December 20, 2012

MEMORANDUM

SUBJECT: Regulatory Impact Results for the Reconsideration Final Rule for Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Commercial and Industrial Solid Waste Incineration Units

FROM: Tom Walton
Economist
AEG (C439-02)

TO: Toni Jones
Environmental Engineer
FIG (E143-03)

The EPA analyzed the economic impacts and benefits of this reconsideration final rule using the methodology that was discussed in the original final rule RIA and in the preamble to the original final rule. *See* FR 76 15704.

Changes Since 2010 Final Rule to Emission Reductions and Engineering Costs

The changes in emission reductions and annual engineering costs in the final CISWI reconsideration are the result of revisions made to the CISWI unit inventory since promulgation of the March 2011 final rule. Since the March 2011 final rule, some units were identified that were not previously in the CISWI inventory database, some units were removed from the inventory, and one unit was moved from one subcategory to another . Making these changes resulted in 1 additional incinerator, 14 additional small remote incinerators, 8 fewer energy recovery units burning solid waste, no change in the number of energy recovery units burning liquid waste, and 11 additional waste-burning kilns. Altogether, the current CISWI inventory comprises 18 more units than the inventory at the time the March 2011 final rule was promulgated. If all units choose to comply with the rule, the resulting incremental cost impact for the revised inventory of CISWI units to comply with the final amended rule is approximately 184 million dollars in capital expenditures and 42 million dollars per year in total annual costs.

The changes in emission reductions and annual engineering costs in the final CISWI reconsideration are mainly the result of revisions made to the emission limits due to receiving new data, subcategory inventory changes, and changes to the emissions monitoring provisions. Incremental annual engineering costs for liquid/gas burning energy recover units decreased by approximately $219,000 because a lower baseline CO emission concentration was determined for one of the units, thus eliminating the need for an oxidation catalyst to meet the new CO limit. Incremental annual engineering costs for energy recover units burning solids decreased by about $70 million because eight units were cut from the inventory and a revised activated carbon injection cost algorithm was used in estimating costs. Incremental annual engineering costs for incinerators increased by about $340,000 because of a more stringent CO limit, which prompted the need for afterburner retrofits on units that can't meet the revised limit. Incremental annual engineering costs for small remote units increased by approximately $3.2 million; although limits became less stringent and fewer controls were required per unit, the additional annual costs required for an additional 14 units to comply ($3.7 million) outweighed the cost reduction from decreased control requirements ($498,000). Incremental annual engineering costs for waste-burning kilns increased by about $109 million because additional wet scrubbers, activated carbon injection, regenerative thermal oxidizers, and fabric filter improvements were required for the original 12 units to meet revised limits, and an additional 11 units were added to the inventory, many of which require similar controls to meet the revised limits.

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

Table 1. Changes in Emission Reductions for the Final CISWI Reconsideration[a]

	Direct $PM_{2.5}$ (tons per year)	**SO_2 (tons per year)**	**NOx (tons per year)**
Final CISWI Rule (March 2011)	759	5,259	5,734
Changes due to increase in scope (addition of 18 units)	+98	+970	-8
Changes due to provision changes in this final reconsideration	+60	+33	-327
Net changes since final rule	+158	+1,003	-335
Final CISWI Reconsideration	917	6,262	5,399

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

Table 2. Changes in Benefits and Costs for the Final CISWI Reconsideration

	Monetized Benefits in 2015[a]		Annual Engineering Costs[b] (considering fuel savings)
	3% discount rate	7% discount rate	
Final CISWI Rule (March 2011)	$360 to $870 million	$320 to $790 million	$218 million
Changes due to increase in scope (addition of 18 units)	+$51 to $120 million	+$46 to $110 million	+$30 million
Changes due to provision changes in this final reconsideration	+$13 to $32 million	+12 to $29 million	+$10 million
Net changes since final rule	+$64 to $160 million	+58 to $140 million	$40 million
Final CISWI Reconsideration	$420 to $1,000 million	$380 to $930 million	$258 million

[a] These benefits do not include benefits associated with reduced exposure to HAP, direct exposure to SO_2, visibility impairment, or ecosystem effects. These benefits reflect the final rule, which were 4% higher than shown in the RIA.

[b] Minimum and maximum fuel savings reflect a range of fuel prices for the final reconsideration. These costs reflect the final rule, which were 22% lower than shown in the RIA.

We estimated the total monetized benefits for the final CISWI RIA (March 2011) to be $340 million to $830 million at 3 percent discount rate and $310 million to $750 million at 7 percent discount rate. However, EPA noted that the RIA did not incorporate the final engineering costs and emission reductions, which would decrease the engineering costs by approximately 22% and increase the monetized benefits by approximately 4%. For this final reconsideration, we estimate the total monetized benefits to be $420 million to $1 billion at 3 percent discount rate and $380 million to $930 million at 7 percent discount rate. All estimates are in 2008$.

Revised Economic Impacts

The market impact results are very similar to the results in the final rule RIA. The Agency's economic model suggests average national price increases for industrial sectors are less than 0.001 percent, while average annual domestic production may fall by less than 0.001 percent. Because of higher domestic prices, imports slightly rise by 0.001 percent and exports fall by 0.001 percent. The change in US surplus is now -258 million dollars (2006$). For the final rule RIA, the change in surplus was -283 million dollars (2006$). Table 3 provides the price, production, import, and export changes for this final reconsideration rule, which are very close to the estimated changes for the final rule RIA.

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

Industry Sector	U.S. Prices	U.S. Production	Imports	U.S. Consumption	Exports
Energy	0.001%	-0.001%	0.002%	0.000%	0.000%
Nonmanufacturing	0.004%	-0.001%	0.003%	0.000%	-0.003%
Manufacturing					
Food, beverages, and textiles	0.001%	-0.001%	0.001%	0.000%	0.000%
Lumber, paper, and printing	0.020%	-0.009%	0.021%	-0.005%	-0.014%
Chemicals	0.000%	-0.001%	0.000%	-0.001%	0.000%
Plastics and Rubber	0.000%	-0.001%	0.000%	-0.001%	0.000%
Nonmetallic Minerals	0.087%	-0.020%	0.032%	-0.012%	-0.072%
Primary Metals	0.001%	-0.001%	0.001%	-0.001%	-0.001%
Fabricated Metals	0.000%	0.000%	0.000%	0.000%	0.000%
Machinery and Equipment	0.000%	0.000%	0.000%	0.000%	0.000%
Electronic Equipment	0.000%	0.000%	0.000%	0.000%	0.000%
Transportation Equipment	0.000%	0.000%	0.000%	0.000%	0.000%
Other	0.000%	-0.001%	0.001%	0.000%	0.000%
Wholesale and Retail Trade	0.000%	0.000%	0.000%	0.000%	0.000%
Transportation Services	0.000%	-0.001%	0.000%	0.000%	0.000%
Other Services	0.000%	0.000%	0.000%	0.000%	0.000%

The results for sales tests for small businesses are lower for the reconsideration final than those calculated for the final rule. The number of small entities affected by the rule dropped from nine to five. For the final rule, four of the nine had cost-to-sales percentages of more than 3 percent. For the reconsideration final only one of the five had a cost-to-sales percentage of more than 3 percent and the other four had small savings. This is not a significant impact on a substantial number of small entities.

The change in employment estimates between the final rule RIA and the reconsideration final is small. The estimated employment changes range between −500 to +1000 employees, with a central estimate of +300 employees for the final rule RIA. For the reconsideration final, the estimated employment changes range between −400 to +800 employees, with a central estimate of +200.

Revised Benefits

The health benefits were calculated using the methodology described in the final CISWI RIA (U.S. EPA, 2011)[1] using the revised emission reductions estimated for the final reconsideration. We were unable to estimate the benefits from reducing exposure to HAPs and ozone, ecosystem impairment, and visibility impairment, including reducing 20,000 tons of carbon monoxide, 780 tons of HCl, 2.5 tons of lead, 1.8 tons of cadmium, 680 pounds of

[1] U.S. Environmental Protection Agency (U.S. EPA). 2011. *Regulatory Impact Analysis: Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Commercial and Industrial Solid Waste Incineration Units.* February. Available at http://www.epa.gov/ttnecas1/regdata/RIAs/CISWIRIAfinal110221_psg2.pdf

mercury, and 58 grams of dioxins/furans. Please refer to the full description in the final CISWI RIA of the unquantified benefits as well as analysis limitations and uncertainties. These monetized benefits are approximately 18% higher than the final CISWI NSPS due to the increased emission reductions of $PM_{2.5}$ and SO_2. 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)[2,3], 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. More information on these updates can be found in the PM NAAQS proposal RIA. We provide the benefits results in Tables 4 and 5 and Figure 2. We also provide the breakdown of monetized benefits by subcategory in Figure 1.

Table 4: Summary of Monetized Benefits Estimates for the Final CISWI Reconsideration in 2015 (2008$)

Pollutant	Emissions Reductions (tons)	Benefit per ton (Pope, 3%)	Benefit per ton (Laden, 3%)	Benefit per ton (Pope, 7%)	Benefit per ton (Laden, 7%)	Total Monetized Benefits (millions 2008$ at 3%)			Total Monetized Benefits (millions 2008$ at 7%)		
Direct $PM_{2.5}$	917	$230,000	$560,000	$210,000	$500,000	$210	to	$510	$190	to	$460
$PM_{2.5}$ Precursors											
SO_2	6,262	$29,000	$72,000	$27,000	$65,000	$180	to	$450	$170	to	$410
NO_2	5,399	$4,900	$12,000	$4,400	$11,000	$26	to	$64	$24	to	$58
					Total	**$420**	**to**	**$1,000**	**$380**	**to**	**$930**

*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 or ozone benefits.

[2] 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.

[3] 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 5: Summary of Estimated Reductions in Health Incidences from $PM_{2.5}$ for the Final CISWI Reconsideration in 2015*

Avoided Premature Mortality	
Pope et al.	47
Laden et al.	120
Avoided Morbidity	
Chronic Bronchitis	32
Acute Myocardial Infarction	75
Hospital Admissions, Respiratory	11
Hospital Admissions, Cardiovascular	24
Emergency Room Visits, Respiratory	45
Acute Bronchitis	76
Work Loss Days	6,200
Asthma Exacerbation	830
MRAD	37,000
Lower Respiratory Symptoms	910
Upper Respiratory Symptoms	680

*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 and ozone exposure, nor energy disbenefits associated with the increased emissions from additional energy usage.

Figure 1: Breakdown of Monetized Benefits by Subcategory

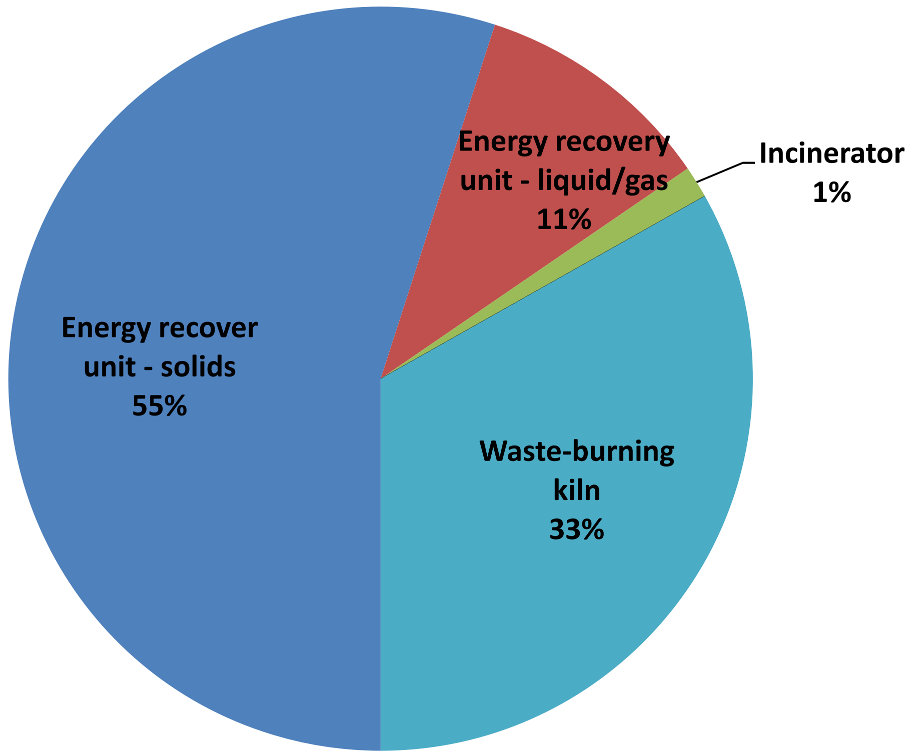
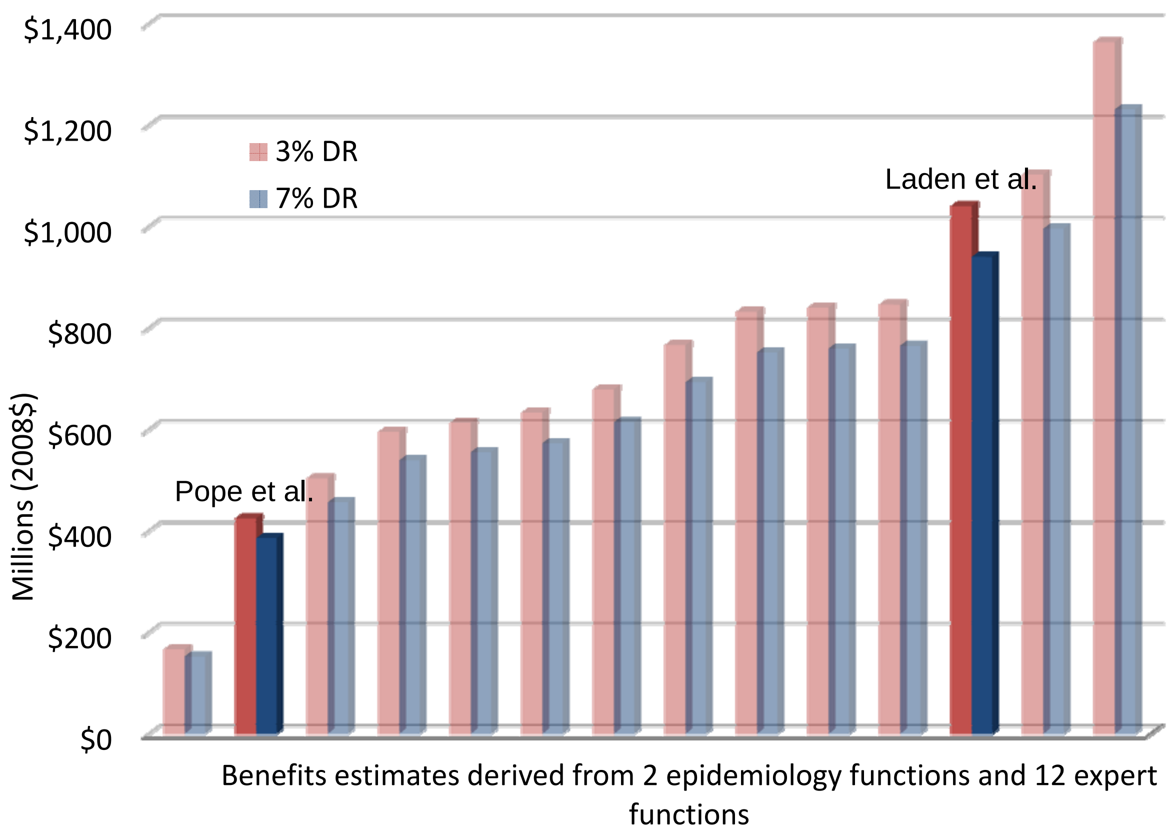


Figure 2: Total Monetized $PM_{2.5}$ Benefits Estimates for the Final CISWI Reconsideration in 2015



Revised Net Benefits

Table 6 shows the estimated costs and benefits for the reconsideration final. The estimated net benefits are higher than the final rule RIA, which was $30 million to $470 million at 7 percent and was $60 million to $550 million at 3 percent.

Table 6. Summary of Estimated Social Costs and Benefits

Category	Primary Estimate	Low Estimate	High Estimate	Year Dollar	Discount Rate	Period Covered
Benefits						
Annualized Monetized ($millions/year)		$380	$930	2008	7%	2015
		$420	$1,000	2008	3%	2015
Costs						
Annualized Monetized ($millions/year)	$258			2008	7%	2015
	$258			2008	3%	2015
Net Benefits						
Annualized Monetized ($millions/year)		$120	$670	2008	7%	2015
		$160	$770	2008	3%	2015

February 2011

Regulatory Impact Analysis: Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Commercial and Industrial Solid Waste Incineration Units

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards (OAQPS)
Air Economics Group
Risk and Benefits Group
(MD-C439-02)
Research Triangle Park, NC 27711

CONTENTS

Appendixes

LIST OF FIGURES

LIST OF TABLES

SECTION 1
INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is promulgating new standards of performance and emission guidelines based on a review of the standards and guidelines as part of the Clean Air Act Section 129(a)(5) requirement to review the new source performance standards and emission guidelines every 5 years. Additionally, when revising the standards of performance and emission guidelines we considered the District of Columbia Circuit Court rulings on maximum achievable control technology standards that were issued after promulgation of the new source performance standards and emission guidelines for commercial and industrial solid waste incineration units in 2000 and a concurrently promulgated definition of nonhazardous secondary materials as solid waste under the Resource Conservation and Recovery Act. EPA is also promulgating other amendments that EPA believes are necessary to adequately address air emissions from commercial and industrial solid waste incineration units and to clarify certain portions of the rules. 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.

The RIA does not include the final engineering costs and emission reductions into this RIA (see Chapter 2 for more detail on the engineering costs that were not accounted for). We estimate that incorporating these final estimates would decrease the engineering costs by approximately 22% and increase the monetized benefits by approximately 4% from those shown in this RIA.

1.1 Executive Summary

The key results of the RIA are as follows:

- **Engineering Cost Analysis:** EPA estimates the promulgated rule's total annualized costs will be $280 million (2008$).
- **Market Analysis:** Under the promulgated rule, the Agency's economic model suggests the average national market-level variables (prices, production-levels, consumption, international trade) will not change significantly (e.g., are less than 0.1%).
- **Social Cost Analysis:** The estimated social cost is approximately $280 million (2008$). In the near term, the Agency's economic model suggests that industries are able to pass approximately $76 million of the rule's costs to consumers (e.g., marginally higher market prices). Domestic industries' surplus falls by $207 million, while other countries on net benefit from higher prices (a net increase in rest-of-the

world [ROW] surplus of $3 million). Additional new source costs not included in the economic model represent a net cost of less than $1 million.

- **Employment Changes:** The estimated employment changes range between −500 to 1,000 employees, with a central estimate of +300 employees.

- **Small Entity Analyses:** EPA performed a screening 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 exceeded 3% for four of nine small entities included in the screening analysis. After reviewing screening analysis results, EPA has determined the promulgated rule will not have a SISNOSE and presumes that rule is eligible for certification under the RFA as amended by SBREFA. We provide the factual basis for certification in Section 4.

- **Benefits Analysis:** The benefits from reducing some air pollutants have not been monetized in this analysis, including reducing a 25,000 tons of carbon monoxide, 470 tons of HCl, 4.1 tons of lead, 0.95 tons of cadmium, 260 pounds of mercury, and 92 grams of total dioxins/furans each year. We assess the benefits of these emission reductions qualitatively in this analysis. Thus, all monetized benefits reported reflect improvements in ambient $PM_{2.5}$ concentrations. As such, although the monetized benefits likely underestimate the total benefits, the extent of the underestimate is unclear. In the year of full implementation (2016), EPA estimates the monetized $PM_{2.5}$ benefits of the promulgated NSPS and Emission Guidelines are $340 million to $830 million and $310 million to $750 million, at 3% and 7% discount rates respectively. All estimates are in 2008$. 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. In addition, ecosystem benefits and visibility benefits have not been monetized in this analysis.

- **Net Benefits:** The net benefits for the NSPS and Emission Guidelines are $60 million to $550 million and $30 million to $470 million, at 3% and 7% discount rates respectively (Table 1-1). All estimates are in 2008$ for the year 2016. These results are shown in Tables 1-1

1.2 Organization of this Report

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

- Section 2 describes the engineering cost analysis.
- Section 3 describes the economic impact analysis.
- Section 4 describes the small entity analyses.
- Section 5 presents the benefits estimates.
- Section 6 presents the net benefits.

- Appendix A describes the multimarket model used in the economic analysis.
- Appendix B describes the affected Industry profiles.

Table 1-1. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the CISWI NSPS and Emissions Guidelines in 2016 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Option 1: MACT Floor						
Total Monetized Benefits[b]	$340	to	$830	$310	To	$750
Total Social Costs[c]		$280			$280	
Net Benefits	$60	to	$550	$30	To	$470
Non-monetized Benefits	25,000 tons of carbon monoxide					
	470 tons of HCl					
	260 pounds of mercury					
	0.95 tons of cadmium					
	4.1 tons of lead					
	92 grams of dioxins/furans					
	Health effects from NO_2 and SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					
Option 2: Beyond the Floor						
Total Monetized Benefits[b]	$430	to	$1,100	$390	To	$960
Total Social Costs[c]		$300			$300	
Net Benefits	$130	to	$770	$90	To	$660
Non-monetized Benefits	25,000 tons of carbon monoxide					
	470 tons of HCl					
	260 pounds of mercury					
	0.95 tons of cadmium					
	4.1 tons of lead					
	92 grams of dioxins/furans					
	Health effects from NO_2 and SO_2 exposure					
	Ecosystem effects					
	Visibility impairment					

[a] All estimates are for the implementation year (2016), 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 NO_x and 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 valued at $3.8 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.

SECTION 2
OVERVIEW OF THE ENGINEERING COST ANALYSIS

This RIA does not incorporate the final engineering costs and emission reductions. We estimate that incorporating these final estimates would decrease the engineering costs by approximately 22% and increase the monetized benefits by approximately 4% from those shown in this RIA. The changes made that were not included in the RIA are the following:

- The cost estimates for existing units were revised to reflect removal of several units from the CISWI population, including one energy recovery unit, several cyclonic burn barrels, and a few cement kilns.
- -For the remaining kilns, we identified ones that will likely install regenerative thermal oxidizers to meet the NESHAP limits, and therefore should not have these costs repeated in the CISWI cost estimates.

This section provides an overview of the engineering cost analysis used to estimate the 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 "Revised Compliance Cost Analysis for Existing and New CISWI Units" in the EPA-HQ-OAR-2003-0119 Docket. Note that there were some very late adjustments made to the CISWI inventory and carbon monoxide test data that were performed shortly before signature of the final package. These adjustments affected the bottom-line cost estimate of the final rules. The cost memorandum in the docket reflects the results of the late inventory and data revisions and the resulting costs. However, there was insufficient time to revise the RIA to reflect these late revisions, so the cost totals presented below differ from those presented in "Revised Compliance Cost Analysis for Existing and New CISWI Units" in the EPA-HQ-OAR-2003-0119 Docket.

To estimate the national cost impacts of the rule for existing sources, EPA compared the maximum three-run average value for each pollutant measured in tests (i.e., the highest result of an emission test performed) of each unit in the inventory to its corresponding emission limit to determine which, if any, control devices would be needed in order to comply with the standards. In order to fill data gaps for units having no emissions data, these maximum test averages were averaged over each subcategory to develop an emission factor for each pollutant and each subcategory. If identical units were operated at the facility but emissions data were available for only one unit, the emissions data from the unit with data were applied to the identical units. For the remaining units that did not report emissions data, we assigned the appropriate emission factor for the units in that subcategory[1]. The control analysis considered fabric filters to be the

---

[1] Data gaps varied by pollutant, but overall over all units and all nine pollutants, about 28% of the baseline emission concentration data gaps were filled using average emission factors.

primary control device for particulate matter, cadmium, and lead control; packed bed scrubbers and dry sorbent injection for hydrogen chloride and sulfur dioxide control; activated carbon injection for mercury and dioxins/furans control; selective non-catalytic reduction (SNCR) for oxides of nitrogen; and afterburner retrofits, regenerative thermal oxidizers, tune-ups, advanced combustion controls, and oxidation catalysts for carbon monoxide controls. We also considered whether existing control devices could be improved to achieve the limits, such as adding more lime to duct sorbent injection systems to meet the sulfur dioxide limits. We included costs for testing and monitoring requirements contained in the rule. Finally, we analyzed the costs of waste segregation practices and alternative disposal options, such as diverting waste to a landfill to see if less expensive options to incineration were available. In certain cases, such as incinerators, our data suggest that sending waste to a landfill may likely be less costly than operating and maintaining an incineration unit. The resulting total national cost impact of the rule is 706 million dollars in capital expenditures and 280 million dollars per year in total annual costs. The total capital and annual costs include costs for control devices, work practices, testing and monitoring. Costs include testing and monitoring costs, as well as estimated recordkeeping and reporting costs. Based on the cost to comply with the rule, availability of alternatives to incineration, and historic negative growth in this source category, we anticipate only one new incineration unit within the next five years, with an annual compliance cost of $829,500, and up to five new small remote incinerators at an annual cost of $351,000 per unit[2].

Table 2-1. Summary of Capital and Annual Costs for Existing CISWI Sources

Subcategory	Number of Affected Units	Capital Costs (millions of 2008$)	Annualized Costs (millions of 2008$)
Energy Recovery Units – Solids	31	507.6	194.3
Energy Recovery Units – Liquid/Gas	6	32.3	7.6
Cement Kilns	16	157.7	73.7
Incinerators	28	5.7	3.3
Small remote incinerators	19	2.8	1.2

Based on this analysis, EPA anticipates an overall total capital investment of $706 million plus the cost of recordkeeping and reporting required by this rule, with an associated total

[2] For new units, EPA fully anticipates new kilns and boilers would choose fuels in such a way that would not subject to CISWI regulation. The only new sources are facilities that dispose of waste and only have incineration options available.

annual cost of $280 million plus recordkeeping and reporting costs. The requirements result in industry recordkeeping and reporting burden associated with reviewing the amendments for all CISWI and inspections of scrubbers, fabric filters, and other air pollution control devices that may be used to meet the emission limits for all CISWI. Ongoing parametric monitoring requirements for ESPs, SNCR, dry sorbent injection and activated carbon injection are also required of all CISWI units. Stack testing and development of new parameter limits would be necessary for CISWI that need to make performance improvements to meet the emission limits and for CISWI that, prior to this action, have not been required to demonstrate compliance with certain pollutants. Visual emissions tests of ash handling would be required for all subcategories except kilns on an annual basis. Energy recovery units would be required to continuously monitor opacity, and units larger than 250 MMBtu/hr would be required to monitor PM emissions using a PM CEMS. Kilns would be required to continuously monitor Hg emissions using an Hg CEMS. Any new CISWI would also be required to continuously monitor CO emissions. Annualized capital/startup costs and operation and maintenance (O&M) costs are associated with the EG monitoring requirements, EPA Method 22 of Appendix A-7 testing, initial stack testing, storage of data and reports, and photocopying and postage.

SECTION 3
ECONOMIC IMPACT ANALYSIS

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

The Office of Air Quality Planning and Standards (OAQPS) adopted a standard market analysis as described in the Office's resource manual (U.S. 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; for this analysis, we use the model to approximate baseline conditions for 2016. In this analysis, 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 (U.S. EPA, 1999, 5-6). The intermediate 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).

3.1 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 used in the analysis.

3.1.1 Overview

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 (U.S. 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 (U.S. EPA, 1999). Recent studies suggest short-run analyses can complement full dynamic general equilibrium analysis. For example, Morgenstern and colleagues examine carbon price policies with short- and long-term time horizons (Morgenstern and colleagues, 2004; Ho, Morgenstern, and Shih, 2008). Aldy and Pizer (2009) assess near-term competitiveness effects of a domestic cap-and-trade program to address stakeholder concerns about shifts in economic activity and jobs to other countries. A single-period multimarket partial equilibrium model contains the following features:

- Industry sectors and benchmark data set
  - All industries aggregated to 100 industry sectors
  - a single benchmark year (2010)[1]
  - estimates of industry employment
- Economic behavior
  - industries respond to regulatory costs by changing production rates
  - market prices rise to reflect higher energy and other non-energy 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 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) behavior considered
- Model time horizon ("short run")
  - 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
  - Appendix A provides additional details on the behavioral assumptions, data, parameters, and model equations.

[1] For this analysis, we use the model to approximate baseline conditions for 2016.

3.1.2 Economic Impact Analysis Results

3.1.2.1 Market-Level Results

Market-level impacts include price and quantity adjustments including the changes in international trade (Table 3-1). The Agency's economic model suggests the average national market-level variables (prices, production-levels, consumption, international trade) will not significantly change (e.g., are less than 0.1%). Similar results are present for the Beyond the MACT floor option and are presented in Table 3-2.

Table 3-1. Market-Level Price and Quantity Changes: 2016 (MACT Floor)

Industry Sector	Prices	Production	Imports	Consumption	Exports
Energy	0.00243%	−0.00086%	0.00508%	−0.00064%	−0.00040%
Nonmanufacturing	0.00239%	−0.00056%	0.00151%	−0.00041%	−0.00184%
Manufacturing					
Food, beverages, and textiles	0.00068%	−0.00093%	0.00114%	−0.00051%	−0.00042%
Lumber, paper, and printing	0.03014%	−0.01259%	0.03070%	−0.00727%	−0.02103%
Chemicals	0.00010%	−0.00136%	0.00014%	−0.00105%	−0.00010%
Plastics and Rubber	0.00046%	−0.00110%	0.00049%	−0.00088%	−0.00045%
Nonmetallic Minerals	0.04871%	−0.01153%	0.01782%	−0.00720%	−0.04026%
Primary Metals	0.00059%	−0.00099%	0.00057%	−0.00058%	−0.00056%
Fabricated Metals	−0.00015%	−0.00041%	−0.00015%	−0.00035%	0.00008%
Machinery and Equipment	−0.00007%	−0.00028%	−0.00006%	−0.00019%	0.00012%
Electronic Equipment	−0.00004%	−0.00043%	−0.00001%	−0.00020%	0.00010%
Transportation Equipment	0.00002%	−0.00019%	0.00004%	−0.00011%	−0.00004%
Other	0.00058%	−0.00130%	0.00098%	−0.00044%	−0.00054%
Wholesale and Retail Trade	−0.00027%	−0.00018%	−0.00018%	−0.00018%	0.00020%
Transportation Services	−0.00052%	−0.00045%	−0.00026%	−0.00031%	0.00043%
Other Services	0.00001%	−0.00018%	−0.00006%	−0.00018%	−0.00002%

Table 3-2. Market-Level Price and Quantity Changes: 2016 (Beyond the MACT Floor)

Industry Sector	Prices	Production	Imports	Consumption	Exports
Energy	0.00254%	−0.00090%	0.00531%	−0.00068%	−0.00042%
Nonmanufacturing	0.00243%	−0.00058%	0.00153%	−0.00043%	−0.00187%
Manufacturing					
Food, beverages, and textiles	0.00071%	−0.00096%	0.00118%	−0.00053%	−0.00044%
Lumber, paper, and printing	0.03158%	−0.01319%	0.03217%	−0.00761%	−0.02204%
Chemicals	0.00022%	−0.00156%	0.00027%	−0.00118%	−0.00021%
Plastics and Rubber	0.00064%	−0.00124%	0.00069%	−0.00097%	−0.00063%
Nonmetallic Minerals	0.04872%	−0.01157%	0.01783%	−0.00723%	−0.04027%
Primary Metals	0.00093%	−0.00128%	0.00089%	−0.00071%	−0.00088%
Fabricated Metals	−0.00010%	−0.00045%	−0.00008%	−0.00038%	0.00005%
Machinery and Equipment	−0.00006%	−0.00031%	−0.00004%	−0.00021%	0.00009%
Electronic Equipment	−0.00004%	−0.00046%	−0.00001%	−0.00022%	0.00010%
Transportation Equipment	0.00003%	−0.00020%	0.00006%	−0.00012%	−0.00006%
Other	0.00063%	−0.00140%	0.00107%	−0.00047%	−0.00059%
Wholesale and Retail Trade	−0.00029%	−0.00019%	−0.00020%	−0.00019%	0.00022%
Transportation Services	−0.00055%	−0.00047%	−0.00028%	−0.00033%	0.00046%
Other Services	0.00001%	−0.00018%	−0.00006%	−0.00018%	−0.00002%

3.1.2.2 Social Cost Estimates

In the short run, 2016, industries are able to pass on $76 million (2008$) the costs to U.S. households in the form of higher prices (Table 3-3). In 2016, existing U.S. industries' surplus falls by $207 million, and the net loss for U.S. stakeholders is $283 million. As U.S. prices rise, other countries are affected through international trade relationships. Households that buy goods from the United States experience losses, while industries that sell goods to the United States benefit; the model estimates a net gain of $3 million. After accounting for international trade effects, the Agency's economic model projects the net total surplus loss associated with the rule is $280 million. Similar results are present for the Beyond the MACT floor option (Table 3-4).

As shown in Figure 3-1, the surplus losses are concentrated in lumber, paper, and printing (29.0%) and other services (21.8%). The Agency also considered other elements of the engineering cost analysis that could not be modeled within the multimarket model (e.g., total annualized cost for new sources). The net effect of the adjustments is approximately $1 million.

Table 3-3. Distribution of Social Costs (million, 2008$): 2016

Method	MACT Floor
Partial Equilibrium Model (Multiple Markets)	
Change in U.S. consumer surplus	−$76
Change in U.S. producer surplus	−$207
Change in U.S. surplus	−$283
Direct Compliance Costs Method	
Total annualized costs, new sources (not modeled)	$1
Change in U.S. Surplus	−$284
Net change in rest of world surplus	$3
Net change in total surplus	−$281

Table 3-4. Distribution of Social Costs (million, 2008$): 2016

Method	Beyond the MACT Floor
Partial Equilibrium Model (Multiple Markets)	
Change in U.S. consumer surplus	−$78
Change in U.S. producer surplus	−$220
Change in U.S. surplus	−$298
Direct Compliance Costs Method	
Total annualized costs, new sources (not modeled)	$1
Total annualized cost savings, unknown sources (not modeled)	Less than $1 million
Change in Total Surplus	−$299
Net change in rest of world surplus	$4
Net change in total surplus	−$295

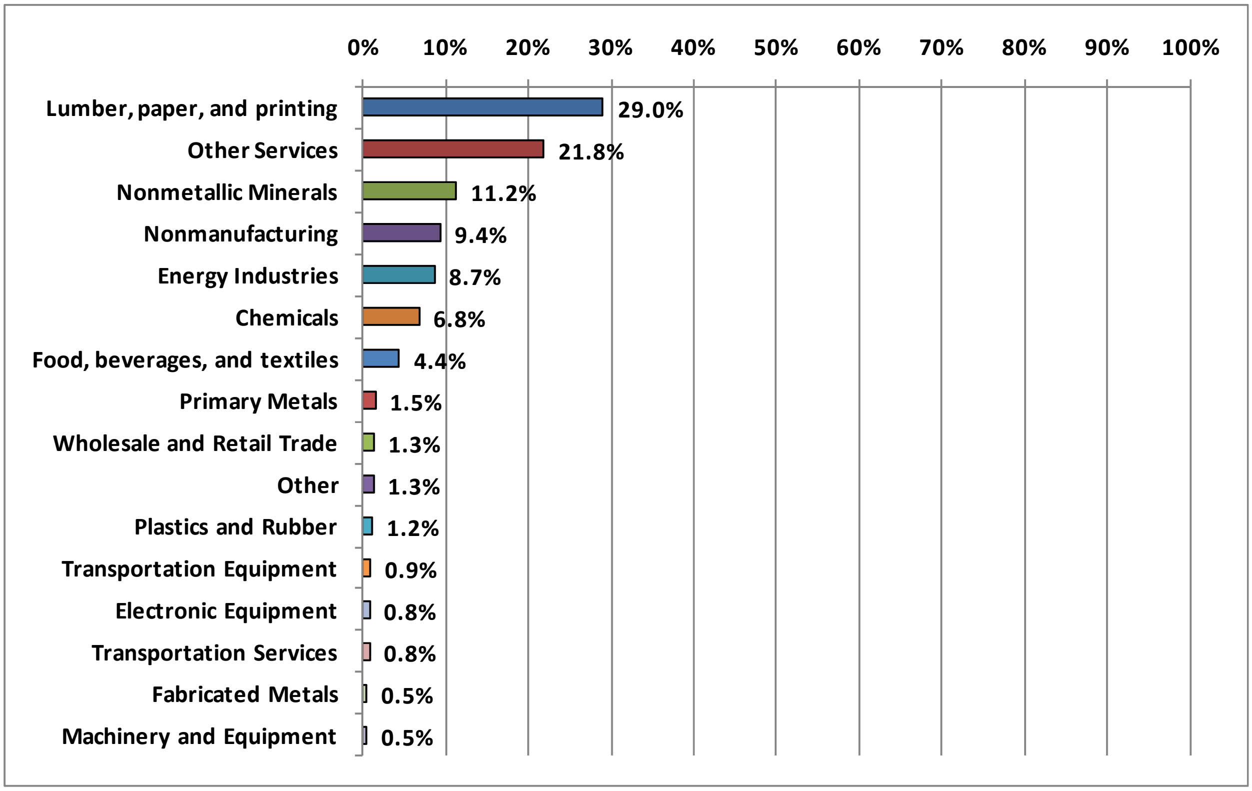


Figure 3-1. Distribution of Total Surplus Changes by Industry (Total Surplus Change = $224 million, 2008$) (MACT Floor)

3.1.2.3 Job Effects

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.

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.[2]

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.

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 [3];

[2] 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.

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

- 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.[4] “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.”[5] By applying these estimates to pollution abatement costs, we estimated the 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). [6, 7]

---

[4] 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.

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

[6] 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)

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

Table 3-5. 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	−600	400	500	300
	−1,300 to +100	+100 to +700	Less than 100 to +900	−500 to +1,000

[a] Expressed in 1987 dollars. See footnote 7 for inflation adjustment factor used in the analysis.

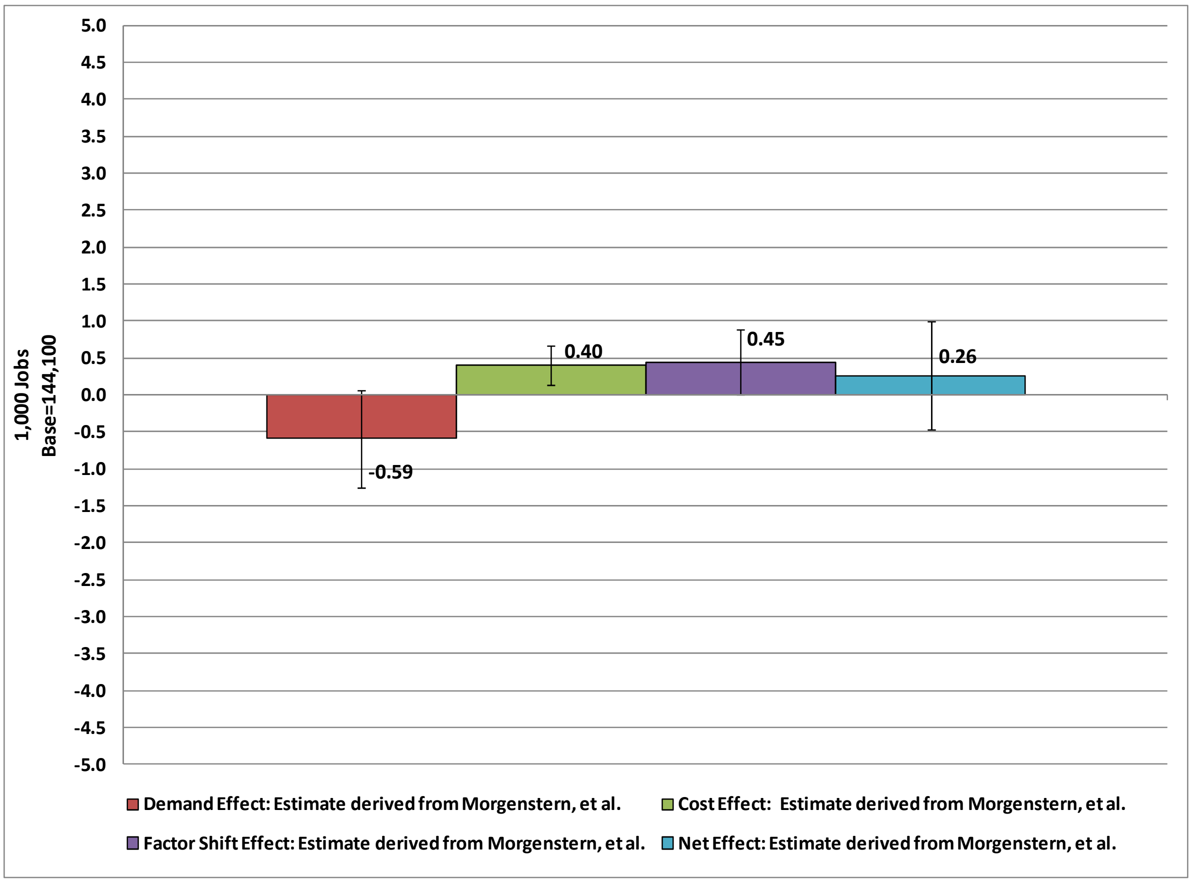


Figure 3-2. Employment Impacts Using Morgenstern, Pizer, Shih (2002) (1,000 FTEs)

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 4
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 the promulgated rule will not have a SISNOSE and presumes that rule is eligible for certification under the RFA as amended by SBREFA. We provide the factual basis for certification below.

4.1 Small Entity Screening Analysis

4.1.1 Small Businesses

The sectors covered by the rule were identified through lists of small entities provided by the engineering analysis. Table 4-1 provides a list of the sectors affected (3-digit NAICS) and the range of SBA size definitions.

Table 4-1. Affected Sectors and Size Standards

2007 NAICS	Description	Size Standard (Effective August 22, 2008)
221	Utilities	[a]
311	Food Manufacturing	500 to 1,000 employees
321	Wood Product Manufacturing	500 employees
322	Paper Manufacturing	500 to 750 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
337	Furniture and Related Product Manufacturing	500 employees
562	Waste Management and Remediation Services	Typically $7 to $14 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.

4.1.2 Small Entity Analysis

Using the information collection effort for facilities with combustion units in the major source Boiler rule, we identified affected facility names listed as small, traced the ultimate parent company name to verify the facility was owned by a small business, and collected the most recent parent company sales and employment figures. As Table 4-2 shows, the average cost-to-sales ratios for small companies are approximately 3.4% and 3.5% for the MACT Floor and Beyond the MACT Floor options. The median ratios are 2.2% for the MACT Floor option and 2.3% for the Beyond the MACT Floor option. Each option has 4 entities that have sales test that exceeds 3%.

Table 4-2. Sales Tests Using Small Companies Identified in the Combustion Survey

Sample Statistic	MACT Floor	Beyond the MACT Floor
Mean	3.4%	3.5%
Median	2.2%	2.3%
Maximum	17.3%	17.3%
Minimum	−2.4%	−2.5%
Ultimate parent company observations	10	10
Ultimate parent company observations with sales data	9	9
Ultimate parent companies with Sale Tests Exceeding 3%	4	4

We estimate that there are 88 entities subject to this regulation, of which 10 of them are considered to be small companies. The small entities directly regulated by the rule are facilities engaged in industrial or commercial operations, such as paper and paperboard manufacturing and utility providers. The average cost-to-sales ratios for small companies are below 3.5 percent. The median ratio is 2.2 percent. Only four entities, which are in 3 different industries, have a sales test that exceeds 3 percent. For the purposes of this rulemaking, four is not considered a "substantial number" of small entities.

Although this rule will not have a significant economic impact on a substantial number of small entities, EPA nonetheless has tried to reduce the impact of this rule on small entities.

SECTION 5
HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

The RIA does not include the final engineering costs and emission reductions into this RIA (see Chapter 2 for more detail on the engineering costs that were not accounted for). We estimate that incorporating these final estimates would decrease the engineering costs by approximately 22% and increase the monetized benefits by approximately 4% from those shown in this RIA.

5.1 Synopsis

In this section, we provide an estimate of the monetized benefits associated with reducing particulate matter (PM) for the CISWI NSPS and EG. For this rule, the PM reductions are the result of emission limits on PM, emission limits on $PM_{2.5}$ precursors such as NO_x and SO_2, as well as ancillary reductions from emission limits on other pollutants. The latter are often referred to as "co-benefits." The total $PM_{2.5}$ reductions are the consequence of the technologies installed or waste diversion to meet these multiple limits. These estimates reflect the monetized human health benefits of reducing cases of morbidity and premature mortality among populations exposed to the $PM_{2.5}$ precursors reduced by this rulemaking. 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 monetized benefits of the CISWI NSPS and EG (MACT floor option) to be $340 million to $830 million in the implementation year (2016). Using a 7% discount rate, we estimate the total monetized benefits of the CISWI NSPS and EG (MACT floor option) to be $310 million to $750 million in the implementation year. All estimates are in 2008$ and include any energy disbenefits from additional energy usage. Due to last minute changes, we were unable to incorporate the final emission reductions into this RIA. We estimate that incorporating these final estimates would increase the monetized benefits by approximately 4% from those shown in this RIA.

These estimates reflect EPA's most current interpretation of the scientific literature (U.S. EPA, 2009b). Higher or lower estimates of benefits are possible using other assumptions; examples of this are provided in Figure 5-2. Methodological and time limitations under the court-ordered schedule prevented EPA from monetizing the benefits from several important benefit categories, including benefits from reducing hazardous air pollutants, ecosystem effects, and visibility impairment. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 25,000 tons of carbon monoxide, 470 tons of HCl, 4.1 tons of lead, 0.95 tons of cadmium, 260 pounds of mercury, and 92 grams of total dioxins/furans each year. We assess the benefits of these emission reductions qualitatively in this analysis.

5.2 Calculation of $PM_{2.5}$ Human Health Benefits

This rulemaking would reduce emissions of $PM_{2.5}$, SO_2, and NO_2. Because SO_x and NO_2 are also precursors to $PM_{2.5}$, reducing these emissions would also reduce $PM_{2.5}$ formation, human exposure, and the incidence of $PM_{2.5}$-related health effects. For this rule, the PM reductions are the result of emission limits on PM, emission limits on $PM_{2.5}$ precursors such as NO_x and SO_2, as well as ancillary reductions from emission limits on other pollutants. The total $PM_{2.5}$ reductions are the consequence of the technologies installed or waste diversion to meet these multiple limits. Due to analytical limitations, it was not possible to provide a comprehensive estimate of $PM_{2.5}$-related benefits. Instead, we used the "benefit-per-ton" approach to estimate these benefits based on the methodology described in Fann, Fulcher, and Hubbell (2009). The key assumptions are described in detail below. These $PM_{2.5}$ benefit-per-ton estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ (or precursor) from a specified source. EPA has used the benefit per-ton technique in several previous RIAs, including the recent SO_2 NAAQS RIA (U.S. EPA, 2010b). Table 5-1 shows the quantified and unquantified benefits captured in those benefit-per-ton estimates.

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

Pollutant / Effect	Quantified and Monetized in Primary Estimates	Unquantified Effects Changes in:
$PM_{2.5}$	Adult premature mortality Bronchitis: chronic and acute Hospital admissions: respiratory and cardiovascular Emergency room visits for asthma Nonfatal heart attacks (myocardial infarction) Lower and upper respiratory illness Minor restricted-activity days Work loss days Asthma exacerbations (asthmatic population) Infant mortality	Subchronic bronchitis cases 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 Visibility Household soiling

Consistent with 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 sensitivity analysis.

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

- One estimate is based on the C-R function developed from the extended analysis of the Harvard Six Cities cohort, as reported by Laden et al. (2006). This study, published after the completion of the Staff Paper for the 2006 $PM_{2.5}$ NAAQS, has been used as an alternative estimate in the $PM_{2.5}$ NAAQS RIA and $PM_{2.5}$ benefits estimates in RIAs completed since the $PM_{2.5}$ NAAQS. When calculating the estimate, EPA applied the effect coefficient as reported in the study without an adjustment for assumed concentration threshold of 10 $\mu g/m^3$ as was done in recent (2006–2009) RIAs.

- Twelve estimates are based on the C-R functions from EPA's expert elicitation study (IEc, 2006; Roman et al., 2008) on the $PM_{2.5}$ -mortality relationship and interpreted for benefits analysis in EPA's final RIA for the $PM_{2.5}$ NAAQS. For that study, twelve experts (labeled A through L) provided independent estimates of the $PM_{2.5}$ -mortality concentration-response function. EPA practice has been to develop independent estimates of $PM_{2.5}$ -mortality estimates corresponding to the concentration-response function provided by each of the twelve experts, to better characterize the degree of variability in the expert responses.

Readers interested in reviewing the general methodology for creating the benefit-per-ton estimates used in this analysis should consult Fann, Fulcher, and Hubbell (2009). As described in Fann, Fulcher, and Hubbell (2009), benefit-per-ton estimates are developed for selected pollutant/source category combinations. The per-ton values calculated therefore apply only to tons reduced from those specific pollutant/source combinations (e.g., SO_2 emitted from electric generating units; NO_2 emitted from mobile sources). In this analysis, we apply the national average benefit-per-ton estimate for a 2016 analysis year and multiply it by the corresponding emission reductions of directly emitted $PM_{2.5,}$ $SO_{2,}$ and NO_x to quantify the benefits of this rule. The benefit-per-ton estimates found in Fann, Fulcher, and Hubbell (2009) reflect a specific set of key assumptions and input data. As we update these underlying assumptions to reflect the scientific literature, we re-estimate the benefit-per-ton estimates and post the updated estimates at http://www.epa.gov/air/benmap/bpt.html. In addition, we adjust these estimates to match the currency year for the costs in this analysis.

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, 2009b). Directly emitted PM, SO_2, and NO_x 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 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. The benefit-per-ton coefficients in this analysis were derived using modified versions of the health impact functions used in the PM NAAQS Regulatory Impact Analysis. Specifically, this analysis uses the benefit-per-ton method first applied in the Portland Cement NESHAP RIA (U.S. EPA, 2009a), which incorporated three updates: a new population dataset, an expanded geographic scope of the benefit-per-ton calculation, and the functions directly from the epidemiology studies without an adjustment for an assumed threshold.[1] Removing the threshold assumption is a key difference between the method used in this analysis of PM benefits and the methods used in RIAs prior to the Portland Cement proposal, and we now calculate incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels.

EPA strives to use the best available science to support our benefits analyses, and we recognize that interpretation of the science regarding air pollution and health is dynamic and evolving. Based on our review of the current body of scientific literature, EPA now estimates PM-related mortality without applying an assumed concentration threshold. EPA's Integrated Science Assessment for Particulate Matter (U.S. EPA, 2009b), which was recently reviewed by EPA's Clean Air Scientific Advisory Committee (U.S. EPA-SAB, 2009a; U.S. EPA-SAB, 2009b), concluded that the scientific literature consistently finds that a no-threshold log-linear model most adequately portrays the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. Since then, the Health Effects Subcommittee (U.S. EPA-SAB, 2010) of EPA's Council concluded, "The HES fully supports EPA's decision to use a no-threshold model to estimate mortality reductions. This decision is supported by the data, which are quite consistent in showing effects down to the lowest measured levels. Analyses of cohorts using data from more

[1]These updates were already included in Fann et al. (2009). An example of the effect of these updates is available in the Portland Cement proposal RIA (U.S. EPA, 2009a). The benefit-per-ton estimates have also been updated since the Portland Cement proposal RIA (U.S. EPA, 2009a) to incorporate a revised VSL, as discussed on the next page.

recent years, during which time PM concentrations have fallen, continue to report strong associations with mortality. Therefore, there is no evidence to support a truncation of the CRF." In conjunction with the underlying scientific literature, this document provided a basis for reconsidering the application of thresholds in $PM_{2.5}$ concentration-response functions used in EPA's RIAs. For a summary of these scientific review statements and the panel members commenting on thresholds since 2002, please consult the Technical Support Document (TSD) Summary of Expert Opinions on the Existence of a Threshold (U.S. EPA, 2010c).

Consistent with this recent scientific advice, we are replacing the previous threshold sensitivity analysis with a new "Lowest Measured Level" (LML) assessment. This information allows readers to determine the portion of population exposed to annual mean $PM_{2.5}$ levels at or above the LML of each study; in general, our confidence in the estimated PM mortality decreases as we consider air quality levels further below the LML in major cohort studies that estimate PM-related mortality. While an LML assessment provides some insight into the level of uncertainty in the estimated PM mortality benefits, EPA does not view the LML as a threshold and continues to quantify PM-related mortality impacts using a full range of modeled air quality concentrations. It is important to emphasize that we have high confidence in $PM_{2.5}$-related effects down to the lowest LML of the major cohort studies. Just because we have greater confidence in the benefits above the LML, this does not mean that we have no confidence that benefits occur below the LML.

For this analysis, policy-specific air quality data is not available due to time or resource limitations. For these rules, we are unable to estimate the percentage of premature mortality associated with this specific rule's emission reductions at each $PM_{2.5}$ level. However, we believe that it is still important to characterize the distribution of exposure to baseline air quality levels. As a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each $PM_{2.5}$ level using the most recent modeling available from the recently proposed Transport Rule (U.S. EPA, 2010e). It is important to note that baseline exposure is only one parameter in the health impact function, along with baseline incidence rates population, and change in air quality. In other words, the percentage of the population exposed to air pollution below the LML is not the same as the percentage of the population experiencing health impacts as a result of a specific emission reduction policy. The most important aspect, which we are unable to quantify for rules without air quality modeling, is the shift in exposure associated with this specific rule. Therefore, caution is warranted when interpreting the LML assessment. For more information on the data and conclusions in the LML assessment for rules without policy-specific air quality modeling, please consult the LML TSD (U.S. EPA, 2010d). The results of this analysis are provided in Section 5.5.

As is the nature of Regulatory Impact Analyses (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 (2004–2008), the Office of Air and Radiation (OAR) valued mortality risk reductions using a value of statistical life (VSL) estimate derived from a limited analysis of some of the available studies. OAR arrived at a VSL using a range of $1 million to $10 million (2000$) consistent with two meta-analyses of the wage-risk literature. The $1 million value represented the lower end of the interquartile range from the Mrozek and Taylor (2002) meta-analysis of 33 studies. The $10 million value represented the upper end of the interquartile range from the Viscusi and Aldy (2003) meta-analysis of 43 studies. The mean estimate of $5.5 million (2000$)[2] 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)[3] while the Agency continues its efforts to update its guidance on this issue. This approach calculates a mean value across VSL estimates

---

[2] After adjusting the VSL to account for a different currency year (2008$) and to account for income growth to 2016, the $5.5 million VSL is $7.9 million.

[3] 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.

derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).[4] 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.

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 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, 2010f).

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

[4]In this analysis, we adjust the VSL to account for a different currency year (2008$) and to account for income growth to 2016. After applying these adjustments to the $6.3 million value, the VSL is $9.1 million.

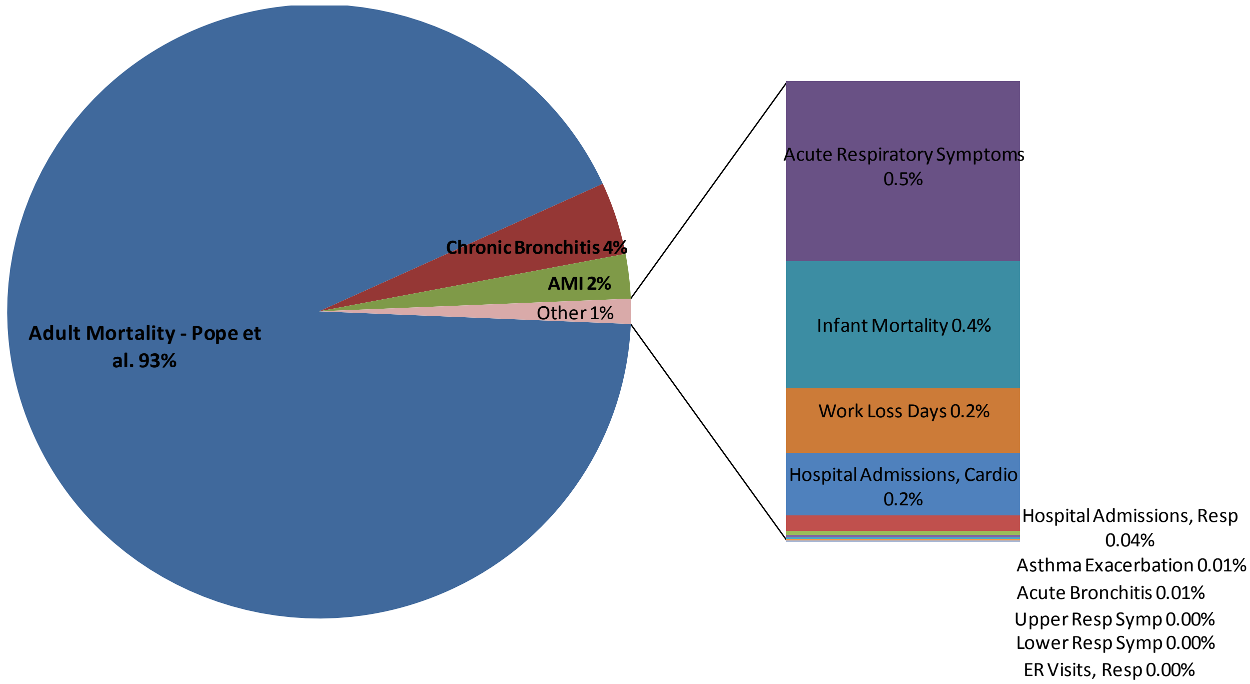


Figure 5-1. Breakdown of Monetized $PM_{2.5}$ Health Benefits Estimates using Mortality Function from Pope et al. (2002)[a]

[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.

Table 5-2 provides a general summary of the primary approach results by pollutant, including the emission reductions and monetized benefits-per-ton at discount rates of 3% and 7%.[5] Table 5-3 provides a summary of the reductions in health incidences as a result of the pollution reductions. In Table 5-4, we provide the benefits using our anchor points of Pope et al. and Laden et al. as well as the results from the expert elicitation on PM mortality. Figures 6-2 through 6-4 provide a visual representation of the range of benefits estimates and the pollutant breakdown of the monetized benefits.

[5] 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., 2016), 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.

Table 5-2. Summary of Monetized Benefits Estimates for the CISWI NSPS and EG in 2016 (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 2008$ at 3%)	Total Monetized Benefits (millions 2008$ at 7%)
MACT Floor	Direct $PM_{2.5}$	710	$230,000	$560,000	$210,000	$500,000	$160 to $400	$150 to $360
	$PM_{2.5}$ Precursors							
	SO_2	5,170	$29,000	$72,000	$27,000	$65,000	$150 to $370	$140 to $340
	NO_2	5,544	$4,900	$12,000	$4,400	$11,000	$27 to $66	$24 to $59
						Total	**$340 to $830**	**$310 to $750**
Beyond-the-Floor	Direct $PM_{2.5}$	713	$230,000	$560,000	$210,000	$500,000	$160 to $400	$150 to $360
	$PM_{2.5}$ Precursors							
	SO_2	7,496	$29,000	$72,000	$27,000	$65,000	$220 to $540	$200 to $490
	NO_2	11,024	$4,900	$12,000	$4,400	$11,000	$53 to $130	$49 to $120
						Total	**$440 to $1,100**	**$400 to $970**

[a] All estimates are for the implementation year (2016), 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 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 form $PM_{2.5}$. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology. These estimates do not include the energy disbenefits valued at $3.8 million, but the rounded totals do not change.

Table 5-3. Summary of Estimated Reductions in Health Incidences from $PM_{2.5}$ Benefits for the CISWI NSPS and EG in 2016[a]

	MACT Floor	Beyond-the-Floor
Avoided Premature Mortality		
Pope et al.	38	49
Laden et al.	98	130
Avoided Morbidity		
Chronic Bronchitis	26	33
Acute Myocardial Infarction	61	78
Hospital Admissions, Respiratory	9	12
Hospital Admissions, Cardiovascular	19	25
Emergency Room Visits, Respiratory	36	46
Acute Bronchitis	62	80
Work Loss Days	5,100	6,500
Asthma Exacerbation	680	870
Minor Restricted Activity Days	30,000	39,000
Lower Respiratory Symptoms	740	950
Upper Respiratory Symptoms	560	720

[a] All estimates are for the analysis year (2016) 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. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology.

Table 5-4. All $PM_{2.5}$ Benefits Estimates for the CISWI NSPS and EG at Discount Rates of 3% and 7% in 2016 (in millions of 2008$)[a]

	MACT Floor		Beyond-the-Floor	
	3%	**7%**	**3%**	**7%**
Benefit-per-ton Coefficients Derived from Epidemiology Literature				
Pope et al.	$340	$310	$440	$400
Laden et al.	$830	$750	$1,100	$970
Benefit-per-ton Coefficients Derived from Expert Elicitation				
Expert A	$880	$800	$1,130	$1,020
Expert B	$680	$610	$870	$790
Expert C	$670	$610	$860	$780
Expert D	$480	$430	$610	$550
Expert E	$1,090	$990	$1,400	$1,260
Expert F	$610	$560	$790	$710
Expert G	$400	$370	$520	$470
Expert H	$510	$460	$650	$590
Expert I	$670	$600	$850	$770
Expert J	$540	$490	$700	$630
Expert K	$130	$120	$170	$160
Expert L	$490	$450	$630	$570

[a] All estimates are rounded to two significant figures. Estimates do not include confidence intervals because they were derived through the benefit-per-ton technique described above. The benefits estimates from the expert elicitation are provided as a reasonable characterization of the uncertainty in the mortality estimates associated with the concentration-response function. Confidence intervals are unavailable for this analysis because of the benefit-per-ton methodology. These estimates do not include the energy disbenefits valued at $3.8 million.

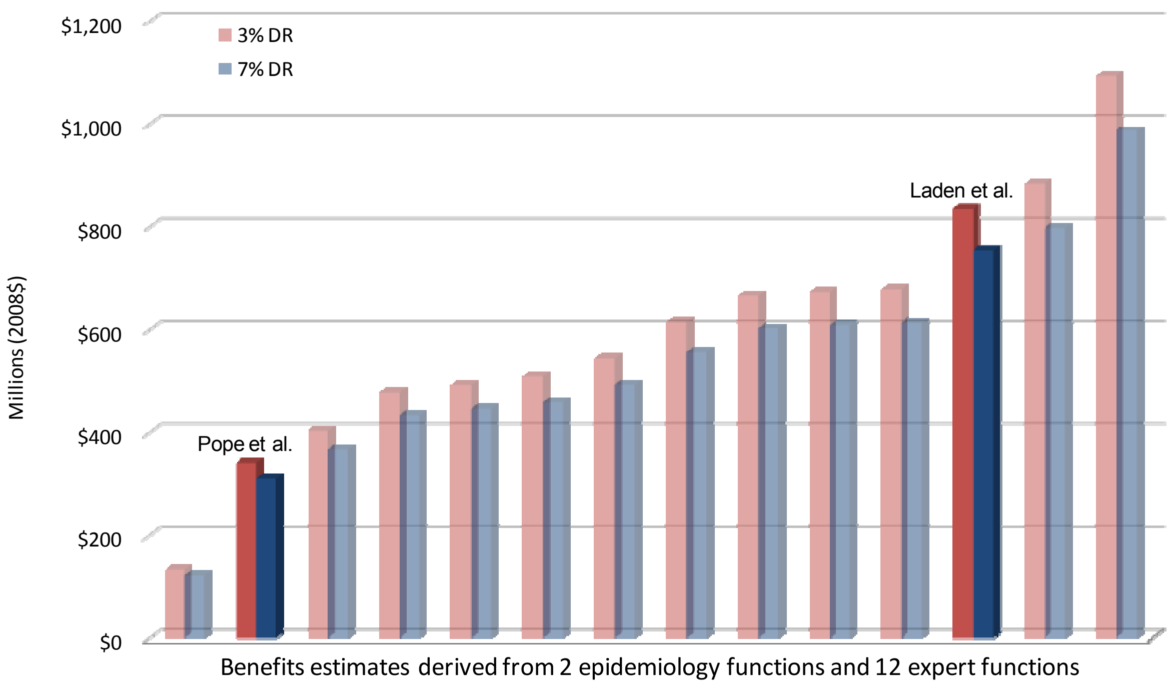


Figure 5-2. Total Monetized $PM_{2.5}$ Benefits Estimates for the CISWI NSPS and EG in 2016

[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 energy disbenefits valued at $3.8 million.

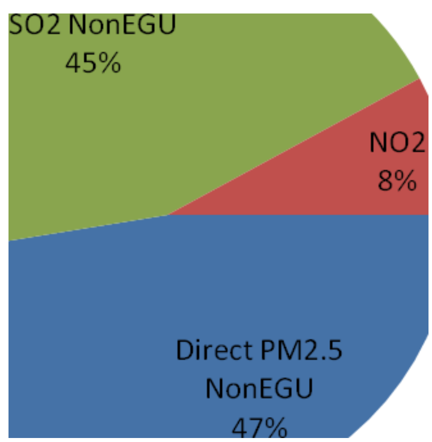


Figure 5-3. Breakdown of Monetized Benefits Estimates for the CISWI NSPS and EG by $PM_{2.5}$ Precursor Pollutant and Source (MACT floor option)

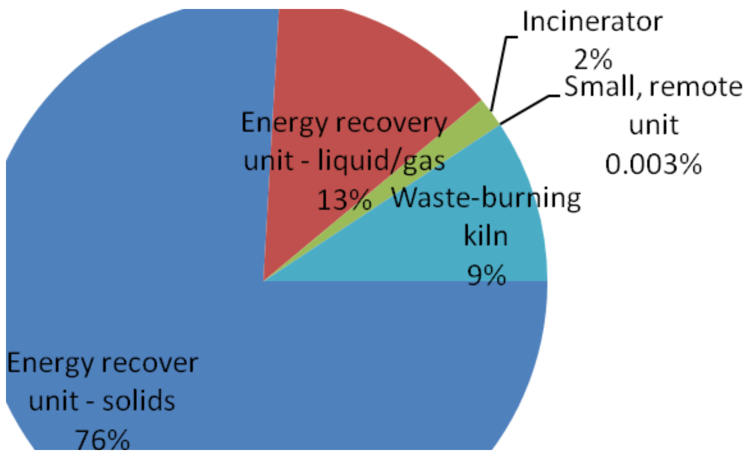


Figure 5-4. Breakdown of Monetized Benefits Estimates for the CISWI NSPS and EG by Subcategory (MACT floor option)

5.3 Energy Disbenefits

In this section, we provide an estimate of the energy disbenefits associated with the increased emissions from additional energy usage.[6] Electricity usage associated with the operation of control devices is anticipated to increase emissions of pollutants from utility boilers that supply electricity to the incinerators. We estimate that the increased electricity consumption associated with the floor option would be 236 million kWh. Using national emission factors from eGRID for electrical generating units (EGUs), we estimate the increased emissions to be 155,000 tpy of CO_2 for the floor option. Since NO_x and SO_2 are covered by capped emissions trading programs, we are only estimating the CO_2 emission increases from the increased electricity demand. The methodology used to calculate these emission increases is described "Secondary Impacts of Control Options for the CISWI Standards," which is available in the docket.

5.3.1 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 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

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

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.[7]

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

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that the interagency group estimated the growth rate of the SCC directly using the three integrated assessment models rather than assuming a constant annual growth rate. This helps to ensure that the estimates are internally consistent with other modeling assumptions. The SCC estimates for the analysis years of 2016, in 2008\$ are provided in Table 5-5.

---

[7] 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

[8] 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).

Table 5-5. Social Cost of Carbon (SCC) Estimates (per tonne of CO2) for 2016[a]

Discount Rate and Statistic		SCC Estimate (2008$)
5%	Average	$5.9
3%	Average	$24.7
2.5%	Average	$39.9
3%	95%ile	$75.6

[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%.[9] These estimates are provided in Table 5-6.

Table 5-6. Monetized SCC-derived Disbenefits of CO_2 Emission Increases in 2016 (millions of 2008$)[a]

Discount Rate and Statistic		MACT Floor	Beyond-the-Floor
CO_2 (tpy)		154,881	157,071
5%	Average	$0.9	$0.9
3%	Average	$3.8	$3.9
2.5%	Average	$6.2	$6.3
3%	95%ile	$12	$12

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

5.4 Unquantified Benefits

The monetized benefits estimated in this RIA only reflect the portion of benefits attributable to the health effect reductions associated with ambient fine particles. Methodological and time limitations under the court-ordered schedule prevented EPA from quantifying or monetizing the benefits from several important benefit categories, including benefits from reducing toxic emissions, ecosystem effects, and visibility impairment. The health benefits from reducing hazardous air pollutants (HAPs) and carbon monoxide 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, increased mercury methylation, as well as visibility impairment. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 25,000 tons of carbon monoxide, 470 tons of HCl, 4.1 tons of lead, 0.95 tons of cadmium, 260 pounds of mercury, and 92 grams of total dioxins/furans each year. 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.

[9] 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.

5.4.1 Carbon Monoxide Benefits

Carbon monoxide (CO) exposure is associated with a variety of health effects. Without knowing the location of the emission reductions and the resulting ambient concentrations using fine-scale air quality modeling, we were unable to estimate the exposure to CO for nearby populations. Due to 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, 2010a) concluded that short-term exposure to CO is "likely to have a causal relationship" with cardiovascular morbidity, particularly in individuals with coronary heart disease. Epidemiologic studies associate short-term CO exposure with increased risk of emergency department visits and hospital admissions. Coronary heart disease includes those who have angina pectoris (cardiac chest pain), as well as those who have experienced a heart attack. Other subpopulations potentially at risk include individuals with diseases such as chronic obstructive pulmonary disease (COPD), anemia, or diabetes, and individuals in very early or late life stages, such as older adults or the developing young. The evidence is suggestive of a causal relationship between short-term exposure to CO and respiratory morbidity and mortality. The evidence is also suggestive of a causal relationship for birth outcomes and developmental effects following long-term exposure to CO, and for central nervous system effects linked to short- and long-term exposure to CO.

5.4.2 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 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 U.S. EPA has 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, 2009c). 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, 2009c). 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. 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) (U.S. EPA, 2008c).

Reducing SO_2 emissions and the secondary formation of $PM_{2.5}$ would improve the level of visibility throughout the United States. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil (Sisler, 1996). These suspended particles and gases degrade visibility by scattering and absorbing light. Higher visibility impairment levels in the East are due to generally higher concentrations of fine particles, particularly sulfates, and higher average relative humidity levels. 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, 2009b). 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.

5.4.3 HAP Benefits

Americans are exposed to ambient concentrations of air toxics at levels which have the potential to cause adverse health effects.[10] The levels of air toxics to which people are exposed vary depending on where people live and work and the kinds of activities in which they engage. In order to identify and prioritize air toxics, emission source types and locations which are of greatest potential concern, U.S. EPA conducts the National-Scale Air Toxics Assessment (NATA). The most recent NATA was conducted for calendar year 2002, and was released in June 2009.[11] 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

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

Noncancer health effects can result from chronic,[12] subchronic,[13] or acute[14] 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.[15] Figures 6-5 and 6-6 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.[16] 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 account for the toxicity and exposure, as well as the mass of the targeted emissions when designing reduction strategies to maximize health benefits.

[12] 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).

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

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

[15] 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/

[16] 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.

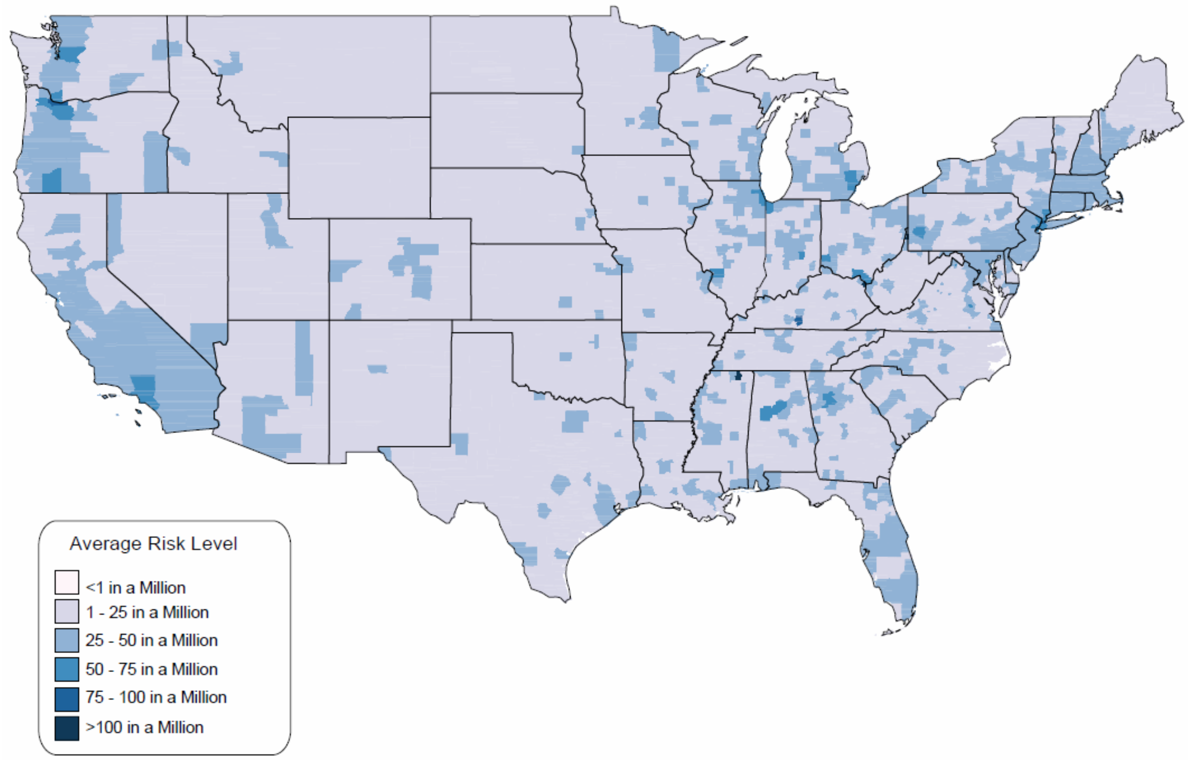


Figure 5-5. Estimated County Level Carcinogenic Risk (from 2002 NATA)

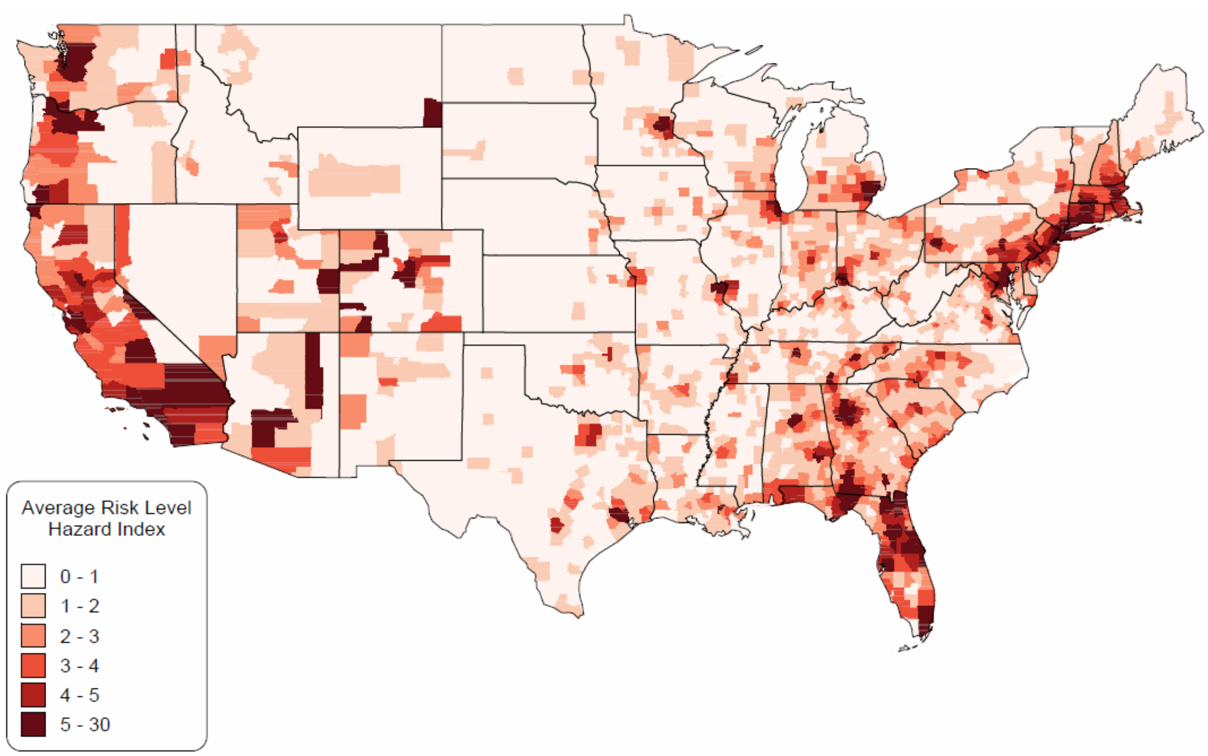


Figure 5-6. Estimated County Level Noncancer (Respiratory) Risk (from 2002 NATA)

Due to methodology and time limitations under the court-ordered schedule, we did not 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.[17] 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 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

[17] 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.

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.[18] 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 several different HAPs are emitted from CISWI. This rule is anticipated to reduce, 470 tons of HCl, 4.1 tons of lead, 0.95 tons of cadmium, 260 pounds of mercury, and 92 grams of total dioxins/furans each year in the primary approach.

5.4.3.1 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, 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 SO_2 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, this rule 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, inorganic ionic mercury, and particulate bound mercury. Gaseous elemental mercury can be transported very long distances, even globally, to regions far from the emissions source (becoming part of the global “pool”) before deposition occurs. Inorganic ionic and particulate bound mercury have a shorter atmospheric

[18] 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.

lifetime and can deposit to land or water bodies closer to the emissions source. Furthermore, elemental mercury in the atmosphere can undergo transformation into ionic mercury, providing a significant pathway for deposition of emitted elemental mercury.

This source category emitted about 0.5 tons of mercury in the air in 2008 in the U.S. Based on the EPA's National Emission Inventory, about 103 tons of mercury were emitted from all anthropogenic sources in the U.S. in 2005. Moreover, the United Nations has estimated that about 2,100 tons of mercury were emitted worldwide by anthropogenic sources in 2005. We believe that total mercury emissions in the U.S. and globally in 2008 were about the same magnitude in 2005. Therefore, we estimate that in 2008, these sources emitted about 0.5% of the total anthropogenic mercury emissions in the U.S. and about 0.03% of the global emissions. Overall, this rule would reduce mercury emissions by about 260 pounds 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, we were unable to model mercury dispersion, deposition, methylation, bioaccumulation in fish tissue, and human consumption of mercury-contaminated fish that would be needed in order to estimate the human health benefits from reducing mercury emissions.

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

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

Several studies suggest that the methylmercury content of fish may reduce 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.[19] 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.[20] The NRC also noted a study of 917 seven year old children in the Faroe Islands, whose initial exposure to methylmercury was *in utero* although post natal exposures may have occurred as well. At seven years of age, these children exhibited an increase in blood pressure and a decrease in heart rate variability.[21] 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 animals."[22] NAS 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

---

[19] 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.

[20] 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.

[21] 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, pp 370-375.

[22] 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.

methylmercury exposure. These studies include epidemiological, toxicological, and toxicokinetic investigations. Over a dozen review papers have also been published. If there is a causal relationship between methylmercury exposure and adverse cardiovascular effects, then reducing exposure to methylmercury would result in public health benefits from reduced cardiovascular effects.

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

5.4.3.2 Cadmium[23]

Breathing air with very high levels of cadmium can severely damage the lungs and may cause death. In the United States, where proper industrial hygiene is generally practiced, inhaling very high levels of cadmium at work is expected to be rare and accidental. Breathing air with lower levels of cadmium over long periods of time (for years) results in a build-up of cadmium in the kidney, and if sufficiently high, may result in kidney disease. Lung cancer has been found in some studies of workers exposed to cadmium in the air and studies of rats that breathed in cadmium. The U.S. Department of Health and Human Services (DHHS) has determined that cadmium and cadmium compounds are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that cadmium is carcinogenic to humans. The EPA has determined that cadmium is a probable human carcinogen.

5.4.3.3 Lead[24]

The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anemia. At high levels of

---

[23] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Public Health Statement for Cadmium. CAS# 1306-19-0. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/PHS/PHS.asp?id=46&tid=15>.

[24] All health effects language for this section came from: Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Public Health Statement for Lead. CAS#: 7439-92-1. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/ToxProfiles/phs13.html>.

exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production.

We have no conclusive proof that lead causes cancer (is carcinogenic) in humans. Kidney tumors have developed in rats and mice that had been given large doses of some kind of lead compounds. The Department of Health and Human Services (DHHS) has determined that lead and lead compounds are reasonably anticipated to be human carcinogens based on limited evidence from studies in humans and sufficient evidence from animal studies, and the EPA has determined that lead is a probable human carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic lead is probably carcinogenic to humans. IARC determined that organic lead compounds are not classifiable as to their carcinogenicity in humans based on inadequate evidence from studies in humans and in animals.

Children are more sensitive to the health effects of lead than adults. No safe blood lead level in children has been determined. Lead affects children in different ways depending on how much lead a child swallows. A child who swallows large amounts of lead may develop anemia, kidney damage, colic (severe "stomach ache"), muscle weakness, and brain damage, which ultimately can kill the child. In some cases, the amount of lead in the child's body can be lowered by giving the child certain drugs that help eliminate lead from the body. If a child swallows smaller amounts of lead, such as dust containing lead from paint, much less severe but still important effects on blood, development, and behavior may occur. In this case, recovery is likely once the child is removed from the source of lead exposure, but there is no guarantee that the child will completely avoid all long-term consequences of lead exposure. At still lower levels of exposure, lead can affect a child's mental and physical growth. Fetuses exposed to lead in the womb, because their mothers had a lot of lead in their bodies, may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood also may slow mental development and cause lower intelligence later in childhood. There is evidence that these effects may persist beyond childhood.

5.4.3.4 Hydrogen Chloride (HCl) [25]

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

[25] 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>.

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.

5.4.3.5 Dioxins (Chlorinated dibenzodioxins (CDDs) [26]

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

[26] 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>.

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.

5.4.3.6 Furans (Chlorinated dibenzofurans (CDFs)) [27]

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.

5.4.3.7 Other Air Toxics

In addition to the compounds described above, other compounds from SI RICE would be affected by this rule. Information regarding the health effects of these compounds can be found in EPA's IRIS database.[28]

5.5 Characterization of Uncertainty in the Monetized $PM_{2.5}$ Benefits

In any complex analysis, there are likely to be many sources of uncertainty. Many inputs are used to derive the final estimate of economic benefits, including emission inventories, air

[27] 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>.

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

quality models (with their associated parameters and inputs), epidemiological estimates of concentration-response (C-R) functions, estimates of values, population estimates, income estimates, and estimates of the future state of the world (i.e., regulations, technology, and human behavior). For some parameters or inputs it may be possible to provide a statistical representation of the underlying uncertainty distribution. For other parameters or inputs, the necessary information is not available.

The annual benefit estimates presented in this analysis are also inherently variable due to the processes that govern pollutant emissions and ambient air quality in a given year. Factors such as hours of equipment use and weather are constantly variable, regardless of our ability to measure them accurately. As discussed in the $PM_{2.5}$ NAAQS RIA (Table 4-5) (U.S. EPA, 2006), there are a variety of uncertainties associated with these PM benefits. Therefore, the estimates of annual benefits should be viewed as representative of the magnitude of benefits expected, rather than the actual benefits that would occur every year.

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 do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors. Use of these $/ton values to estimate benefits associated with different emission control programs (e.g., for reducing emissions from large stationary sources like EGUs) may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on national or broad regional emission reduction programs and therefore represent average benefits-per-ton over the entire United States. The benefits-per-ton for emission reductions in specific locations may be very different than the estimates presented here.

$PM_{2.5}$ mortality benefits are the largest benefit category that we monetized in this analysis. To better characterize the uncertainty associated with mortality impacts that are estimated to occur in areas with low baseline levels of $PM_{2.5}$, we included the LML assessment. Without policy-specific air quality modeling, we are unable to quantify the shift in exposure associated with this specific rule. For this rule, as a surrogate measure of mortality impacts, we provide the percentage of the population exposed at each $PM_{2.5}$ level using the most recent modeling available from the recently proposed Transport Rule (U.S. EPA, 2010e). A very large proportion of the population is exposed at or above the lowest LML of the cohort studies (Figures 6-7 and 6-8), increasing our confidence in the PM mortality analysis. Figure 5-7 shows a bar chart of the percentage of the population exposed to various air quality levels in the pre- and post-policy policy. Figure 5-8 shows a cumulative distribution function of the same data. Both figures identify the LML for each of the major cohort studies. As the policy shifts the distribution of air quality levels, fewer people are exposed to $PM_{2.5}$ levels at or above the LML. Using the Pope et al. (2002) study, the 85% of the population is exposed to annual mean $PM_{2.5}$ levels at or above the LML of 7.5 µg/m^3. Using the Laden et al. (2006) study, 40% of the population is exposed above the LML of 10 µg/m^3. As we model mortality impacts among populations exposed to levels of $PM_{2.5}$ that are successively lower than the LML of the lowest cohort study, our confidence in the results diminishes. However, the analysis above confirms that the great majority of the impacts occur at or above the lowest cohort study's LML. It is important to emphasize that we have high confidence in $PM_{2.5}$-related effects down to the lowest LML of the major cohort studies. Just because we have greater confidence in the benefits above the LML, this does not mean that we have no confidence that benefits occur below the LML.

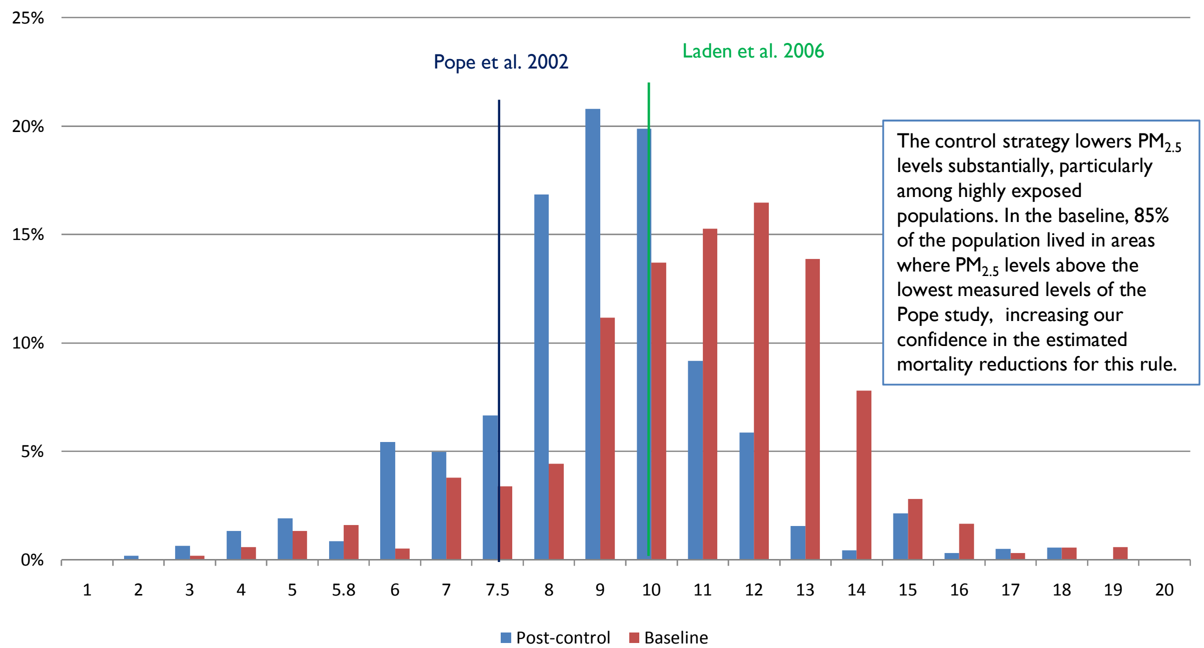


Figure 5-7. Percentage of Adult Population by Annual Mean $PM_{2.5}$ Exposure (pre- and post-policy policy)

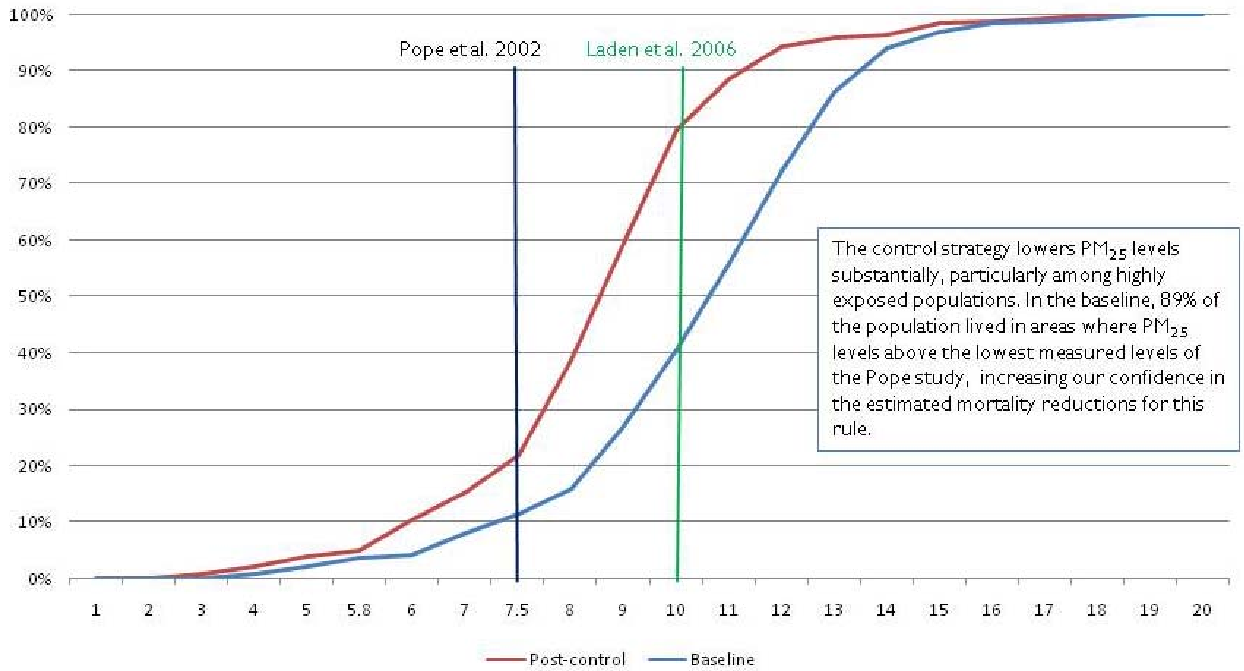


Figure 5-8. Cumulative Distribution of Adult Population at Annual Mean $PM_{2.5}$ levels (pre- and post-policy policy)

Above we present the estimates of the total monetized 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, for key assumptions underlying the estimates for premature mortality, which typically account for at least 90% of the total monetized benefits, we were able to quantify include the following:

1. $PM_{2.5}$ benefits were derived through benefit per-ton estimates, which do not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors that might lead to an over-estimate or under-estimate of the actual benefits of controlling directly emitted fine particulates.

2. We assume that all fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because $PM_{2.5}$ produced via transported precursors emitted from EGUs may differ significantly from direct $PM_{2.5}$ released from diesel engines and other industrial sources, but the scientific evidence is not yet sufficient to allow differentiation of effect estimates by particle type.

3. We assume that the health impact function for fine particles is linear down to the lowest air quality levels modeled in this analysis. Thus, the estimates include health

benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both regions that are in attainment with fine particle standard and those that do not meet the standard down to the lowest modeled concentrations.

4. To characterize the uncertainty in the relationship between $PM_{2.5}$ and premature mortality (which typically accounts for 85% to 95% of total monetized 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 4-5).

This RIA does not include the type of detailed uncertainty assessment found in the PM NAAQS RIA (U.S. EPA, 2006) because we lack the necessary air quality input and monitoring data to run the benefits model. In addition, we have not conducted any air quality modeling for this rule. Moreover, it was not possible to develop benefit-per-ton metrics and associated estimates of uncertainty using the benefits estimates from the PM RIA because of the significant differences between the sources affected in that rule and those regulated here. However, the results of the Monte Carlo analyses of the health and welfare benefits presented in Chapter 5 of the PM RIA can provide some evidence of the uncertainty surrounding the benefits results presented in this analysis.

SECTION 6
COMPARISON OF BENEFITS AND COSTS

This RIA does not include the final engineering costs and emission reductions (see Chapter 2 for a description of the changes that have not been accounted for). We estimate that incorporating these final estimates would decrease the engineering costs by approximately 22% and increase the monetized benefits by approximately 4% from those shown in this RIA.

Using a 3% discount rate, we estimate the total monetized benefits of the CISWI NSPS and Emissions Guidelines to be $340 million to $830 million in the implementation year (2016) (Table 6-1). Using a 7% discount rate, we estimate the total monetized benefits of the CISWI NSPS and Emissions Guidelines to be $310 million to $750 million. The annualized costs are $280 million at a 7% interest rate.[1] Thus, net benefits are $60 million to $550 million at a 3% discount rate for the benefits and $30 million to $470 billion at a 7% discount rate. All estimates are in 2008$. Figures 6-1 and 6-2 show the full range of net benefits estimates (i.e., annual benefits minus annualized costs) utilizing the 14 different $PM_{2.5}$ mortality functions at discount rates of 3% and 7%. The benefits from reducing other air pollutants have not been monetized in this analysis, including reducing 25,000 tons of carbon monoxide, 470 tons of HCl, 4.1 tons of lead, 0.95 tons of cadmium, 260 pounds of mercury, and 92 grams of total dioxins/furans each year.

[1] For more information on the annualized costs, please refer to Section 3 of this RIA. There are no estimates of costs available at a 3% discount rate.

Table 6-1. Summary of the Monetized Benefits, Social Costs, and Net Benefits for the CISWI NSPS and EG in 2016 (millions of 2008$)[a]

	3% Discount Rate			7% Discount Rate		
Option 1: MACT Floor						
Total Monetized Benefits[b]	$340	to	$830	$310	to	$750
Total Social Costs[c]		$280			$280	
Net Benefits	$60	to	$550	$30	to	$470
Non-monetized Benefits	25,000 tons of carbon monoxide 470 tons of HCl 260 pounds of mercury 0.95 tons of cadmium 4.1 tons of lead 92 grams of dioxins/furans Health effects from NO_2 and SO_2 exposure Ecosystem effects Visibility impairment					
Option 2: Beyond the Floor						
Total Monetized Benefits[b]	$430	to	$1,100	$390	To	$960
Total Social Costs[c]		$300			$300	
Net Benefits	$130	to	$770	$90	to	$660
Non-monetized Benefits	25,000 tons of carbon monoxide 470 tons of HCl 260 pounds of mercury 0.95 tons of cadmium 4.1 tons of lead 92 grams of dioxins/furans Health effects from NO_2 and SO_2 exposure Ecosystem effects Visibility impairment					

[a] All estimates are for the implementation year (2016), 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 NO_x and 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 valued at $3.8 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.

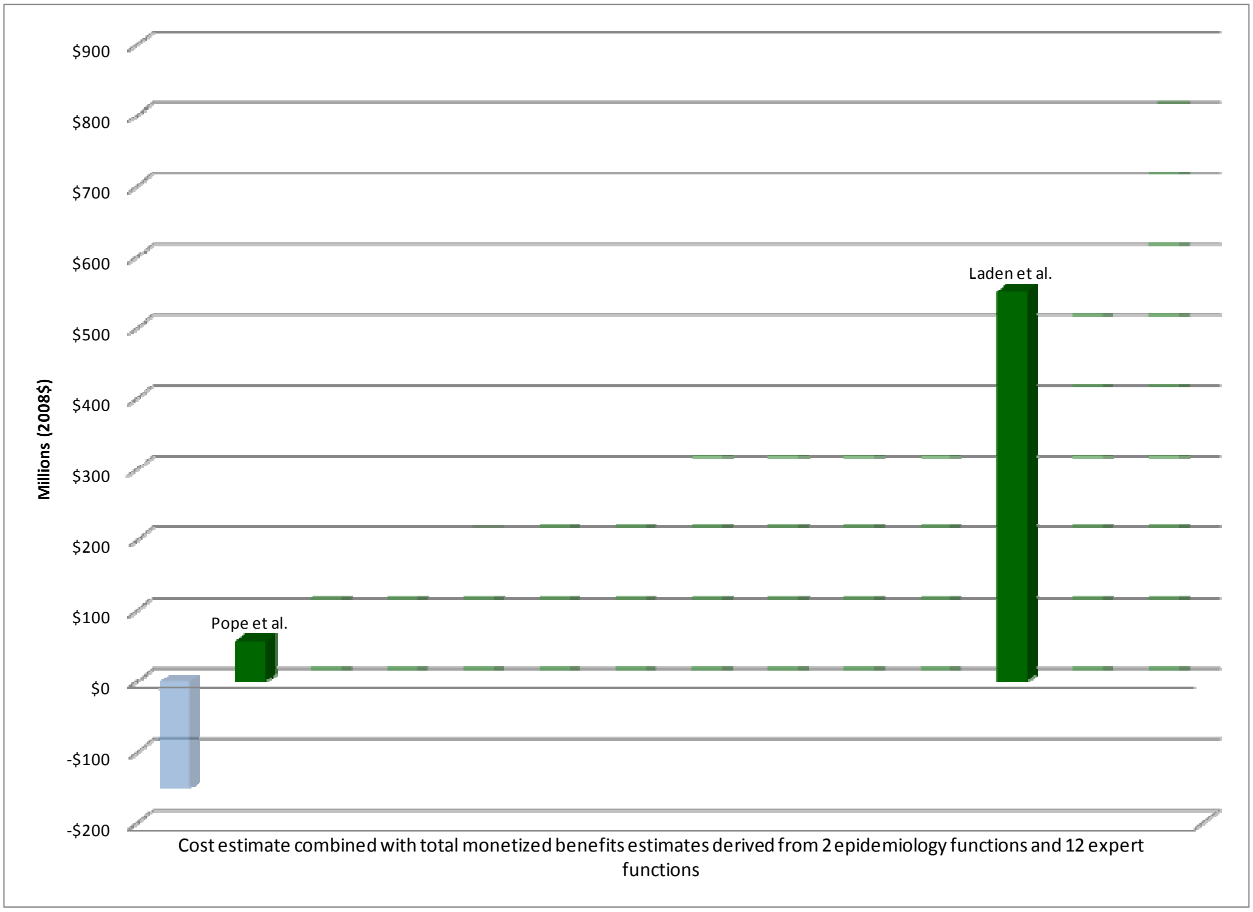


Figure 6-1. Net Benefits for the CISWI NSPS and Emissions Guidelines at 3% Discount Rate[a]

[a] Net benefits are quantified in terms of $PM_{2.5}$ benefits for the implementation year (2016). 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. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. These estimates include energy disbenefits valued at $3.8 million.

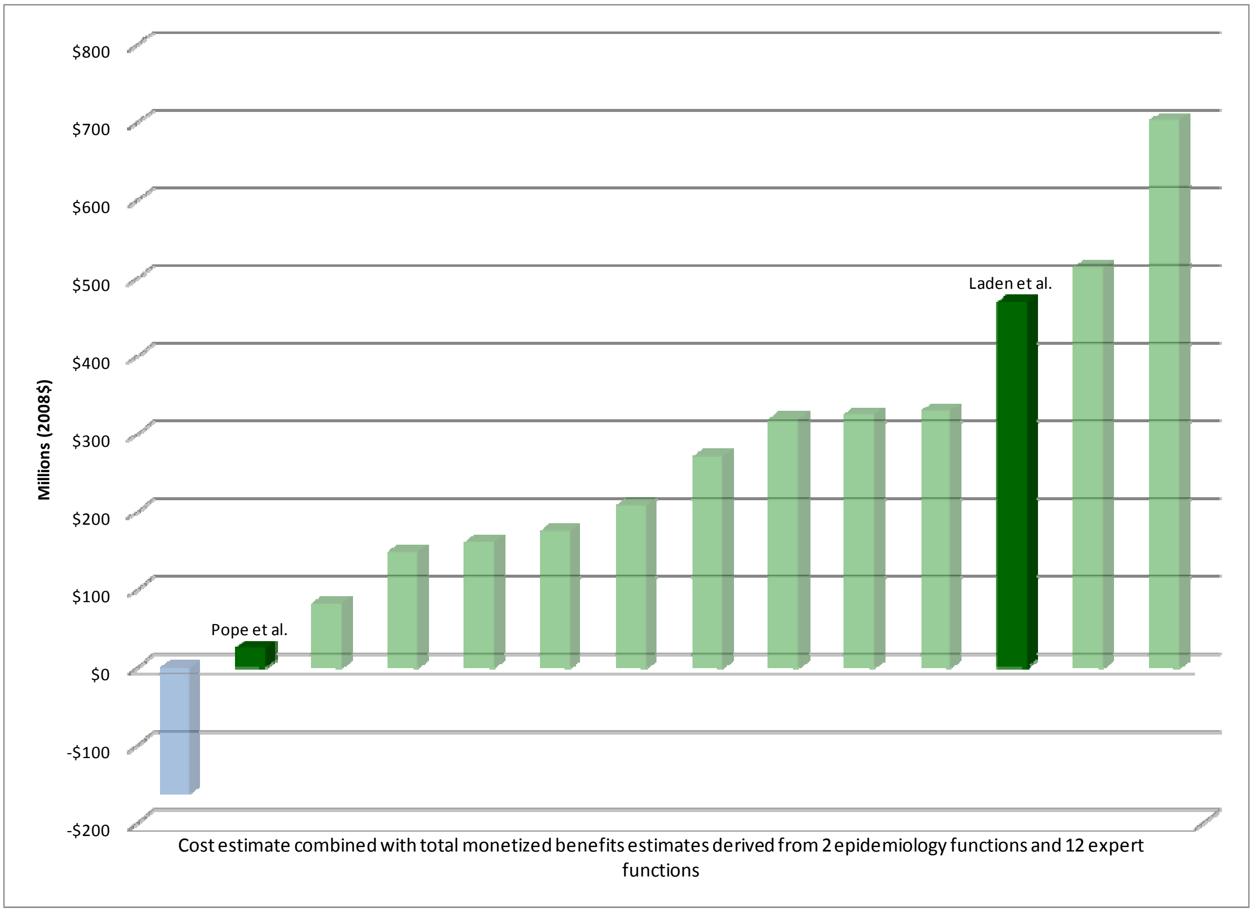


Figure 6-2. Net Benefits for the CISWI NSPS and Emissions Guidelines at 7% Discount Rate[a]

[a] Net benefits are quantified in terms of $PM_{2.5}$ benefits for the implementation year (2016). 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. The monetized benefits incorporate the conversion from precursor emissions to ambient fine particles. These estimates include energy disbenefits valued at $3.8 million.

REFERENCES

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>.

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>.

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>.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Public Health Statement for Lead. CAS#: 7439-92-1. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/ToxProfiles/phs13.html>.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Public Health Statement for Cadmium. CAS# 1306-19-0. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at <http://www.atsdr.cdc.gov/PHS/PHS.asp?id=46&tid=15>.

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

Berck, P., and S. Hoffmann. 2002. "Assessing the Employment Impacts of Environmental and Natural Resource Policy." *Environmental and Resource Economics* 22(1): 133-156.

Berman, E., and L. T. M. Bui. 2001. Environmental regulation and labor demand: Evidence from the south coast air basin. *Journal of Public Economics* 79, no. 2: 265-295.

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.

Broda, C., N. Limao, and D.E. Weinstein. 2008b. "Optimal Tariffs and Market Power: The Evidence." *American Economic Review* 98(5): 2032-2065.

Cole, M. A. and R. J. Elliott. 2007. Do environmental regulations cost jobs? An industry-level analysis of the UK. *B E Journal of Economic Analysis & Policy* 7, no. 1.

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

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):7266–7272.

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* 2:169–176.

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

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

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

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

Greenstone, M. 2002. The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 clean air act amendments and the census of manufactures. *Journal of Political Economy* 110, no. 6: 1175-1219.

Henderson, J. V. 1996. Effects of air quality regulation. *American Economic Review* 86, no. 4: 789-813.

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.

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>.

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

Just, R.E., D.L. Hueth, and A. Schmitz. 2004. *The Welfare Economics of Public Policy*. Northampton, MA: Edward Elgar.

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* 34:385–406.

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.

Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. Jobs versus the environment: An industry-level perspective. *Journal of Environmental Economics and Management* 43(3):412-436.

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.

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):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* 36:33–44.

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.

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.

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). 2009. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.* National Academies Press. Washington, DC.

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.

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

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.

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

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.

Scudder, B.C., Chasar, L.C., Wentz, D.A., Bauch, N.J., Brigham, M.E., Moran, P.W., and Krabbenhoft, D.P. 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.

Shoven, J.B., and J. Whalley. 1995. *Applying General Equilibrium*. New York: Cambridge University Press.

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.

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, pp 370-375.

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 (BLS). 2009a. Producer Price Index. Series ID:PCU321—321—& PCUOMFG—OMFG—<http://www.bls.gov/ppi/home.htm>. (Data accessed on January 8, 2010).

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

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

U.S. Census Bureau. 2008b. “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. 2009. 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>.

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>.

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.

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.

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 27, 2009.

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.

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 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).

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. Environmental Protection Agency (U.S. EPA). 1999. *OAQPS Economic Analysis Resource Document*. Office of Air Quality Planning and Standards. http://www.epa.gov/ttn/ecas/analguid.html.

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 on the Internet at <http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html/$file/cover.pdf>.

U.S. Environmental Protection Agency (U.S. EPA). September 2000. *Guidelines for Preparing Economic Analyses*. EPA 240-R-00-003. Washington, DC: EPA. http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html. Accessed August 2009.

U.S. Environmental Protection Agency (U.S. EPA). 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. 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. 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. Available at <http://yosemite.epa.gov/ee/epa/eermfile.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. 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). 2009c. 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). 2010a. Integrated Science Assessment for Carbon Monoxide. National Center for Environmental Assessment, Research Triangle Park, NC. EPA/600/R-09/019F. January. Available on the Internet at <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=218686>.

U.S. Environmental Protection Agency (U.S. EPA). 2010b. Final Regulatory Impact Analysis (RIA) for the SO_2 National Ambient Air Quality Standards (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>.

U.S. Environmental Protection Agency (U.S. EPA). 2010c. 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/benefits.html>.

U.S. Environmental Protection Agency (U.S. EPA). 2010d. Lowest Measured Level (LML) Assessment for Rules without Policy-Specific Air Quality Data Available: Technical Support Document. 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. *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>.

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 Reduction. EPA-SAB-08-001. October. Available on the Internet 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). 2009a. Review of EPA's Integrated Science Assessment for Particulate Matter (First External Review Draft, December 2008). EPA-COUNCIL-09-008. May. Available on the Internet at <http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/73ACCA834AB44A10852575BD0064346B/$File/EPA-CASAC-09-008-unsigned.pdf>.

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

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>.

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):5-76.

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 (U.S. 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 (U.S. 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 (U.S. 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
  - All industries aggregated to 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 non-energy 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 (U.S. EPA, 2008):

$$\text{Output} + \text{Imports} = \text{Consumption} + \text{Investment} + \text{Government} + \text{Exports} \qquad (A.1)$$

If we abstract and treat each industry as a national market, the identity represents the pre-policy 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.

[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

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:

$$\%\Delta\text{"net" price} = \%\Delta \text{ market price} - \%\Delta \text{ direct costs} - \%\Delta \text{ indirect costs} \qquad (A.2)$$

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:

$$\%\Delta \text{ direct costs} = \$1/\$317 = 0.03\% \qquad (A.3)$$

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 pre-policy production levels (Q).

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.

$$\%\Delta \text{ indirect costs} = \text{input use ratio} \times \%\Delta \text{ input price} \qquad (A.4)$$

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.

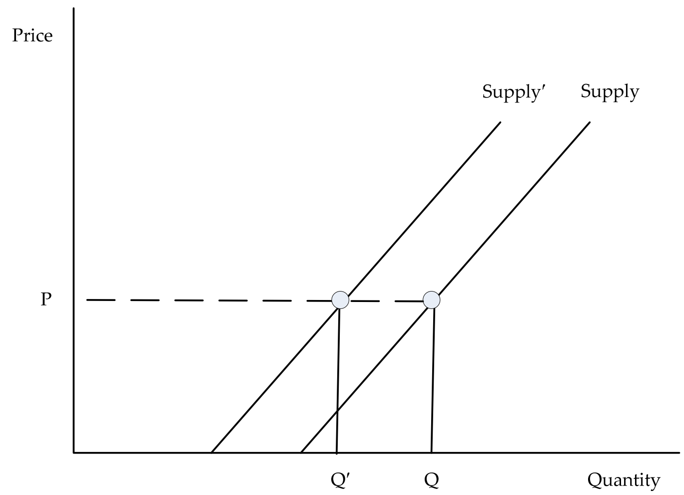


Figure A-1. Direct Compliance Costs Reduce Production Rates at Benchmark Prices

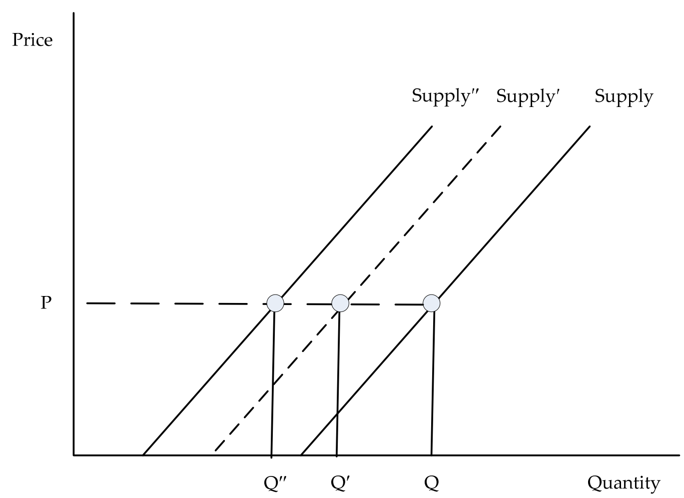


Figure A-2. Indirect Costs Further Reduce Production Rates at Benchmark Prices

Following guidance in the OAQPS economic resource manual (OAQPS, 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).

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
FRT	Fertilizer	1.0	0.7
FRU	Fruits and Vegetables	1.0	0.7
GAS	Natural Gas	12.2	12.2
GEQ	General Equipment	1.0	0.7
GLS	Glass	0.8	0.6
GAS	Natural Gas	12.2	12.2

(continued)

Table A-5. Supply Elasticities (continued)

Industry Label	Industry Description	Rest of World (ROW)	U.S.
FUR	Furniture	1.9	1.9
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
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

(continued)

Table A-5. Supply Elasticities (continued)

Industry Label	Industry Description	Rest of World (ROW)	U.S.
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
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.

A.2.2.3 Price Elasticity of Supply: Rest of World (ROW)

Broda and colleagues (2008) 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).[2]

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).[3] 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[4]), 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

[2] Broda et al.'s intent was to use these categories to describe or proxy for domestic market power.

[3] 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.

[4] 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,[5] 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 (OAQPS, 1999), we use a general form for the U.S. industry demand function:

[5]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.

APPENDIX B
INDUSTRY PROFILES

In this section, we provide an introduction to selected industries that are affected by the rule. 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.

B.1 Wood Product Manufacturing

B.1.1 Introduction

The wood product industry is not forecasted to earn high profits in the near future. According to a report by Standard & Poor's (O'Reilly, 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 B-1 shows that revenues in this industry are variable, exhibiting a decrease in shipment revenue between 1997 and 2002, an increase to within $5 billion of the 1997 value in 2006 and another decline to within $14 billion of the 2006 value in 2007. Upon closer review, one also notices a rise in the cost of labor (shipment revenue per dollar of payroll—$5.54 in 2002, $6.20 in 2006, and $5.84 in 2007) and material inputs during this same time period, making high profit margins difficult to predict.

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

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 planing machine to achieve smoothness and uniformity of size.

Table B-1. Key Statistics: Wood Product Manufacturing (NAICS 321)

	1997	2002	2006	2007
Shipments ($2007, 10^6)	$110,956	$102,721	$115,390	$101,879
Payroll ($2007, 10^6)	$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.

Table B-2. Industry Ratios: Wood Product Manufacturing (NAICS 321)

Industry Ratios	1997	2002	2006	2007
Total shipments ($2007, 10^6)	$110,956	$102,721	$115,390	$101,879
Shipments per establishment ($$10^3$)	$25,613	$5,953	NA	$6,855
Shipments per employee ($2007)	$194,648	$189,014	$215,243	$196,053
Shipments per $ of payroll ($2007)	$6.18	$5.54	$6.20	$5.84
Annual payroll per employee ($2007)	$31,504	$34,093	$34,738	$33,558
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.

- 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 B-1 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 B-2 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.

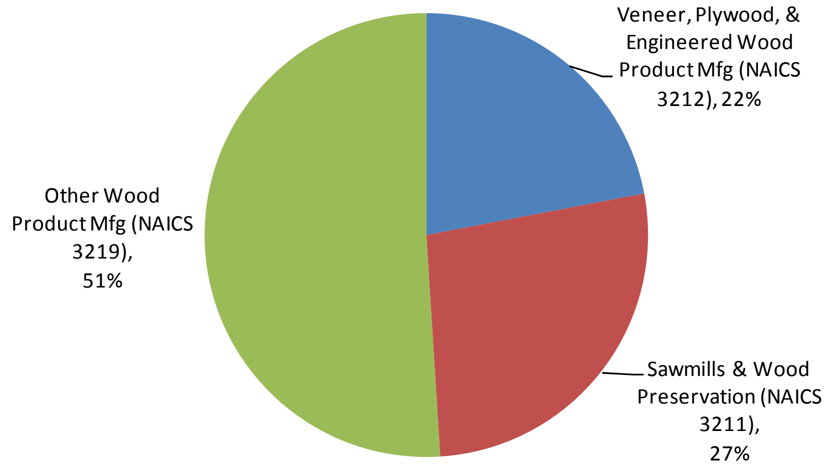


Figure B-1. Distribution of Value of Shipments within Wood Product Manufacturing (NAICS 322): 2007

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]

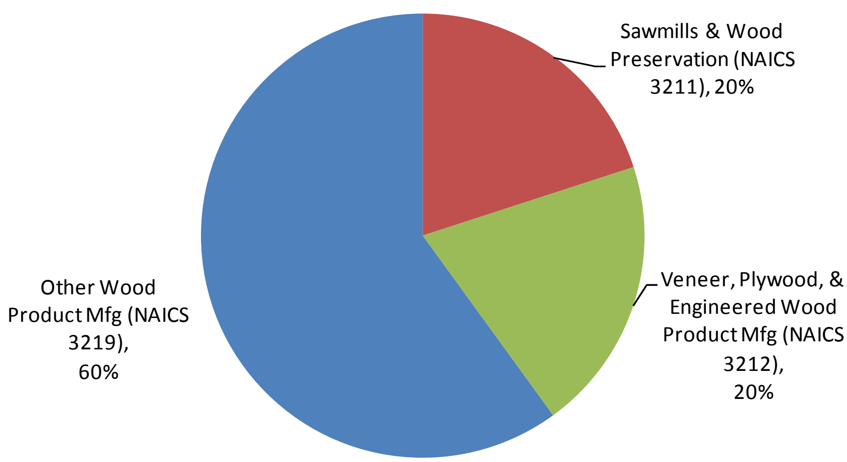


Figure B-2. Distribution of Employment within Wood Product Manufacturing (NAICS 322): 2007

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. [Source for 2007 numbers]

B.1.2 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.

B.1.2.1 Goods and Services Used in Wood Product Manufacturing

In 2007, the cost of materials comprised 59% of the total shipment value of goods in the wood product manufacturing industry (Table B-3). 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%.

Table B-3. Costs of Goods and Services in Wood Product Manufacturing (NAICS 321)

Industry Ratios	2005	Share	2006	Share	2007	Share
Total shipments ($2007, 10^6)	$118,705	100%	$115,390	100%	$102,002	100%
Total compensation ($2007, 10^6)	$23,327	20%	$23,306	20%	$22,513	22%
Annual payroll ($2007)	$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 ($2007)	$43,286		$43,473		$42,947	
Total production workers' wages ($2007, 10^6)	$13,363	11%	$13,132	11%	$12,086	12%
Total production workers	431,569		432,315		417,471	
Total production hours (10^3)	911,332		887,613		837,074	
Average production wages per hour ($2007)	$15		$15		$14	
Total cost of materials ($2007, 10^3)	$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 ($2007)	$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. [Source for 2007 numbers]

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 B-4). 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 B-4. Key Goods and Services Used in Wood Product Manufacturing (NAICS 321) ($2007, 10^6)

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.

B.1.2.1.1 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 B-5 shows that total energy use decreased between 1998 and 2002 by 26 and then between 2002 and 2006, total energy use rose by 19%. However, Figure B-3 shows that electrical power use decreased rapidly during this period, including a steady decline in the latter part of 2000. Following a rapid decrease at the end of 2002, electric power use has been increasing steadily since then.

Table B-5. Energy Used in Wood Product Manufacturing (NAICS 321)

Fuel Type	1998	2002	2006
Total (trillion BTU)	504	375	445
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

[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]

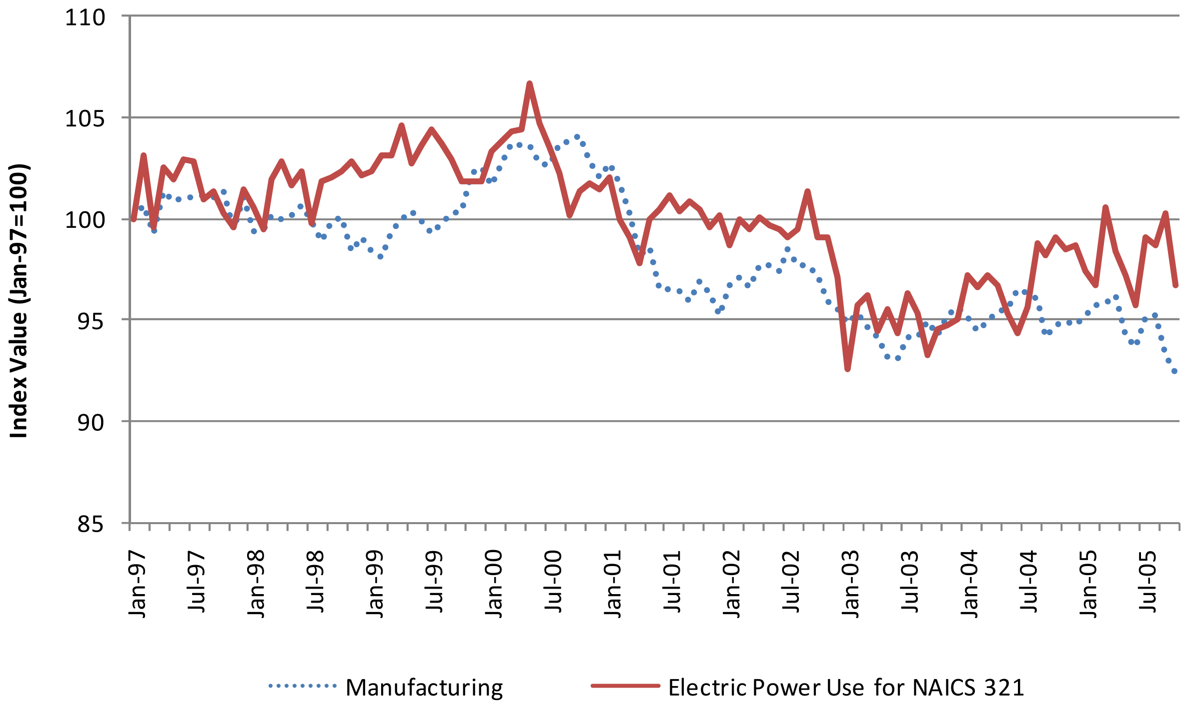


Figure B-3. Electrical Power Use Trends in the Wood Product Manufacturing Industry (NAICS 321): 1997–2005

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

B.1.2.2 Uses and Consumers

Table B-6 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.

B.1.3 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.

Table B-6. Demand by Sector: Wood Product Manufacturing (NAICS 321) ($2007, 10^6)

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.

B.1.3.1 Location

As Figure B-4 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.

B.1.3.2 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 B-5).

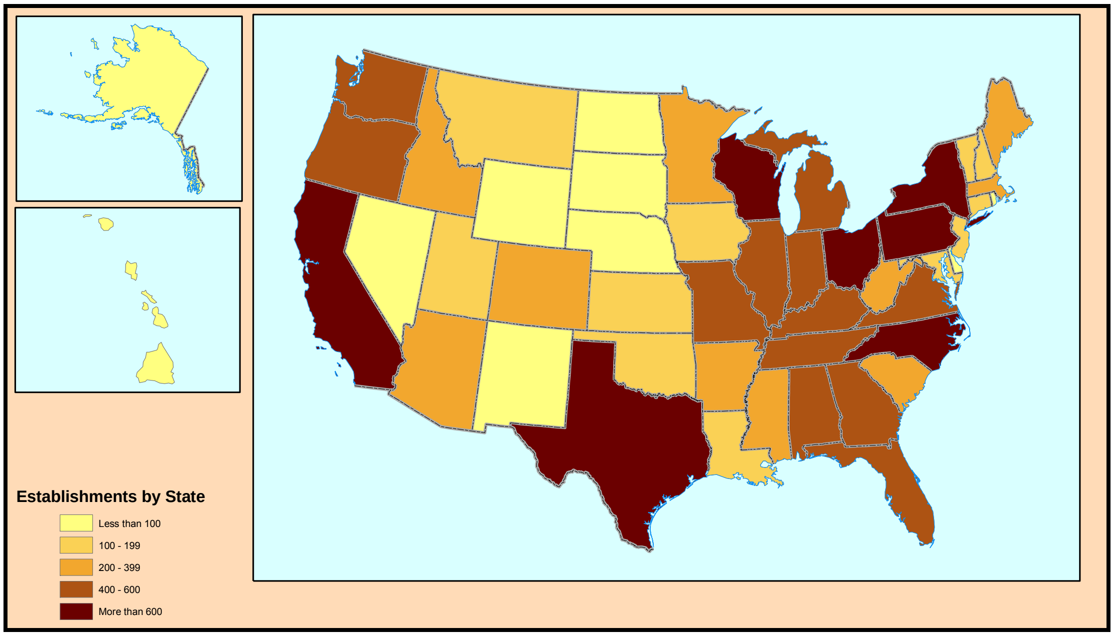


Figure B-4. Establishment Concentration in the Wood Product Manufacturing Industry (NAICS 321): 2002

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).

Figure B-5. 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/>..

B.1.3.3 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 B-6). 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 B-6, 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.

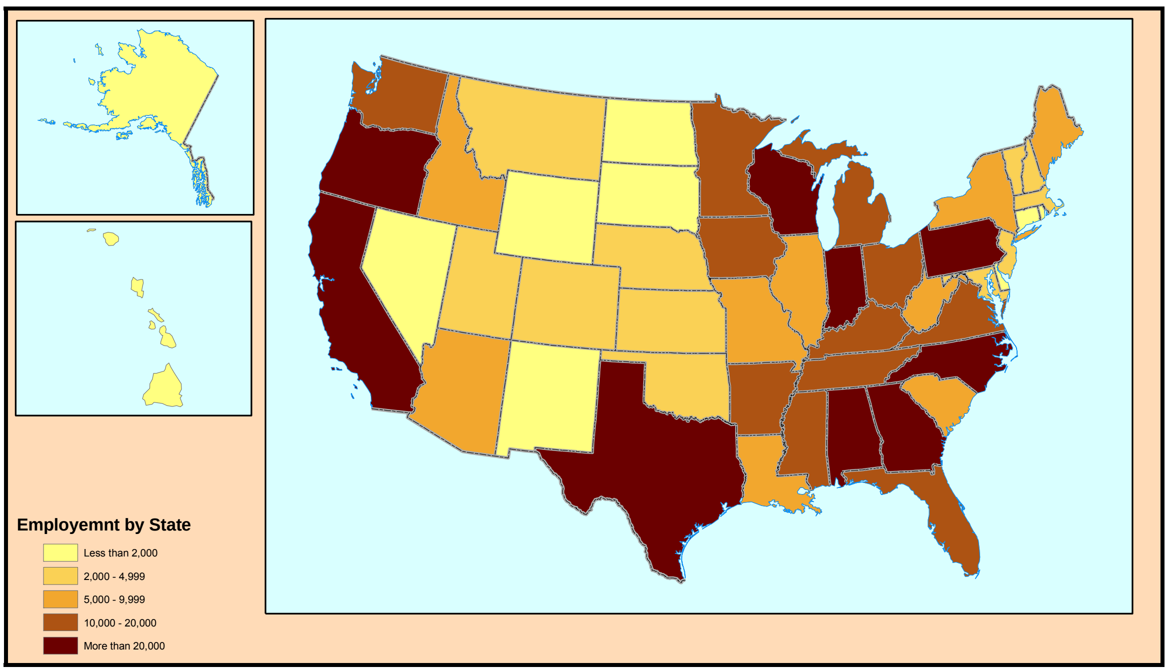


Figure B-6. Employment Concentration in the Wood Product Manufacturing Industry (NAICS 321): 2002

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).

B.1.3.4 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 B-7).

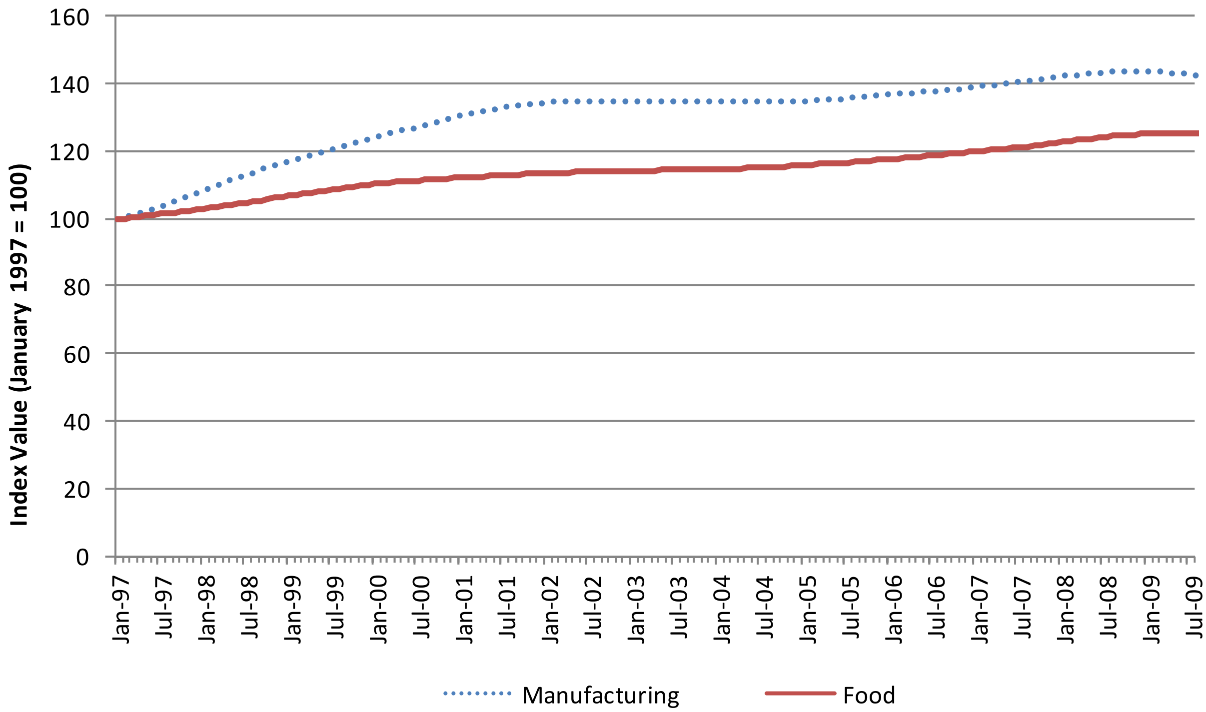


Figure B-7. Capacity Trends in the Wood Product Manufacturing Industry (NAICS 321)

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

B.1.3.5 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 B-7). 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.

B.1.3.6 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 B-8). The number of employees in the small business cutoff is 500 employees for all sub-industries in the wood product manufacturing industry (Table B-9).

Table B-7. Largest U.S. Paper and Forest Products Companies: 2006

Company	Revenues ($$10^6$)[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).

B.1.3.7 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 B-8). Similar to capacity utilization trends (Figure B-8), the index shows a faster rate of decline for wood products than the entire manufacturing sector.

B.1.3.8 International Trade

Since 1997, the wood product manufacturing industry has contributed to an increasing trade deficit (Figure B-9). The value of imports has fluctuated greatly since 1997; however, exports have remained fairly constant, with seasonal changes, since 1997.

B.1.3.9 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, while producer prices for all manufacturing goods increased by roughly 34% at its peak and was at 23% in November 2008 and 24% in November 2009 (Figure B-10).

Table B-8. Distribution of Economic Data by Enterprise Size: Wood Product Manufacturing (NAICS 321)

Variable	Total	Enterprises with 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 ($$10^{3}$)	$88,649	$8,204	$18,276	$19,717	$3,192	$1,902	$3,118
Receipts/firm ($$10^3$)	$5,833	$842	$5,572	$24,927	$50,673	$70,453	$103,927
Receipts/establishment ($$10^3$)	$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 B-9. 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
321214	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>.

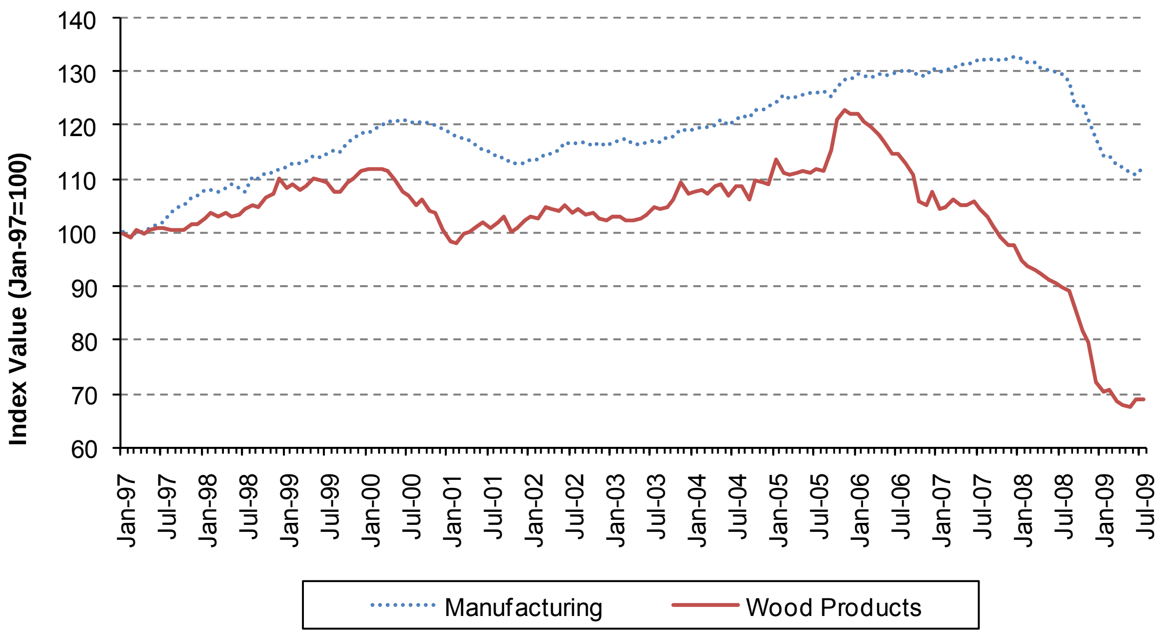


Figure B-8. Industrial Production Trends in the Wood Product Manufacturing Industry (NAICS 321): 1997–2009

Source: Federal Reserve Board. "Industrial Production and Capacity Utilization: Industrial Production." <http://www.federalreserve.gov/datadownload/>. Accessed on December 15, 2009.

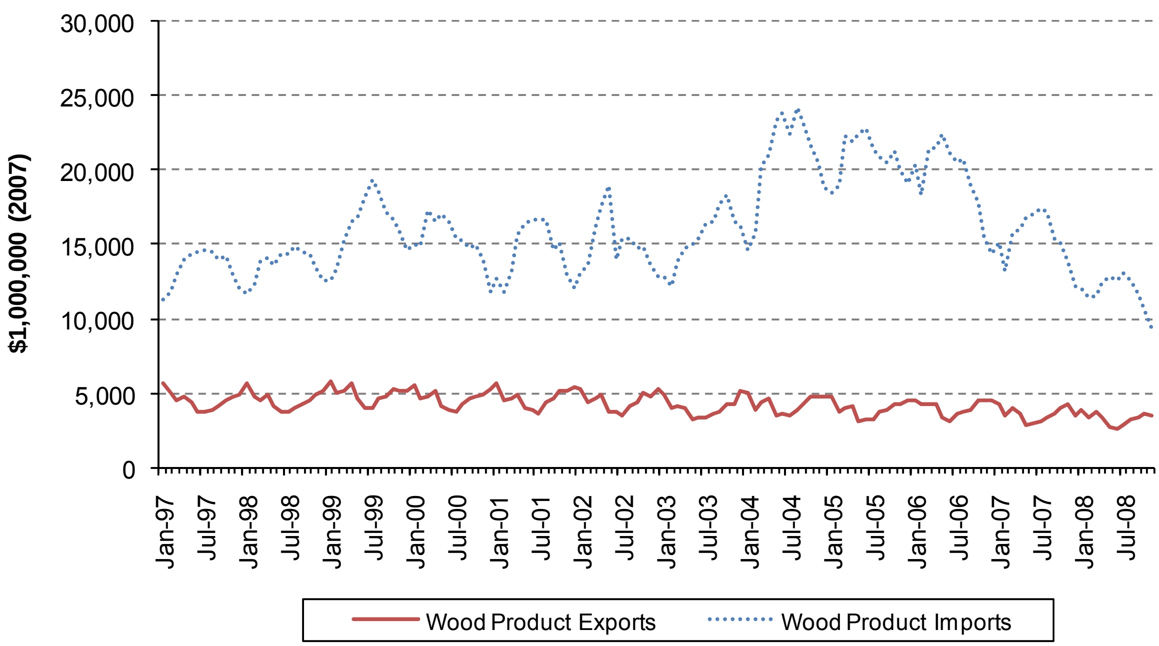


Figure B-9. International Trade Trends in the Wood Product Manufacturing Industry (NAICS 321)

Source: U.S. International Trade Commission. 2008a. "U.S. Domestic Exports" & "U.S. Imports for Consumption." <http://dataweb.usitc.gov/scripts/user_set.asp>; (July 17, 2008).

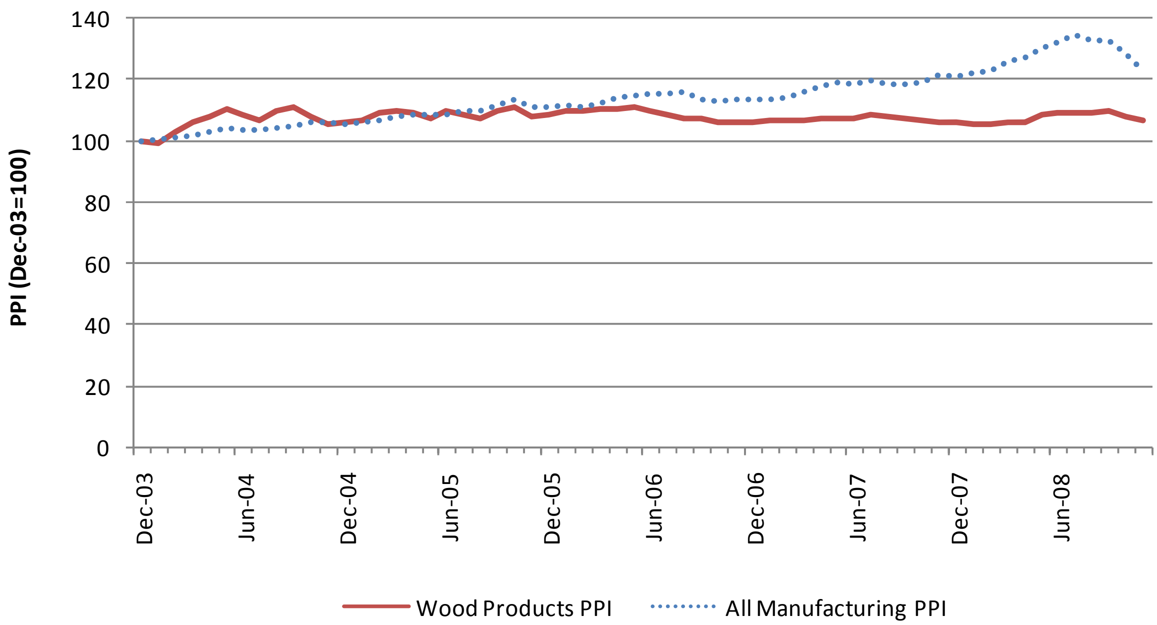


Figure B-10. Producer Price Trends in the Wood Product Manufacturing Industry (NAICS 321)

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.

B.2 Paper Manufacturing

B.2.1 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 B-10). 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). Shipments per employee grew 28% from 1997 to 2007, with much of that growth taking place between 2002 and 2006 (Table B-11).

Table B-10. Key Statistics: Paper Manufacturing (NAICS 322)

	1997	2002	2006	2007
Shipments ($2007, 10^6)	$188,496	$175,983	$174,887	$175,806
Payroll ($2007, 10^6)	$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 B-11. Industry Ratios: Paper Manufacturing (NAICS 322)

Industry Ratios	1997	2002	2006	2007
Total shipments ($2007, 10^6)	$188,496	$175,983	$174,887	$175,806
Shipments per establishment ($2007, 10^3)	$32,123	$32,026	NA	$36,603
Shipments per employee ($2007)	$328,233	$359,614	$422,381	$421,712
Shipments per $ of payroll ($2007)	$6.74	$7.17	$8.25	$8.45
Annual payroll per employee ($2007)	$48,727	$50,189	$51,174	$49,904
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 :

- 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 B-11 shows that the value of shipments for converted paper products was slightly higher in 2007, 54%, than the value of shipments for pulp, paper, and paperboard products in that year, 46%. However, Figure B-12 indicates that significantly more employees worked in the converted paper product category of the industry, 70%, thus making converted paper products more labor intensive.

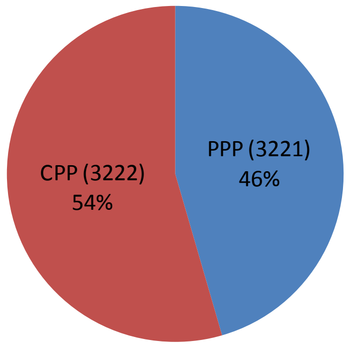


Figure B-11. Distribution of Value of Shipments within Paper Manufacturing (NAICS 322): 2007

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.

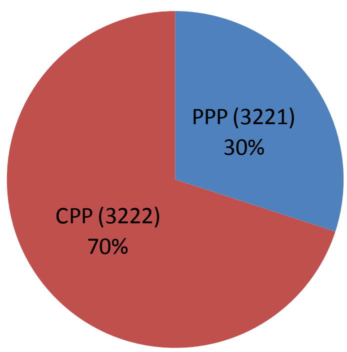


Figure B-12. Distribution of Employment within Paper Manufacturing (NAICS 322): 2007

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.

2.2.2 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.

B.2.2.1 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 B-12). 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.

Table B-12. Costs of Goods and Services Used in the Paper Manufacturing Industry (NAICS 322)

Variable	2005	Share	2006	Share	2007	Share
Total shipments ($2007, 10^6)	$171,477	100%	$174,887	100%	$176,018	100%
Total compensation ($2007, 10^6)	$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, 10^6)	$14,965	9%	$14,689	8%	$14,190	8%
Total production workers	331,228		321,684		321,937	
Total production hours (10^3)	716,963		691,134		680,732	
Average production wages per hour	$21		$21		$21	
Total cost of materials ($2007, 10^3)	$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]

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 B-13). 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.

Table B-13. Key Goods and Services Used in the Paper Manufacturing Industry (NAICS 322) ($$10^6$, $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.

B.2.2.1.1 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 (U.S. EPA, 2002).

Likewise, Table B-14 shows that total energy use decreased between 1998 and 2006 by 14%. Figure B-13 indicates that total electrical power use changed sporadically between 2002 and 2004 but decreased consistently and rapidly after 2004.

Table B-14. Energy Used in Paper Manufacturing (NAICS 322)

Fuel Type	1998	2002	2006
Total (trillion BTU)	2,744	2,361	2,354
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

[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]

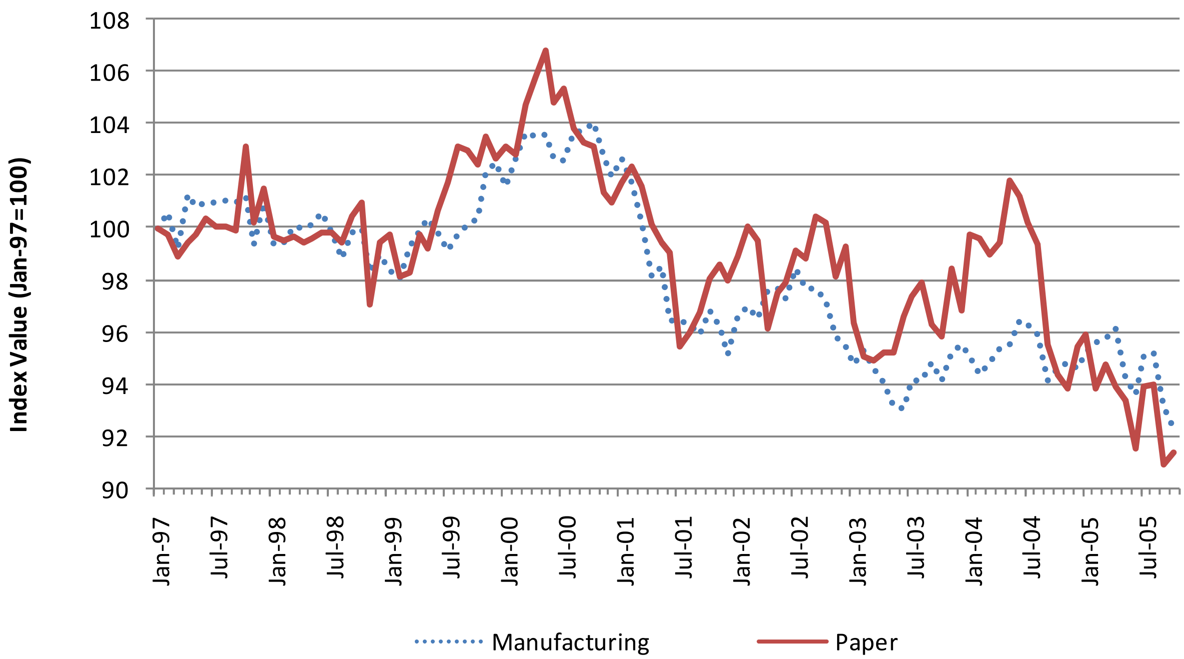


Figure B-13. Electrical Power Use Trends in the Paper Manufacturing Industry: 1997–2005

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

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 B-15). 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% (U.S. EPA, 2002).

B.2.2.2 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 B-16). Pulp, paper, and paperboard products have a large trade deficit, while converted paper products have a very small trade surplus.

Table B-15. 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>.

Table B-16. Demand by Sector: Paper Manufacturing Industry (NAICS 322) ($$10^6$, $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.

B.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, and give a complete picture of the recent historical trends of production and pricing.

B.2.3.1 Location

As Figure B-14 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.

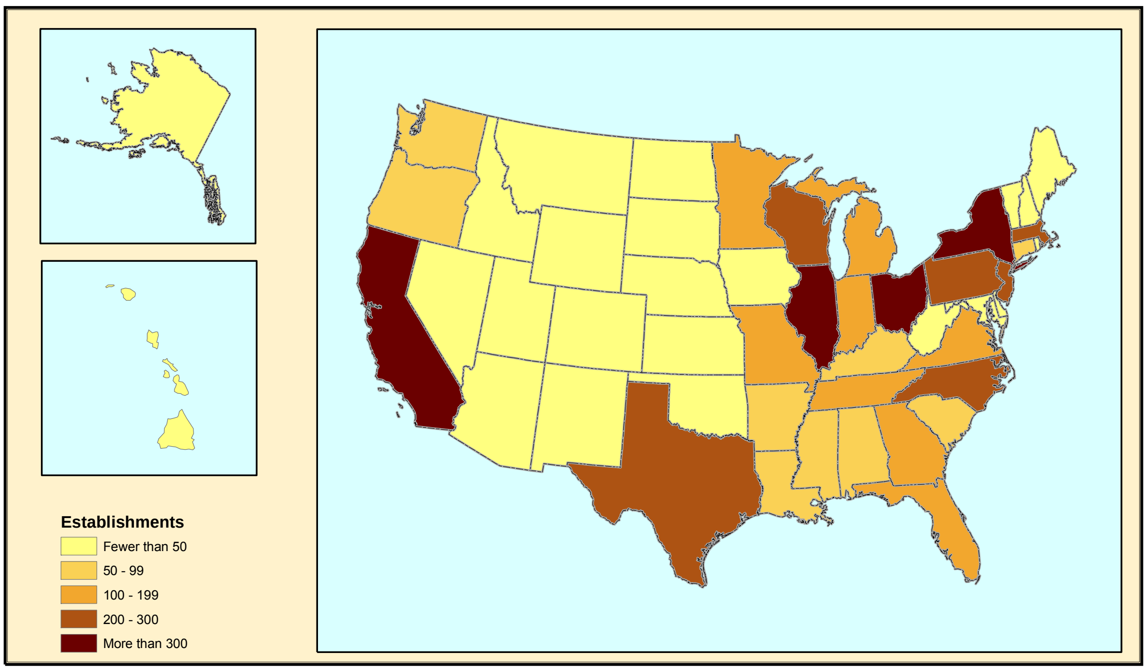


Figure B-14. Establishment Concentration in Paper Manufacturing Industry (NAICS 322): 2002

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).

B.2.3.2 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 B-15).

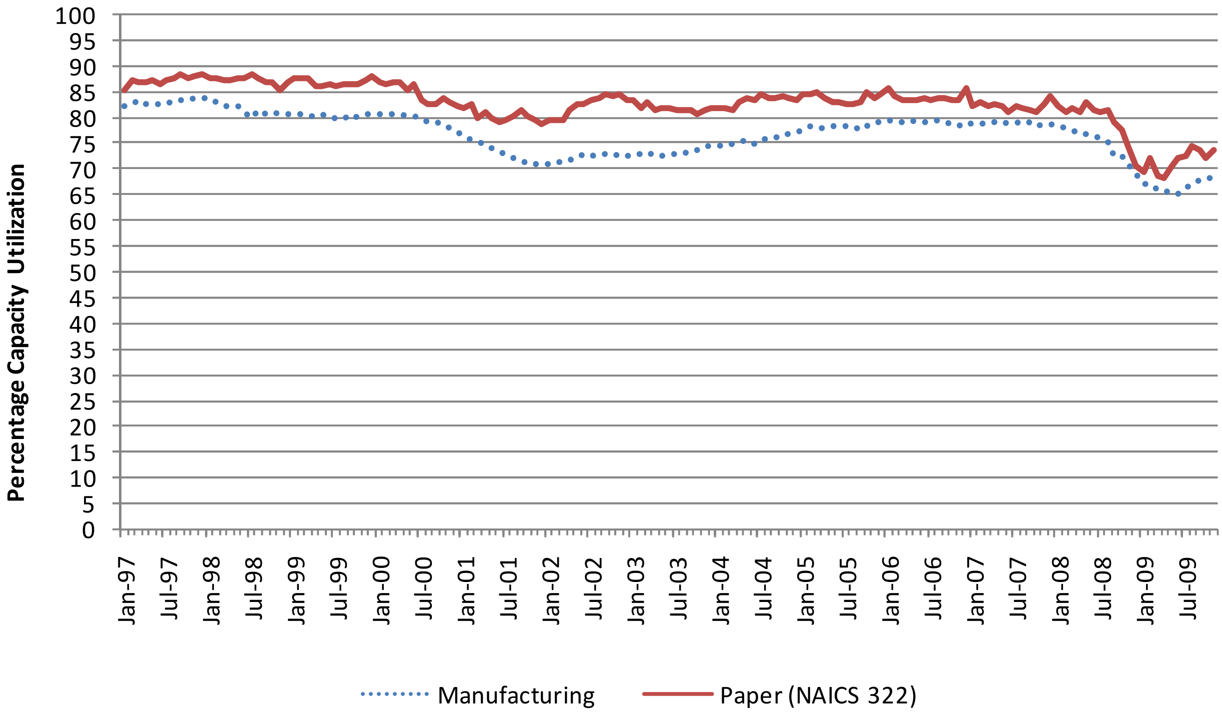


Figure B-15. Capacity Utilization Trends in the Paper Manufacturing Industry (NAICS 322)

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

B.2.3.3 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 B-16). The converted paper products group has more employees per establishment, 283, than the pulp, paper, and paperboard group, 67.

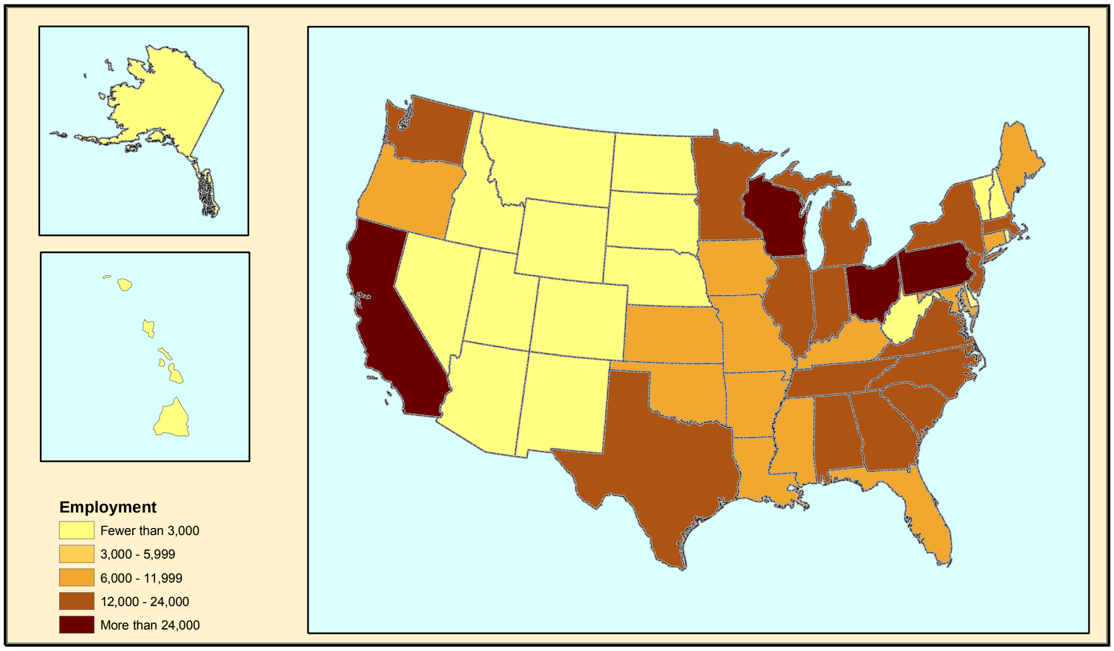


Figure B-16. Employment Concentration in the Paper Manufacturing Industry (NAICS 322): 2002

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).

B.2.3.4 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 B-17).

B.2.3.5 Firm Characteristics

In 2006, the top 10 paper and forest product companies produced over $1.6 billion in sales, with the top two companies—International Paper and Weyerhaeuser—generating nearly $22 billion each (Table B-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 paper products, they do convey the market environment in which firms in this sector compete.

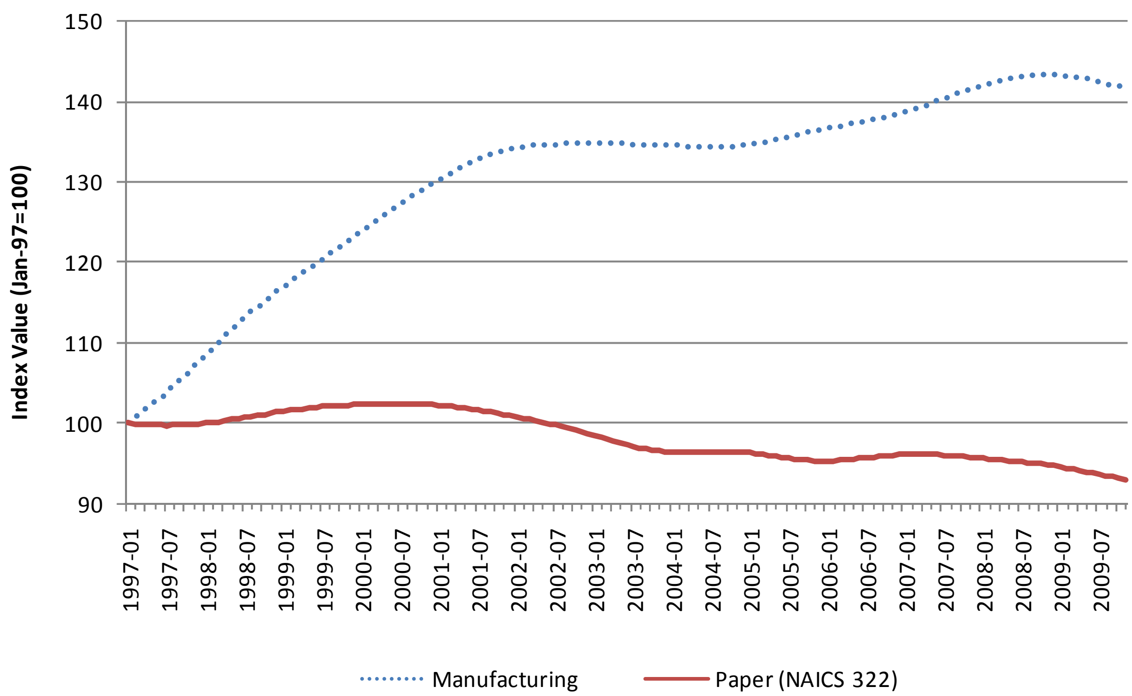


Figure B-17. Capacity Trends in the Paper Manufacturing Industry (NAICS 322)

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

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

Company	Revenues ($\$10^6$)[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.

B.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, large companies dominated revenue-generating transactions in the paper manufacturing subsector; 80% of receipts were generated by companies with 500 employees or more (Table B-18). 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 B-19). 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.

B.2.3.7 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 B-18). 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.

Table B-18. 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 ($$10^6$)	$154,746	$2,218	$9,483	$17,620	$3,034	$3,951	$6,798
Receipts/firm ($$10^3$)	$43,738	$1,497	$7,903	$37,017	$70,561	$179,577	$206,001
Receipts/establishment ($$10^3$)	$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 B-19. 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>.

B.2.3.8 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 B-19). Imports and exports have been changing at similar rates since 1999.

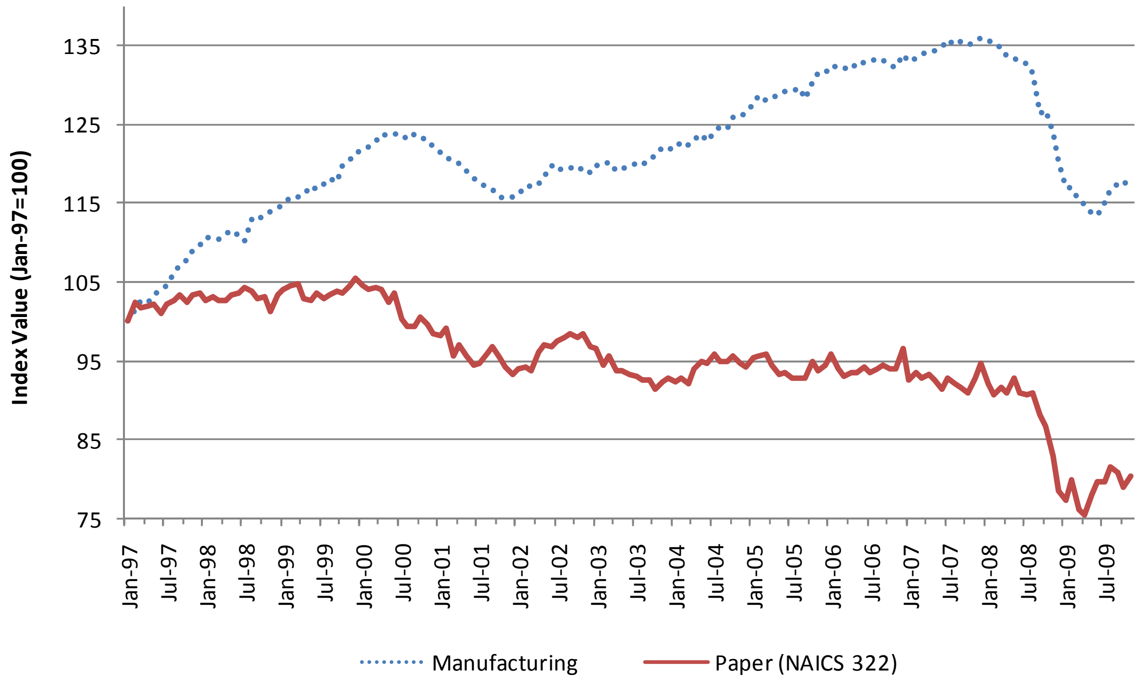


Figure B-18. Industrial Production Trends in the Paper Manufacturing Industry (NAICS 322): 1997–2009

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

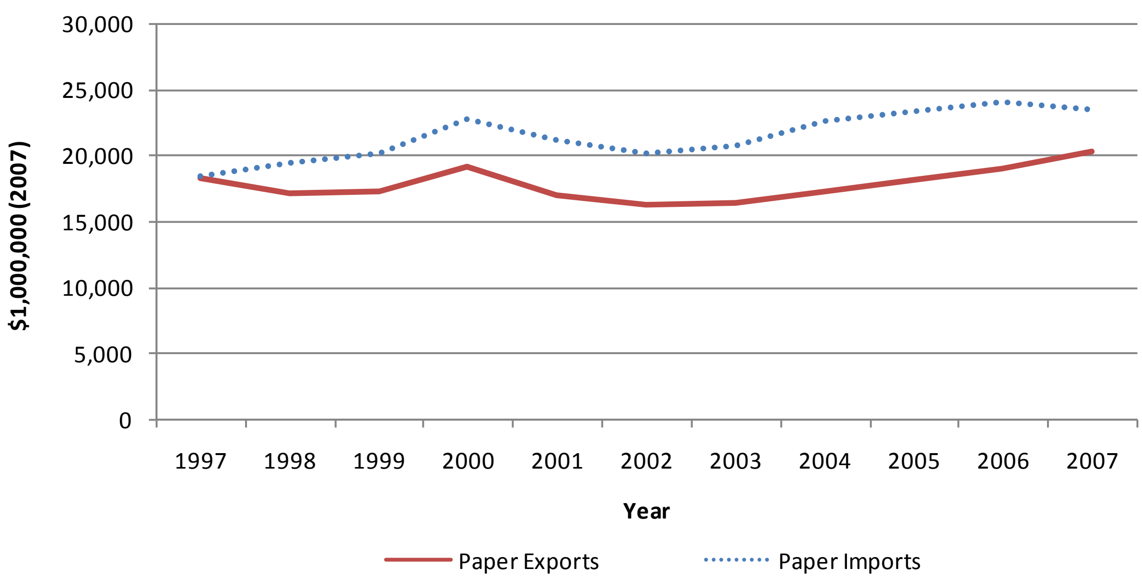


Figure B-19. International Trade Trends in the Paper Manufacturing Industry (NAICS 322)

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

B.2.3.9 Market Prices

Prices of goods in paper manufacturing have been increasing at a rate consistent with all manufacturing products (Figure B-20). 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%.

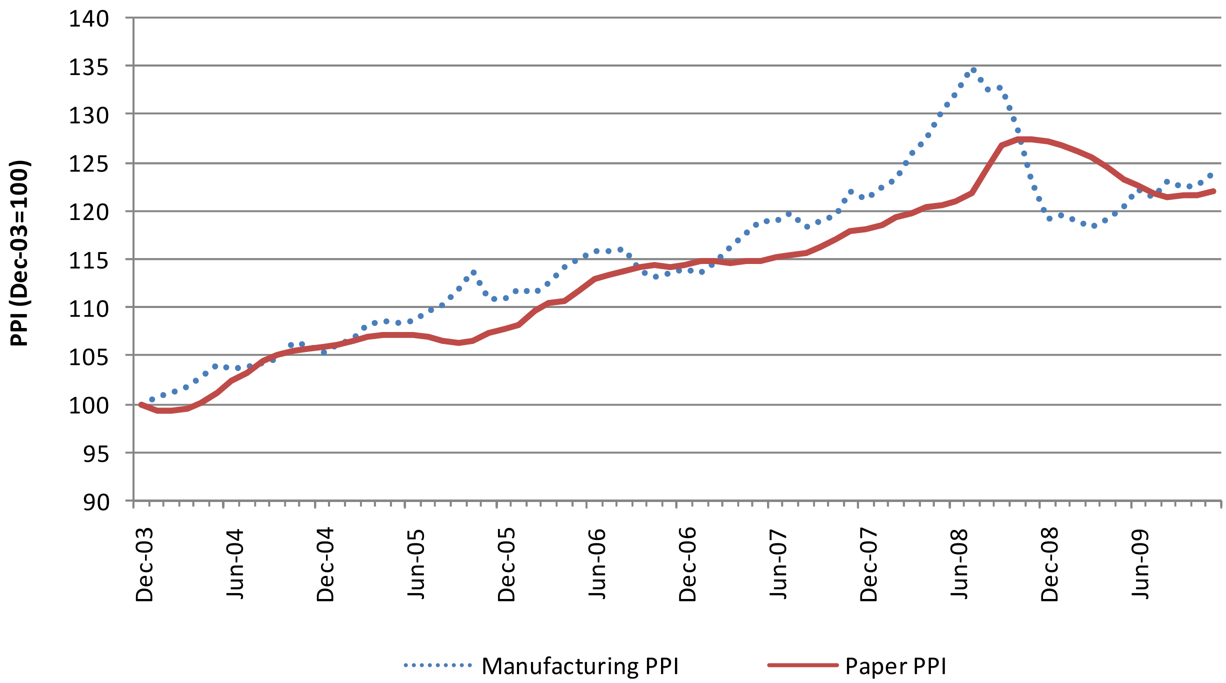


Figure B-20. Producer Price Trends in the Paper Manufacturing Industry (NAICS 222)

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>.

B.3 Chemical Manufacturing

B.3.1 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 to2007, shipments in the industry grew 42%, while employment declined by 8% (Table B-20). 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 B-21). Shipments per employee grew 54% from 1997 to 2007, with much of that growth taking place between 2002 and 2006 (Table B-21).

Table B-20. Key Statistics: Chemical Manufacturing (NAICS 325)

	1997	2002	2006	2007
Shipments ($2007, 10^6)	$521,251	$531,173	$675,223	$738,303
Payroll ($2007, 10^6)	$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 B-21. Industry Ratios: Chemical Manufacturing (NAICS 325)

Industry Ratios	1997	2002	2006	2007
Total shipments ($2007, 10^6)	$521,251	$531,173	$675,223	$738,303
Shipments per establishment ($$10^3$)	$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]

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) (DOE/EIA-0554, 2008): 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 B-21). The bulk chemicals group accounted for the biggest share of chemical manufacturing's total value of shipments (Figure B-22).

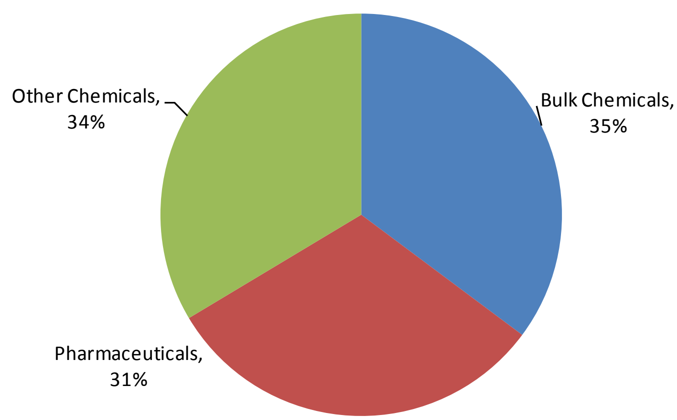


Figure B-21. Distribution of Employment within Chemical Manufacturing (NAICS 325): 2007

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.

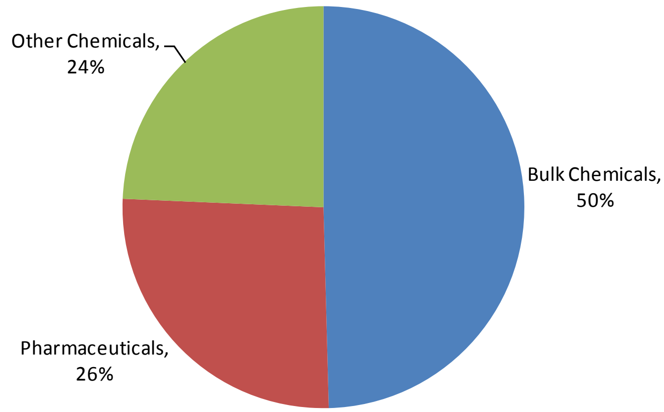


Figure B-22. Distribution of Total Value of Shipments within Chemical Manufacturing (NAICS 325): 2007

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.

B.3.2 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 B-22). 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.

B.3.2.1 Goods and Services Used in Chemical Manufacturing

In2007, the cost of materials made up 49% of chemical manufacturing's total shipment value (Table B-22). Total compensation to employees represented 9% of total shipment value, down from 10% in 2005.

B.3.2.1.1 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).

Table B-22. Key Goods and Services Used in Chemical Manufacturing (NAICS 325) ($2007, 10^6)

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.

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 B-23).

As a whole, chemical manufacturing has become less energy intensive 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 B-24). From 1997 to 2005, when data ceased to be available, chemical manufacturing became less electricity intensive faster than the manufacturing sector as a whole (Figure B-23).

Table B-23. Costs of Goods and Services Used in Chemical Manufacturing (NAICS 325)

Variable	2005	Share	2006	Share	2007	Share
Total shipments ($2007)	$646,895	100%	$675,223	100%	$722,494	100%
Total compensation ($2007, 10^6)	$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 ($2007)	$82,887		$82,559		$79,333	
Total production workers' wages ($2007, 10^6)	$22,643	4%	$22,231	3%	$23,157	3%
Total production workers	431,502		430,880		463,802	
Total production hours (10^3)	899,499		885,993		948,244	
Average production wages per hour	$25		$25		$24	
Total cost of materials ($$10^3$)	$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.

B.3.2.2 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 B-25).

Table B-24. 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

[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>.

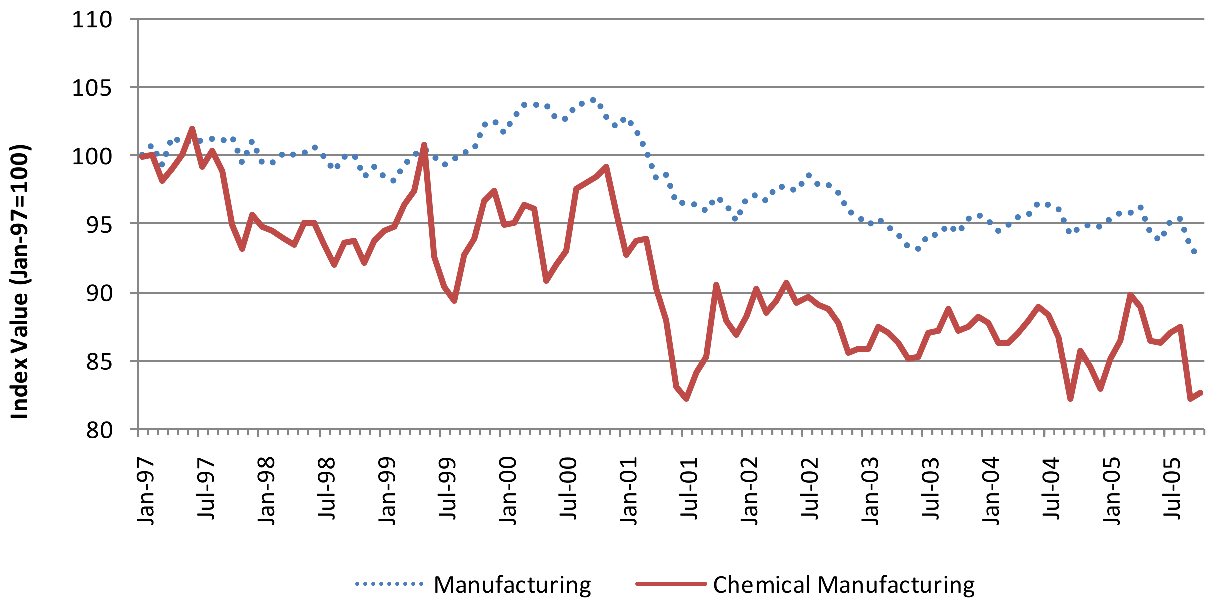


Figure B-23. Electric Power Use Trends in Chemical Manufacturing (NAICS 325): 1997–2005

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

B.3.3 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.

B.3.3.1 Location

In 2002, California had the most chemical manufacturing establishments in the United States, followed by Texas and New Jersey (Figure B-24). 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.

B.3.3.2 Production Capacity and Utilization

Capacity utilization of the chemical manufacturing industry has been broadly in line with the manufacturing sector (Figure B-25). 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.

Table B-25. Demand by Sector: Chemical Manufacturing (NAICS 325) ($2007 10^6)

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.

B.3.3.3 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 B-26).

B.3.3.4 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 B-27).

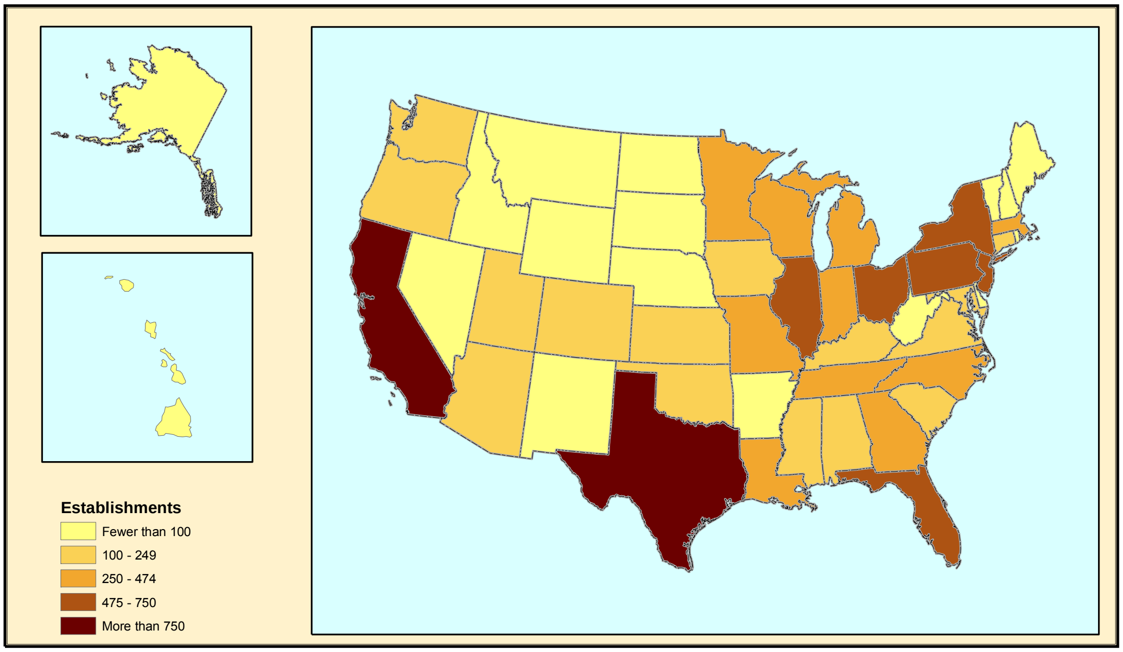


Figure B-24. Establishment Concentration in Chemical Manufacturing (NAICS 325): 2002

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).

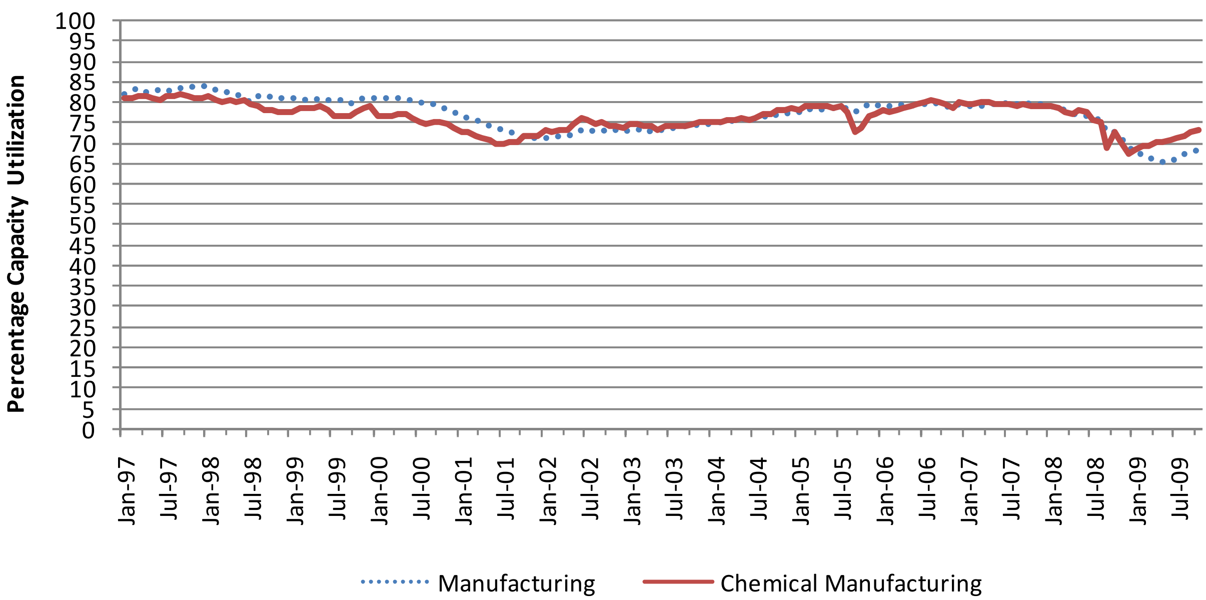


Figure B-25. Capacity Utilization Trends in Chemical Manufacturing (NAICS 325)

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

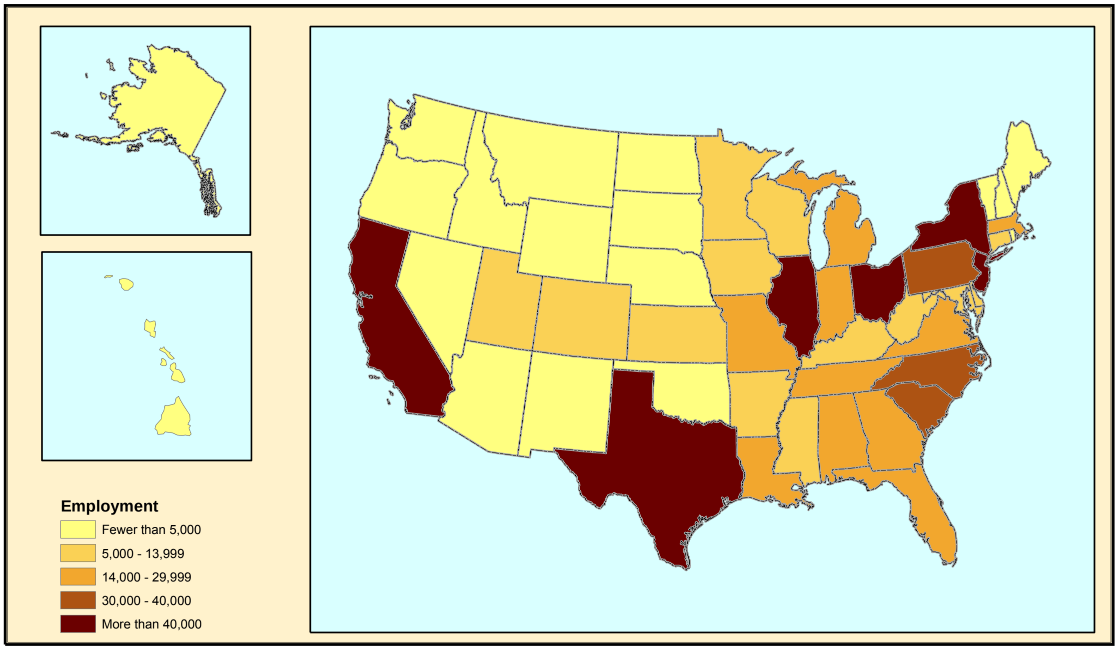


Figure B-26. Employment Concentration in Chemical Manufacturing (NAICS 325): 2002

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).

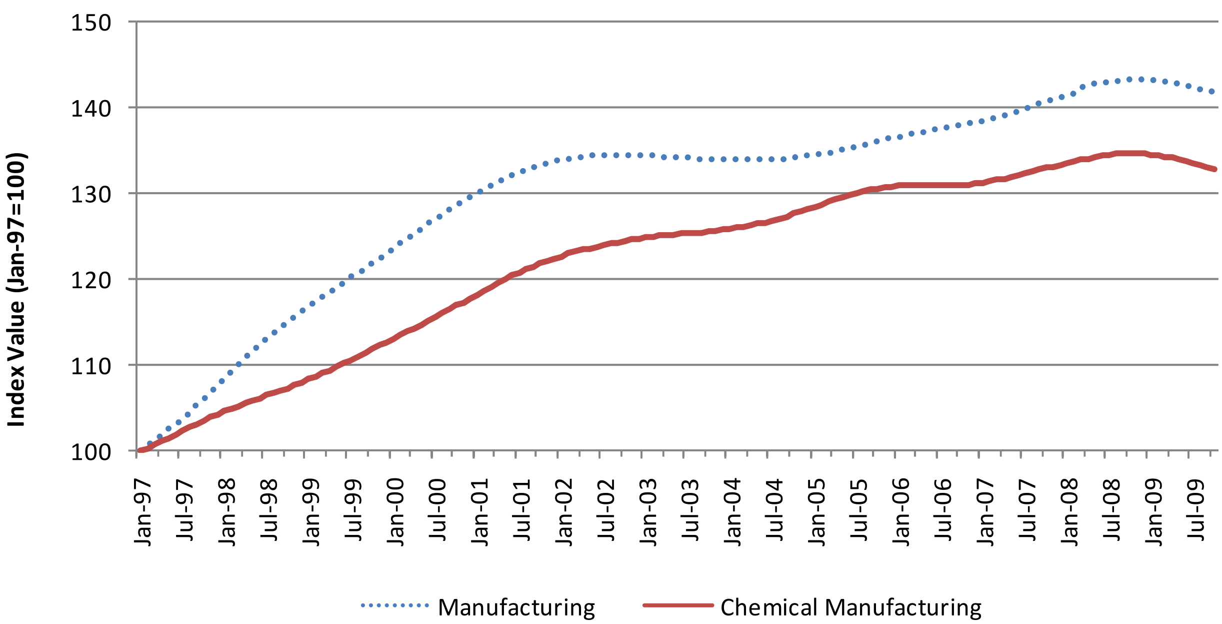


Figure B-27. Capacity Trends in Chemical Manufacturing (NAICS 325)

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

B.3.3.5 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 B-26). The largest chemical manufacturing company, Dow Chemicals, has 108 out of 150 manufacturing sites located outside of the United States (Dow Chemical Company, 2008).

Table B-26. Top Chemical Producers: 2007

	Chemical Sales ($$10^6$)	% 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.

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

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 B-27).

B.3.3.6 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 B-28. In 2002, enterprises with fewer than 500 employees accounted for 27% of employment and 15% of receipts within the chemical manufacturing industry (Table B-29).

Table B-27. 2007 Corporate Income and Profitability (NAICS 325)

Industry	Number of Corporations	Number of Corporations with Net Income	Total Receipts ($\$10^3$)	Business Receipts ($\$10^3$)	Before-Tax Profit Margin	After-Tax Profit Margin
Chemical manufacturing	9,564	5,512	$912,353,710	$808,897,810	10.24%	7.89%
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%

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).

B.3.3.7 Domestic Production

In the late 1990s, overall manufacturing production was growing much faster than the chemical manufacturing component (Figure B-28). 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.

B.3.3.8 International Trade

In the year 2000, the United States moved from having a trade surplus to a trade deficit in chemical manufacturing products (Figure B-29). 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.

B.3.3.9 Market Prices

Prices of goods in chemical manufacturing have accelerated rapidly in the last 2 years, having outpaced overall manufacturing since 2002 (Figure B-30). 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 B-28. 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 B-29. 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 ($$10^6$)	$468,211	$9,631	$21,394	$39,111	$12,217	$7,324	$14,762
Receipts/firm ($$10^3$)	$50,124	$1,779	$10,838	$49,507	$128,603	$130,779	$207,913
Receipts/establishment ($$10^3$)	$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>.

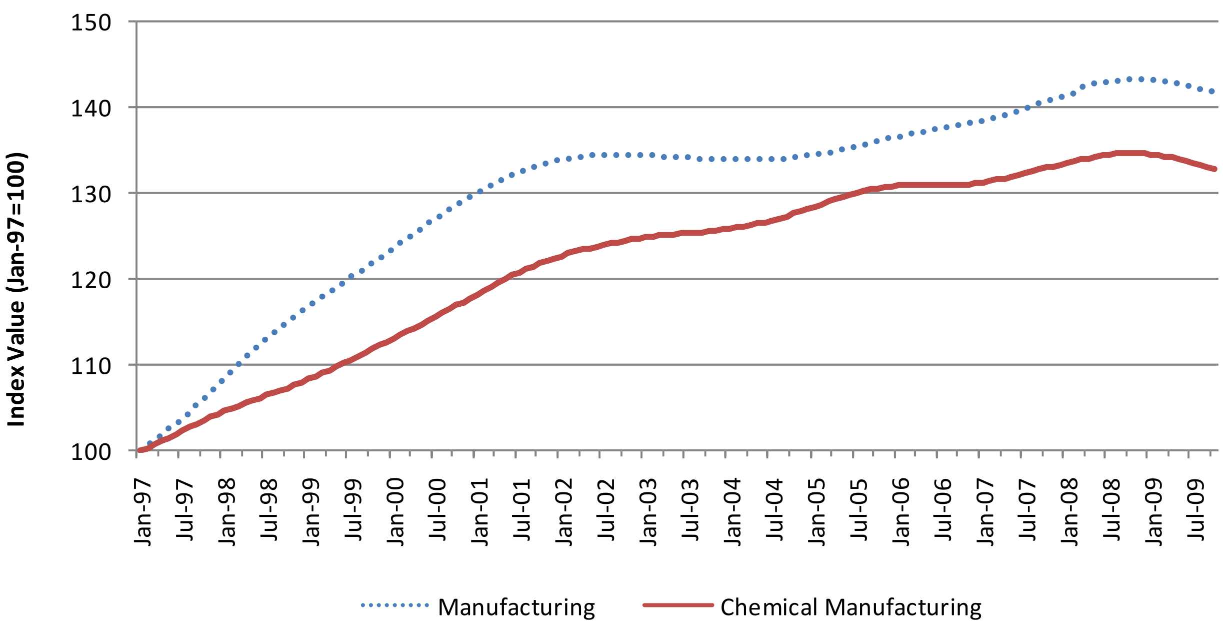


Figure B-28. Industrial Production Trends in Chemical Manufacturing (NAICS 325)

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

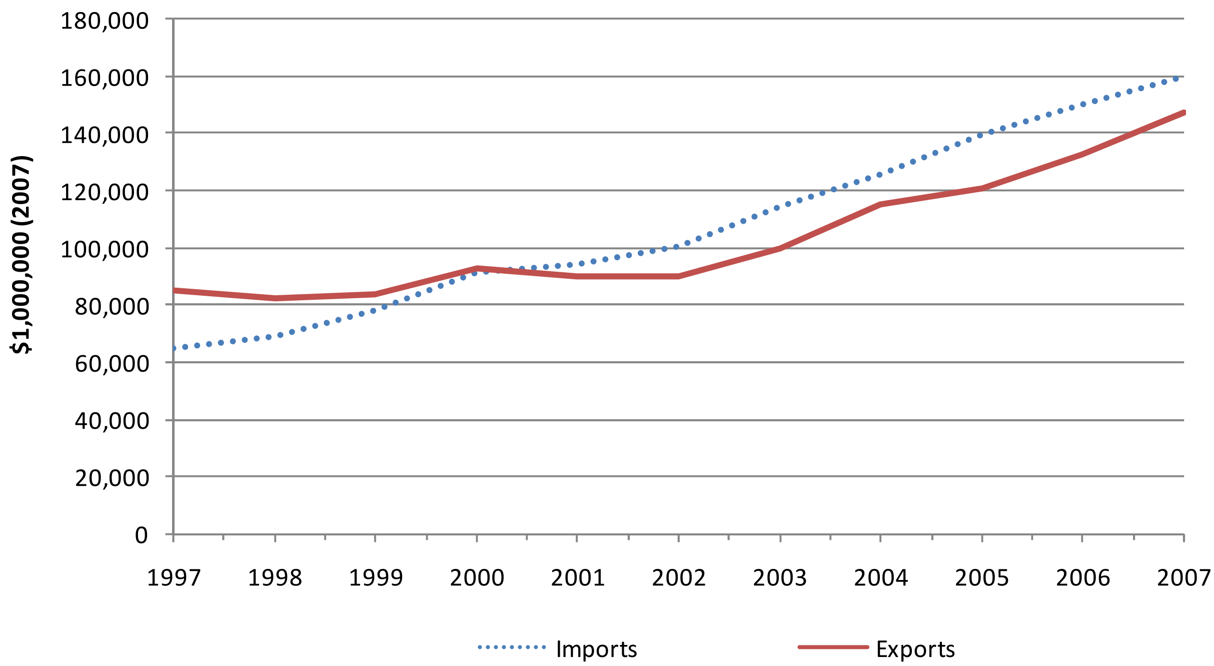


Figure B-29. International Trade Trends in Chemical Manufacturing (NAICS 325)

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

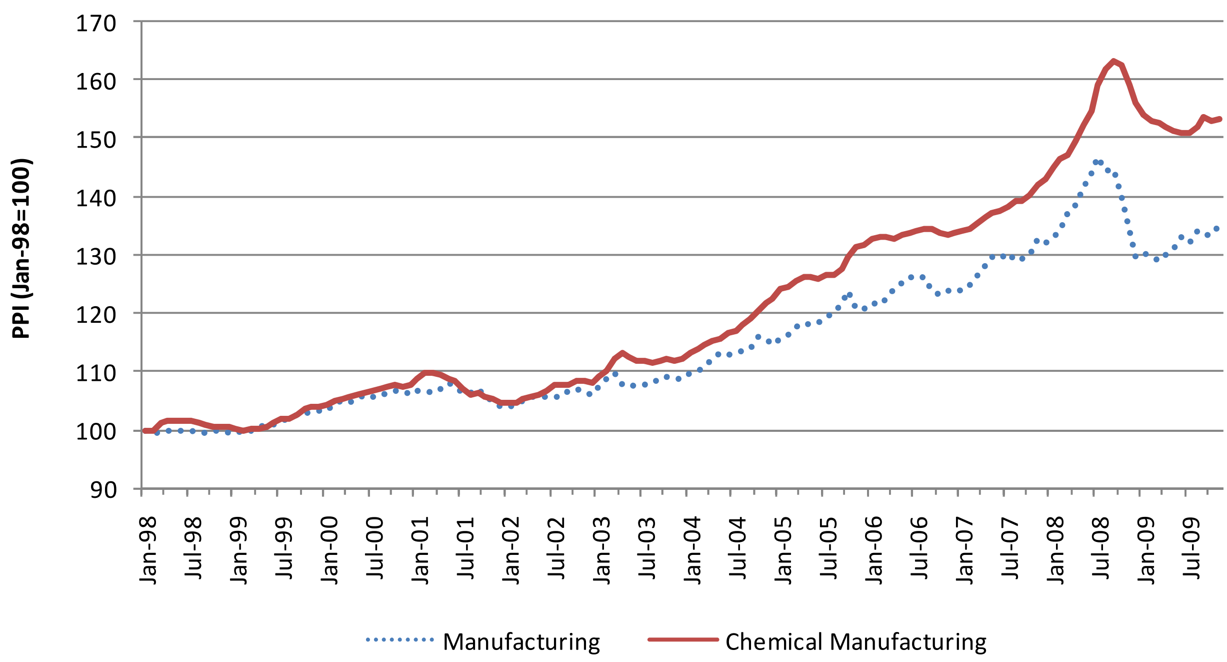


Figure B-30. Producer Price Trends in Chemical Manufacturing (NAICS 325)

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>