor Statistics (BLS) 2008 end-of year-employment (Current Employment Statistics—CES [National]). Typically, 3-digit NAICS sectors' employment estimates are either directly reported in the updated AEO 2009 release or Global Insights For multimarket industries with finer NAICs detail, estimates were calculated by selecting a primary NAICS supersector estimate (AEO or Global Insights) and distributing total employment from the larger NAICS supersectors across more detailed NAICS sectors within the super-sector. The distributions were determined using observed 2008 BLS employment data. In the last step, In order to match aggregate U.S. employment numbers reported in the AEO 2009 release (140.1 million), a single adjustment factor was applied to all sectors that use Global Insights' supersector data.[1] Table A-4 reports the baseline employment for each of the 100 sectors.

A.2.2 Economic Behavior

A.2.2.1 U.S. Supply

In a postpolicy scenario, industry responds to changes in the new market-clearing "net" price for the good or service sold:

$$\%\Delta\text{"net" price} = \%\Delta \text{ market price} - \%\Delta \text{ direct costs} - \%\Delta \text{ indirect costs} \qquad \text{(A.2)}$$

The %Δ direct costs are approximated using the engineering cost analysis and baseline value of output. For example, a \$1 billion increase in compliance costs for the electricity sector (ELE) would be represented in the model as follows:

$$\%\Delta \text{ direct costs} = \$1/\$317 = 0.03\% \qquad \text{(A.3)}$$

As shown in Figure A-1, the cost change provides the industry with incentives to alter production rates at current market prices; market prices must rise to maintain the original prepolicy production levels (Q).

[1]This step is required because Global Insight's data used by EPA are an older vintage than the forecasts used in the AEO.

Table A-4. 2010 U.S. Employment Projections

Industry Label	Industry Description	Projected Employment (1,000)
ACM	Accommodations	11,239
ADM	Administrative Services	9,274
AGR	Agricultural	1,607
ALU	Aluminum	87
ANM	Animal Foods	45
APP	Appliances	33
ARC	Aircraft	449
ART	Arts	1,939
ATP	Air Transportation	506
BAK	Baked Goods	247
BEV	Beverages and Tobacco	92
BOI	Boilers and Tanks	67
CEM	Cement	164
CEQ	Construction and Agricultural Equipment	176
CHM	Chemicals and Gases	147
CLY	Clay	38
CMQ	Communication Equipment	73
CNS	Construction	7,446
COL	Coal	79
CPP	Converted Paper Products	306
CPU	Computers	104
CRU	Crude Oil Extraction	384
CUT	Cutlery	34
EDU	Education	2,892
EEQ	Engines	75
EGV	Engraving	100
ELE	Electric Generation	219
ELQ	Electric Equipment	72
FIN	Finance and Insurance	6,051
FMP	Fabricated Metals	285
FRG	Forging and Stamping	75
FRT	Fertilizer	35
FRU	Fruits and Vegetables	153
FUR	Furniture	327

(continued)

Table A-4. 2010 U.S. Employment Projections (continued)

Industry Label	Industry Description	Projected Employment (1,000)
GAS	Natural Gas	98
GEQ	General Equipment	198
GLS	Glass	71
GRN	Grain Milling	55
HLT	Health Care	15,190
HRD	Hardware	20
HVC	HVAC Equipment	109
I_S	Iron and Steel	205
IEQ	Industrial Equipment	88
INF	Information	2,939
INS	Instruments	250
LEA	Leather	3
LGT	Lighting	26
LIM	Lime and Gypsum	10
LUM	Other Lumber	216
M_V	Motor Vehicles	170
MEA	Meat Products	450
MED	Drugs and Medicine	279
MEQ	Metalworking Equipment	139
MGT	Magnetic Recording Equipment	20
MIL	Dairy Products	113
MIN	Mining	599
MNG	Management	1,732
MSC	Miscellaneous Manufacturing	180
MSP	Machine Shops	251
MVP	Motor Vehicle Parts	485
OCM	Other Chemicals	92
OEQ	Other Electric Equipment	63
OFD	Other Food Products	144
OFM	Other Fabricated Metals	196
OIL	Refined Petroleum	70
ONM	Other Non-metallic Minerals	61
OPM	Other Primary Metals	87
OSV	Other Services	5,271
OTP	Other Transportation Services	1,064

(continued)

Table A-4.   2010 U.S. Employment Projections (continued)

Industry Label	Industry Description	Projected Employment (1,000)
OTQ	Other Transport Equipment	36
PAI	Paints and Adhesives	60
PAP	Pulp and Paper Mills	121
PFS	Professional Services	18,989
PIP	Pipeline Transport	43
PLS	Plastic	473
PLY	Plywood and Veneer	74
PRN	Printing	248
PUB	Public Services	21,787
R_R	Rail Cars	25
REL	Real Estate	2,158
RSN	Resins	102
RTL	Retail Trade	15,283
RTP	Railroad Transportation	236
RUB	Rubber	117
SAW	Sawmills	84
SEA	Seafood	36
SEQ	Service Industry Equipment	77
SGR	Sugar	62
SHP	Ships	140
SMI	Semiconductor Equipment	245
SOP	Soap	104
TEX	Textile Mills	110
TKB	Truck Bodies	126
TPM	Textile Product Mills	32
TTP	Freight Truck Transportation	1,429
TVQ	TV Equipment	15
WAP	Wearing Apparel	153
WHL	Wholesale Trade	5,869
WIR	Springs and Wires	36
WTP	Water Transportation	67
Total		144,100

The multimarket model also simultaneously considers how the policy influences other important production costs (via changes in energy and other intermediate material prices). As a result, the multimarket model can provide additional information about how policy costs are transmitted through the economy. As shown in Figure A-2, the indirect cost change provides the industry with additional incentives to alter production rates at current market prices.

The %Δ indirect effects associated with each input are approximated using an input "use" ratio and the price change that occurs in the input market.

$$\%\Delta \text{ indirect costs} = \text{input use ratio} \times \%\Delta \text{ input price} \tag{A.4}$$

The social accounting matrix provides an internally consistent estimate of the use ratio and describes the dollar amount of an input that is required to produce a dollar of output. Higher ratios suggest strong links between industries, while lower ratios suggest weaker links. Given the short time horizon, we assume the input use ratio is fixed and cannot adjust their input mix; this is a standard assumption in public and commercial input-output (IO) and SAM multiplier models (Berck and Hoffmann, 2002). Morgenstern and colleagues (2004) and Ho and colleagues (2008) also use this assumption when examining near-term effects of environmental policy.

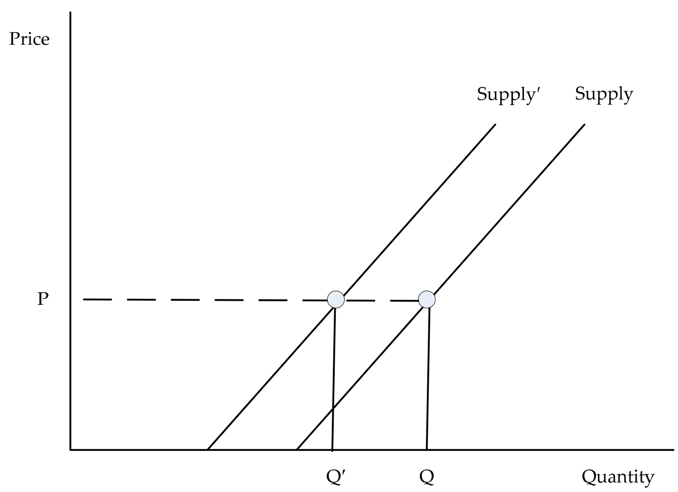

Figure A-1. Direct Compliance Costs Reduce Production Rates at Benchmark Prices

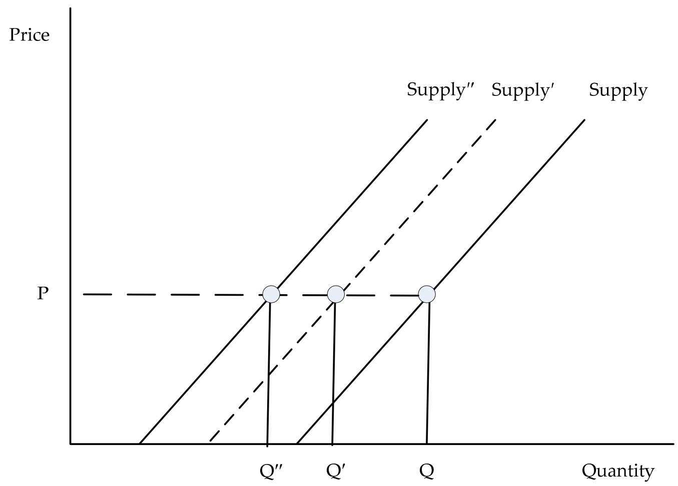

Figure A-2. Indirect Costs Further Reduce Production Rates at Benchmark Prices

Following guidance in the OAQPS economic resource manual (EPA, 1999), we use a general form for the U.S. industry supply function:

$$Q'_g = b\left(P'_g - t - \sum_{i=1}^{n} \alpha_{gi}(P'_i - P_i)\right)^{\varepsilon_g} \tag{A.5}$$

where

Q'_g = with-policy supply quantity (g)

b = calibrated scale parameter for the supply price relationship

P'_g = with-policy price for output (g)

t = direct compliance costs per unit of supply

α_{gi} = input use ratio (g using input i)

P'_i = with-policy input (i) price

P_i = benchmark input (i) price

ε_g = price elasticity of supply for output (g)

The key supply parameter that controls the industry production adjustments is the price elasticity of supply (ε_g). To our knowledge, there is no existing empirical work that estimates short-run supply elasticities for all industry groups used in the multimarket model. As a result, we assume the U.S. supply elasticities are a function of econometrically estimated rest-of-world

(ROW) export supply elasticities (see discussion in the next section). We report the values currently available in the model in Table A-5.

A.2.2.2 International Competition

International competition is captured by a single ROW supply function:

$$Q'_g = c\left(P'_g\right)^{\varepsilon_g^{ROW}} \tag{A.6}$$

where

Q'_g	=	with-policy supply quantity (g)
c	=	calibrated scale parameter for the supply and price relationship
P'_g	=	with-policy U.S. price for output (g)
ε_g^{ROW}	=	price elasticity of supply of goods from the ROW to the United States (imports) (g)

The key supply parameter that controls the ROW supply adjustments is the price elasticity of supply (ε_g^{ROW}). We obtained these estimates for a variety of industry groups from a recently published article by Broda and colleagues (2008b).

A.2.2.3 Price Elasticity of Supply: Rest of World (ROW)

Broda and colleagues (2008a and 2008b) provide an empirical basis for the multimarket model supply elasticities. Broda et al. provide over 1,000 inverse elasticities that RTI organized to be comparable with the 100-sector model. The first step was to match the Harmonized Trade System (HS) elasticities estimated in the article to the appropriate NAICS codes. Many of the HS codes correspond with a detailed NAICS codes (5- and 6-digit level), while the multimarket sector industries typically correspond with more aggregated sectors (NAICS 2-, 3-, or 4-digit levels). To adapt these labels to our model, we combined the 5- and 6-digit NAICS under their 3- and 4-digit codes and calculated an average inverse elasticity value for codes that fell within the multimarket model's aggregate industrial sectors. This gives a crude way to account for the variety of products detailed in the original data set. We also restricted the elasticity sample to those that Broda et al. classify as "medium" and "low" categories; these categories tend to have lower elasticity values that are consistent with the multimarket model's modeling horizon (i.e., in the short run importers are likely to have less flexibility to respond to price changes and elasticities are low).[1]

[1]Broda et al.'s intent was to use these categories to describe or proxy for domestic market power.

Table A-5. Supply Elasticities

Industry Label	Industry Description	Rest of World (ROW)	U.S.
ACM	Accommodations	0.7	0.7
ADM	Administrative Services	0.7	0.7
AGR	Agricultural	1.0	1.0
ALU	Aluminum	0.8	0.5
ANM	Animal Foods	1.1	0.8
APP	Appliances	0.9	0.8
ARC	Aircraft	0.9	0.6
ART	Arts	0.7	0.7
ATP	Air Transportation	0.7	0.7
BAK	Baked Goods	0.8	0.7
BEV	Beverages and Tobacco	2.9	2.9
BOI	Boilers and Tanks	1.1	0.8
CEM	Cement	0.9	0.7
CEQ	Construction and Agricultural Equipment	0.8	0.6
CHM	Chemicals and Gases	1.1	0.8
CLY	Clay	0.8	0.6
CMQ	Communication Equipment	2.5	1.0
CNS	Construction	0.7	0.7
COL	Coal	2.2	2.2
CPP	Converted Paper Products	0.9	0.7
CPU	Computers	1.0	0.7
CRU	Crude Oil Extraction	3.7	3.7
CUT	Cutlery	1.4	1.1
EDU	Education	0.7	0.7
EEQ	Engines	1.2	1.0
EGV	Engraving	1.1	0.8
ELE	Electric Generation	2.0	2.0
ELQ	Electric Equipment	0.8	0.6
FIN	Finance and Insurance	0.7	0.7
FMP	Fabricated Metals	1.2	1.1
FRG	Forging and Stamping	1.6	1.5

(continued)

Table A-5. Supply Elasticities (continued)

Industry Label	Industry Description	Rest of World (ROW)	U.S.
FRT	Fertilizer	1.0	0.7
FRU	Fruits and Vegetables	1.0	0.7
FUR	Furniture	1.9	1.9
GAS	Natural Gas	12.2	12.2
GEQ	General Equipment	1.0	0.7
GLS	Glass	0.8	0.6
GRN	Grain Milling	1.7	1.5
HLT	Health Care	0.7	0.7
HRD	Hardware	1.1	0.8
HVC	HVAC Equipment	0.9	0.6
I_S	Iron and Steel	1.0	0.6
IEQ	Industrial Equipment	0.9	0.6
INF	Information	0.7	0.7
INS	Instruments	0.9	0.6
LEA	Leather	0.9	0.7
LGT	Lighting	1.1	0.7
LIM	Lime and Gypsum	0.9	0.7
LUM	Other Lumber	0.9	0.7
M_V	Motor Vehicles	1.3	0.7
MEA	Meat Products	1.2	3.9
MED	Drugs and Medicine	1.3	1.0
MEQ	Metalworking Equipment	0.7	0.5
MGT	Magnetic Recording Equipment	1.0	0.7
MIL	Dairy Products	1.1	0.9
MIN	Mining	2.2	2.2
MNG	Management	0.7	0.7
MSC	Miscellaneous Manufacturing	1.0	0.8
MSP	Machine Shops	1.1	0.8
MVP	Motor Vehicle Parts	0.9	0.6
OCM	Other Chemicals	1.1	0.6
OEQ	Other Electric Equipment	1.0	0.7
OFD	Other Food Products	1.1	0.7

(continued)

Table A-5. Supply Elasticities (continued)

Industry Label	Industry Description	Rest of World (ROW)	U.S.
OFM	Other Fabricated Metals	0.9	0.6
OIL	Refined Petroleum	1.0	0.7
ONM	Other Non-metallic Minerals	1.5	0.7
OPM	Other Primary Metals	0.7	0.5
OSV	Other Services	0.7	0.7
OTP	Other Transportation Services	0.7	0.7
OTQ	Other Transport Equipment	1.0	0.7
PAI	Paints and Adhesives	1.0	0.7
PAP	Pulp and Paper Mills	1.1	0.7
PFS	Professional Services	0.7	0.7
PIP	Pipeline Transport	2.0	2.0
PLS	Plastic	1.0	0.7
PLY	Plywood and Veneer	1.3	1.3
PRN	Printing	1.0	0.7
PUB	Public Services	0.7	0.7
R_R	Rail Cars	1.8	0.7
REL	Real Estate	0.7	0.7
RSN	Resins	1.0	0.7
RTL	Retail Trade	0.7	0.7
RTP	Railroad Transportation	0.7	0.7
RUB	Rubber	1.3	1.1
SAW	Sawmills	0.8	0.6
SEA	Seafood	1.1	0.8
SEQ	Service Industry Equipment	0.8	0.6
SGR	Sugar	1.1	0.8
SHP	Ships	1.0	0.7
SMI	Semiconductor Equipment	1.2	1.0
SOP	Soap	0.8	0.6
TEX	Textile Mills	1.0	0.7
TKB	Truck Bodies	3.2	3.1
TPM	Textile Product Mills	0.8	0.6
TTP	Freight Truck Transportation	0.7	0.7
TVQ	TV Equipment	5.8	5.4

(continued)

Table A-5. Supply Elasticities (continued)

Industry Label	Industry Description	Rest of World (ROW)	U.S.
WAP	Wearing Apparel	1.2	0.8
WHL	Wholesale Trade	0.7	0.7
WIR	Springs and Wires	1.9	0.8
WTP	Water Transportation	0.7	0.7

Note: RTI mapped Broda et al. data for their industry aggregation to the multimarket model's 100 industries. Domestic supply elasticities are typically assumed to be within one standard deviation of the sample of supply elasticities used for the ROW. In selected cases where this information is not available, the U.S. supply elasticity is set equal to the ROW.

Source: Broda, C., N. Limao, and D. Weinstein. 2008a. "Export Supply Elasticities." http://faculty.chicagobooth.edu/christian.broda/website/research/unrestricted/TradeElasticities/TradeElasticities.html. Accessed September 2009.

Our ideal preference was to use an exact 3- or 4-digit match from the medium category if one was available. If the multimarket model had a 4-digit code for which there was no direct match, we aggregated up a level and applied the relevant 3-digit elasticity. If a multimarket code was not covered in the medium set of elasticities, we used the low elasticity category. This method was sufficient for mapping the majority of the sectors in the model. After applying our inverse elasticity values to the multimarket sectors, we calculated the inverse of the value to arrive at the actual supply elasticity. Since Broda et al.'s article focused on industrial production goods, some of the multimarket sectors were not covered in the elasticity data. These sectors included mainly service industries, transportation, and energy sources.

In order to fill these gaps, we turned to the source substitution elasticities from Purdue University's Global Trade Analysis Project (GTAP).[1] Although the elasticities in the GTAP model are a different type of international trade elasticity and cannot be directly applied in the multimarket model (e.g., they are based on the Armington structure[2]), the parameters provide us with some additional information about the relative trade elasticity differences between industry sectors. To use the GTAP information to develop assumptions about the multimarket model sectors with missing elasticities, we chose a base industrial sector (iron and steel) for which we had parameter value from Broda et al. Next, we developed industry-specific ratios for missing industries using the corresponding GTAP sector trade elasticities and the GTAP iron and steel

[1]See Chapter 14 of the GTAP 7 Database Documentation for the full description of the parameters at https://www.gtap.agecon.purdue.edu/resources/download/4184.pdf; see Table 14.2 for elasticities.

[2]Detailed documentation of the entire GTAP 7 Database is available at https://www.gtap.agecon.purdue.edu/databases/v7/v7_doco.asp. The GTAP also uses a unique system of categorizing commodities that does not match the NAICS or HS system exactly.

sector. We multiplied the resulting ratio by the Broda et al. iron and steel parameter (1.0). For example, the GTAP trade elasticity for coal (6.10) is approximately 2.2 times the trade elasticity for iron and steel (2.95). As a result, the multimarket import supply elasticity for coal is computed as 2.2 (2.2 x 1.0).

A.2.2.4 Price Elasticity of Supply: United States

We also used Broda et al.'s elasticities to derive a set of domestic supply elasticities for the model. We have assumed that a product's domestic supply would be equal to or less elastic than other countries' supply of imports. When we aggregated and averaged the original elasticities to the 3- and 4-digit NAICS level for our foreign supply elasticities, we also calculated the standard deviation of each 3- and 4-digit NAICS sample. By adding the standard deviation to the corresponding foreign supply and then taking the inverse, we were able to calculate a domestic supply elasticity for each sector that was lower than its foreign counterpart while maintaining the structure of the original elasticities. For sectors in which no standard deviation was available,[1] we used professional judgment to apply the closest available substitute from a similar industry. Without a comparable way of scaling our foreign elasticities for the sectors in which we used the GTAP elasticities, we elected to keep the domestic and foreign supply elasticities the same.

A.2.2.5 Demand

Uses for industry output are divided into three groups: investment/government use, domestic intermediate uses, and other final use (domestic and exports). Given the short time horizon, investment/government does not change. Intermediate use is determined by the input use ratios and the industry output decisions.

$$Q'_i = \alpha_{gi} Q'_g \tag{A.7}$$

Q'_i = with-policy input demand quantity (i)

α_{gi} = input use ratio (g using input i)

Q'_g = with-policy output quantity (g)

Other final use does respond to market price changes. Following guidance in the OAQPS economic resource manual (EPA, 1999), we use a general form for the U.S. industry demand function:

[1]No standard deviations were calculated for the 3- and 4-digit codes that had only one observation (i.e., Broda et al.'s model used the exact 3- or 4-digit code).

$$Q_g' = a\left(P_g'\right)^{\eta_g} \tag{A.8}$$

where

Q_g' = with-policy demand quantity (g)

a = calibrated scale parameter for the demand and price relationship

P_g' = with-policy price for output (g)

η_g = price elasticity of demand (g)

The key parameter that controls consumption adjustments is the price elasticity of demand (η_g). To approximate the response, we use demand elasticities that were simulated with a general equilibrium model (Ho, Morgenstern, and Shih, 2008). Table A-6 reports the values currently available in the model.

A.2.2.6 Model Scope

The multimarket model includes 100 sectors covering energy, manufacturing, and service applications. Each sector's production technology requires the purchase of energy and other intermediate goods made by other sectors included in the model. Linking the sectors in this manner allows the model to trace direct and indirect policy effects across different sectors. Therefore, it is best used when potential economic impacts and equity effects on related markets might be important to stakeholders not directly affected by an environmental policy. However, the model can also be run in single-market partial equilibrium mode to support and provide insights for other types of environmental policies.

A.2.2.7 Model Time Horizon

The model is designed to address short-run and transitional effects associated with environmental policy. Production technologies are fixed; the model does not assess substitution among production inputs (labor, energy intermediates, and other intermediates) and assumes each investment cannot be changed during the time frame of the analysis. These issues are better addressed using other frameworks such as computable general equilibrium modeling. Similarly, government purchases from each sector do not adjust in response to changes in goods/service prices. Although, employment levels (number of jobs) adjust as production levels change, wages are assumed to be fixed.

Table A-6. U.S. Demand Elasticities

Industry Label	Industry Description	Demand Elasticity η_g
ACM	Accommodations	−0.7
ADM	Administrative Services	−0.7
AGR	Agricultural	−0.8
ALU	Aluminum	−1.0
ANM	Animal Foods	−0.6
APP	Appliances	−2.6
ARC	Aircraft	−2.5
ART	Arts	−0.7
ATP	Air Transportation	−0.8
BAK	Baked Goods	−0.6
BEV	Beverages and Tobacco	−0.6
BOI	Boilers and Tanks	−0.5
CEM	Cement	−0.8
CEQ	Construction and Agricultural Equipment	−1.7
CHM	Chemicals and Gases	−1.0
CLY	Clay	−0.8
CMQ	Communication Equipment	−2.6
CNS	Construction	−0.8
COL	Coal	−0.1
CPP	Converted Paper Products	−0.7
CPU	Computers	−2.6
CRU	Crude Oil Extraction	−0.3
CUT	Cutlery	−0.5
EDU	Education	−0.7
EEQ	Engines	−1.7
EGV	Engraving	−0.5
ELE	Electric Generation	−0.2
ELQ	Electric Equipment	−2.6
FIN	Finance and Insurance	−0.7
FMP	Fabricated Metals	−0.5
FRG	Forging and Stamping	−0.5
FRT	Fertilizer	−1.0
FRU	Fruits and Vegetables	−0.6
FUR	Furniture	−0.7

(continued)

Table A-6. U.S. Demand Elasticities (continued)

Industry Label	Industry Description	Demand Elasticity η_g
GAS	Natural Gas	−0.3
GEQ	General Equipment	−1.7
GLS	Glass	−0.8
GRN	Grain Milling	−0.6
HLT	Health Care	−0.7
HRD	Hardware	−0.5
HVC	HVAC Equipment	−1.7
I_S	Iron and Steel	−1.0
IEQ	Industrial Equipment	−1.7
INF	Information	−0.7
INS	Instruments	−2.6
LEA	Leather	−1.1
LGT	Lighting	−2.6
LIM	Lime and Gypsum	−0.8
LUM	Other Lumber	−0.7
M_V	Motor Vehicles	−2.5
MEA	Meat Products	−0.6
MED	Drugs and Medicine	−1.0
MEQ	Metalworking Equipment	−1.7
MGT	Magnetic Recording Equipment	−2.6
MIL	Dairy Products	−0.6
MIN	Mining	−0.6
MNG	Management	−0.7
MSC	Miscellaneous Manufacturing	−1.7
MSP	Machine Shops	−0.5
MVP	Motor Vehicle Parts	−2.5
OCM	Other Chemicals	−1.0
OEQ	Other Electric Equipment	−2.6
OFD	Other Food Products	−0.6
OFM	Other Fabricated Metals	−0.5
OIL	Refined Petroleum	−0.1
ONM	Other Non-metallic Minerals	−0.8
OPM	Other Primary Metals	−1.0
OSV	Other Services	−0.7
OTP	Other Transportation Services	−0.8

(continued)

Table A-6. U.S. Demand Elasticities (continued)

Industry Label	Industry Description	Demand Elasticity η_g
OTQ	Other Transport Equip	−2.5
PAI	Paints and Adhesives	−1.0
PAP	Pulp and Paper Mills	−0.7
PFS	Professional Services	−0.7
PIP	Pipeline Transport	−0.8
PLS	Plastic	−1.0
PLY	Plywood and Veneer	−0.7
PRN	Printing	−0.7
PUB	Public Services	−0.7
R_R	Rail Cars	−2.5
REL	Real Estate	−0.7
RSN	Resins	−1.0
RTL	Retail Trade	−0.7
RTP	Railroad Transportation	−0.8
RUB	Rubber	−1.0
SAW	Sawmills	−0.7
SEA	Seafood	−0.6
SEQ	Service Industry Equipment	−1.7
SGR	Sugar	−0.6
SHP	Ships	−2.5
SMI	Semiconductor Equipment	−2.6
SOP	Soap	−1.0
TEX	Textile Mills	−1.1
TKB	Truck Bodies	−2.5
TPM	Textile Product Mills	−1.1
TTP	Freight Truck Transportation	−0.8
TVQ	TV Equipment	−2.6
WAP	Wearing Apparel	−2.4
WHL	Wholesale Trade	−0.7
WIR	Springs and Wires	−0.5
WTP	Water Transportation	−0.8

Note: RTI assigned an elasticity using the most similar industry from Ho and colleagues' industry aggregation.

Source: Ho, M. S, R. Morgenstern, and J. S. Shih. 2008. "Impact of Carbon Price Policies on US Industry." RFF Discussion Paper 08-37. Http://Www.Rff.Org/Publications/Pages/Publicationdetails.Aspx?. Publicationid=20680. Accessed August 2009. Table B.6.

A.3 Appendix A References

Berck, P., and S. Hoffmann. 2002. "Assessing the Employment Impacts of Environmental and Natural Resource Policy." *Environmental and Resource Economics* 22(1):133-156.

Broda, C., N. Limao, and D.E. Weinstein. 2008a. "Optimal Tariffs and Market Power: The Evidence." *American Economic Review* 98(5):2032-2065.

Broda, C., N. Limao, and D. Weinstein. 2008b. "Export Supply Elasticities." <http://faculty.chicagobooth.edu/christian.broda/website/research/unrestricted/TradeElasticities/TradeElasticities.html.>

Ho, M.S., R. Morgenstern, and J.S. Shih. 2008. "Impact of Carbon Price Policies on US Industry" (RFF Discussion Paper 08-37). <http://www.Rff.Org/Publications/Pages/Publicationdetails.Aspx?.Publicationid=20680>.

Just, R.E., D.L. Hueth, and A. Schmitz. 2004. *The Welfare Economics of Public Policy*. Northampton, MA: Edward Elgar.

Morgenstern, R.D., M. Ho, J.S. Shih, and X. Zhang. 2004. "The Near-Term Impacts of Carbon Mitigation Policies on Manufacturing Industries." *Energy Policy* 32(16): 1825-1841.

Shoven, J.B., and J. Whalley. 1995. *Applying General Equilibrium*. New York: Cambridge University Press.

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1999. *OAQPS Economic Analysis Resource Document*. http://www.epa.gov/ttn/ecas/analguid.html.

U.S. Environmental Protection Agency. 2000. "Guidelines for Preparing Economic Analyses" (EPA 240-R-00-003). <http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/cover.pdf>.

APPENDIX B
DETAILED ECONOMIC MODEL RESULTS BY SECTOR

Table B-1. Prices (Percentage Change from Benchmark): Industry Detail

	Major		Area	
	Selected Option	**Alternative Option**	**Selected Option**	**Alternative Option**
Energy	0.0279%	0.0228%	−0.0001%	−0.0001%
Nonmanufacturing	0.0007%	0.0054%	0.0013%	0.0016%
Manufacturing				
Food, beverages, and textiles	0.0106%	0.0118%	0.0016%	0.0030%
Lumber, paper, and printing	0.1006%	0.2427%	0.0133%	0.0162%
Chemicals	0.0082%	0.0038%	−0.0003%	−0.0005%
Plastics and rubber	0.0183%	0.0147%	−0.0006%	−0.0008%
Nonmetallic minerals	0.0033%	0.0041%	−0.0004%	−0.0005%
Primary metals	0.0221%	0.0139%	−0.0002%	−0.0002%
Fabricated metals	0.0036%	0.0018%	−0.0003%	−0.0004%
Machinery and equipment	0.0051%	0.0004%	−0.0002%	−0.0003%
Electronic equipment	−0.0004%	−0.0006%	−0.0001%	−0.0001%
Transportation equipment	0.0025%	0.0020%	−0.0001%	−0.0001%
Other	0.0035%	0.0079%	0.0005%	0.0006%
Wholesale and retail trade	−0.0018%	−0.0024%	0.0000%	0.0001%
Transportation services	−0.0010%	−0.0022%	−0.0001%	−0.0002%
Other services	0.0001%	0.0000%	0.0012%	0.0014%

Table B-2. Production (Percentage Change from Benchmark): Industry Detail

	Major		Area	
	Selected Option	**Alternative Option**	**Selected Option**	**Alternative Option**
Energy	−0.0087%	−0.0084%	−0.0002%	−0.0002%
Nonmanufacturing	−0.0029%	−0.0046%	−0.0007%	−0.0011%
Manufacturing				
Food, beverages, and textiles	−0.0121%	−0.0136%	−0.0013%	−0.0022%
Lumber, paper, and printing	−0.0442%	−0.0999%	−0.0057%	−0.0071%
Chemicals	−0.0168%	−0.0150%	−0.0001%	−0.0002%
Plastics and rubber	−0.0153%	−0.0155%	−0.0003%	−0.0004%
Nonmetallic minerals	−0.0038%	−0.0054%	−0.0003%	−0.0004%
Primary metals	−0.0233%	−0.0167%	−0.0001%	−0.0001%
Fabricated metals	−0.0047%	−0.0047%	−0.0002%	−0.0003%
Machinery and equipment	−0.0071%	−0.0029%	−0.0001%	−0.0001%
Electronic equipment	−0.0026%	−0.0034%	−0.0001%	−0.0001%
Transportation equipment	−0.0059%	−0.0049%	0.0000%	0.0000%
Other	−0.0077%	−0.0162%	−0.0013%	−0.0016%
Wholesale and retail trade	−0.0012%	−0.0015%	−0.0002%	−0.0004%
Transportation services	−0.0030%	−0.0035%	−0.0002%	−0.0003%
Other services	−0.0011%	−0.0014%	−0.0006%	−0.0008%

Table B-3. Consumption (Percentage Change from Benchmark): Industry Detail

	Major		Area	
	Selected Option	**Alternative Option**	**Selected Option**	**Alternative Option**
Energy	−0.0057%	−0.0059%	−0.0002%	−0.0002%
Nonmanufacturing	−0.0026%	−0.0039%	−0.0006%	−0.0009%
Manufacturing				
Food, beverages, and textiles	−0.0063%	−0.0074%	−0.0009%	−0.0016%
Lumber, paper, and printing	−0.0273%	−0.0566%	−0.0018%	−0.0024%
Chemicals	−0.0114%	−0.0109%	−0.0002%	−0.0003%
Plastics and rubber	−0.0094%	−0.0104%	−0.0003%	−0.0005%
Nonmetallic minerals	−0.0032%	−0.0045%	−0.0003%	−0.0004%
Primary metals	−0.0117%	−0.0088%	−0.0001%	−0.0002%
Fabricated metals	−0.0036%	−0.0036%	−0.0002%	−0.0003%
Machinery and equipment	−0.0034%	−0.0018%	−0.0001%	−0.0001%
Electronic equipment	−0.0014%	−0.0016%	−0.0001%	−0.0001%
Transportation equipment	−0.0033%	−0.0027%	0.0000%	0.0000%
Other	−0.0025%	−0.0050%	−0.0004%	−0.0006%
Wholesale and retail trade	−0.0012%	−0.0015%	−0.0002%	−0.0003%
Transportation services	−0.0026%	−0.0031%	−0.0002%	−0.0003%
Other Services	−0.0011%	−0.0014%	−0.0006%	−0.0008%

Table B-4. Imports (Percentage Change from Benchmark): Industry Detail

	Major		Area	
	Selected Option	**Alternative Option**	**Selected Option**	**Alternative Option**
Energy	0.0509%	0.0413%	−0.0001%	−0.0002%
Nonmanufacturing	0.0010%	0.0037%	0.0008%	0.0010%
Manufacturing				
Food, beverages, and textiles	0.0134%	0.0155%	0.0018%	0.0032%
Lumber, paper, and printing	0.1034%	0.2467%	0.0136%	0.0166%
Chemicals	0.0093%	0.0045%	−0.0004%	−0.0006%
Plastics and rubber	0.0197%	0.0158%	−0.0006%	−0.0009%
Nonmetallic minerals	0.0012%	0.0022%	−0.0001%	−0.0001%
Primary metals	0.0208%	0.0132%	−0.0002%	−0.0002%
Fabricated metals	0.0042%	0.0023%	−0.0003%	−0.0004%
Machinery and equipment	0.0045%	0.0004%	−0.0002%	−0.0003%
Electronic equipment	−0.0003%	−0.0003%	−0.0001%	−0.0002%
Transportation equipment	0.0036%	0.0029%	0.0000%	−0.0001%
Other	0.0059%	0.0137%	0.0011%	0.0013%
Wholesale and retail trade	−0.0012%	−0.0016%	0.0000%	0.0001%
Transportation services	−0.0007%	−0.0014%	0.0000%	−0.0001%
Other services	−0.0002%	−0.0004%	0.0001%	0.0001%

Table B-5. Exports (Percentage Change from Benchmark): Industry Detail

	Major		Area	
	Selected Option	Alternative Option	Selected Option	Alternative Option
Energy	−0.0041%	−0.0033%	0.0000%	0.0000%
Nonmanufacturing	−0.0004%	−0.0040%	−0.0010%	−0.0013%
Manufacturing				
Food, beverages, and textiles	−0.0069%	−0.0076%	−0.0010%	−0.0019%
Lumber, paper, and printing	−0.0702%	−0.1690%	−0.0093%	−0.0113%
Chemicals	−0.0081%	−0.0038%	0.0003%	0.0005%
Plastics and rubber	−0.0181%	−0.0145%	0.0006%	0.0008%
Nonmetallic minerals	−0.0027%	−0.0034%	0.0003%	0.0004%
Primary metals	−0.0211%	−0.0133%	0.0002%	0.0002%
Fabricated metals	−0.0018%	−0.0009%	0.0002%	0.0002%
Machinery and equipment	−0.0084%	−0.0006%	0.0004%	0.0005%
Electronic equipment	0.0010%	0.0015%	0.0003%	0.0004%
Transportation equipment	−0.0062%	−0.0049%	0.0001%	0.0002%
Other	−0.0034%	−0.0069%	−0.0002%	−0.0002%
Wholesale and retail trade	0.0013%	0.0018%	0.0000%	−0.0001%
Transportation services	0.0008%	0.0018%	0.0001%	0.0002%
Other services	−0.0001%	−0.0001%	−0.0009%	−0.0011%