Regulatory Impact Analysis of the Standards of Performance for Stationary Compression Ignition Internal Combustion Engines

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Office of Air Quality Planning and Standards
Air Benefits and Costs Group
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SECTION 1

INTRODUCTION

The Sector Policies and Programs Division (SPPD) of the U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards (OAQPS) is developing a final rule to implement New Source Performance Standards (NSPS) on compression ignition (CI) stationary internal combustion engines by June 28, 2006. This rule, which is in response to a consent decree and is under the authority of Section 111(b) of the Clean Air Act, will address emissions for nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter (PM), nonmethane hydrocarbons (NMHC), and carbon monoxide (CO) from new CI engines. The requirements of the NSPS generally follow the nonroad diesel engine rule developed by EPA's Office of Transportation and Air Quality (OTAQ) in 2004. The NSPS contains requirements for owners, operators, and manufacturers of stationary CI engines. The NSPS requires manufacturers to certify their 2007 and later model year stationary nonemergency CI engines to the Tier 2, Tier 3, and Tier 4 certification emission standards for nonroad diesel engines for all the pollutants (except SO_2). This NSPS incorporates most of the requirements of the final nonroad engine rule. All new stationary CI engines ordered after the proposal date of this rule (June 29, 2005) and manufactured after April 1, 2006 (or July 1, 2006, for fire pump engines) will be covered. Engine manufacturers must follow the certification procedures and warranty, maintenance, installation, and labeling requirements specified in the nonroad engine rule. Only certain new engines will have to put on controls in response to this NSPS. Emergency engines have to certify to the Tier 2 and Tier 3 standards. Nonemergency engines with engine displacement greater than or equal to 10 liters per cylinder and less than 30 liters per cylinder displacement have to certify to the Tier 2 standards for marine engines, and engines with displacement greater than or equal to 30 liters per cylinder do not have to be certified by engine manufacturers; the owners and/or operators of engines with displacement greater than or equal to 30 liters per cylinder have to meet NO_x and PM limits. All other engines must be certified to the final Tier 4 emission standards for all pollutants. Such engines are hereafter referred to as "subject stationary CI engines."

To support EPA's development of these standards, EPA's Air Benefits and Costs Group (ABCG) has conducted an economic impact analysis (EIA) to assess the potential costs of the rule. This report documents the methods and results of this EIA.

1.1 Executive Summary

EPA estimates the NSPS will result in significant increases in market prices but small reductions in output of diesel-powered equipment using the affected engines. The economic approach and engineering cost approach yield approximately the same estimate of the total change in surplus ($57 million). However, the economic approach illustrates how costs flow through the economic system and identifies important transitory impacts on stakeholders. In addition, it identifies the distribution of welfare losses across affected markets. The key results of the RIA are as follows:

- *Engineering Costs (2002$)*: Total annualized costs measure the costs incurred by affected industries annually. The average annualized costs for the rule totaled approximately $57.1 million.
- *Price and Quantity Impacts*: The price impacts are significant; however, demand responses to price changes are estimated to be small.
  - The average prices for affected equipment are projected to increase between 2 and 10 percent. Generator set and welding equipment markets experience the highest relative change in baseline price (9.4 percent).
  - Production/consumption remain essentially unchanged, declining by less than 0.5 percent. The analysis shows that demand responses to price changes are small because the elasticities of demand for the final products or services that use affected equipment and the cost share of equipment in production of these goods and services are small.
- *Small Businesses*: EPA performed a screening analysis for impacts on small businesses by comparing compliance costs to baseline company revenues. When we compare compliance costs (costs of controls, testing, and monitoring) to total company revenue, the ratio of compliance cost to company revenue falls below 1 percent for 57 of the 60 small companies included in the screening analysis. Two small businesses have costs between 1 and 3 percent of company sales, and one small company has costs exceeding 3 percent of company sales. Assuming that these small businesses or new businesses like them will be affected by the NSPS, we do not believe that the CI NSPS will have a significant impact on a substantial number of small entities.
- *Social Costs (2002$)*: The economic model estimates a total social cost of the rule of $57.0 million, including $21.0 million of recordkeeping and reporting costs

borne largely by emergency equipment owners to record hours of nonemergency operation. Equipment producers pass on essentially all costs of control to downstream markets and consumers. Total consumer surplus change is –$37.6 million. Three-quarters of these losses occur in the generator set and welding equipment markets.

- *Energy Use Impacts*: The NSPS will reduce emissions of SO_2 by requiring the use of ultra-low sulfur diesel (ULSD) fuel. Use of low-sulfur fuel is required beginning in 2007, and in the baseline year of analysis (2015), new stationary CI equipment subject to the NSPS will be required to switch to ULSD fuel (i.e., must consume fuel meeting a 15 ppm sulfur standard). As a result, demand for ULSD fuel will increase and demand for high-sulfur No. 2 distillate will decline. Based on review of fuel consumption data from the nonroad rule, the size of the shift in quantities between these markets in 2015 is very small, and EPA anticipates this change will have negligible influence on diesel fuel prices and production/consumption choices.

- *Benefits:* The NSPS will yield benefits of almost $1.4 billion in 2015. This is due the emission reductions primarily of direct PM2.5, but the reductions in SO_2 and NOx also contribute to this total. These benefits exceed the costs by more than 20 to 1.

1.2 Organization of this Report

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

- Section 2 presents a profile of the affected industry.
- Section 3 describes the estimated costs of the regulation.
- Section 4 describes the EIA methodology and reports market welfare impacts.
- Section 5 presents estimated impacts on small companies.
- Section 6 present the benefits methodology and reports the results from applying this methodology.

SECTION 2

INDUSTRY PROFILE

2.1 The Supply Side

In this industry profile, we discuss related supply-side issues associated with industries that manufacture equipment powered by diesel engines affected by the NSPS. These industries provide three broad services: power (generator sets and welding equipment), pumping and compression, and irrigation. In this section, we discuss two important supply-side issues: costs of equipment production and technologies associated with emission controls.

2.1.1 Materials and Other Costs of Producing Equipment

The U.S. Economic Census data provide production cost data by industry. Because industry definitions are so broad, the data are limited in their ability to provide insight into absolute expenditures levels; however, the statistics provide a reasonable proxy of the relative importance of inputs in the manufacturing process. As discussed below, all of the industries have similar distributions of production costs across materials, labor, and capital. Diesel engine costs are approximately 1 to 2 percent of product value in these industries.

2.1.1.1 Generator Sets and Welding Equipment

The U.S. Economic Census classifies generator sets under "Motor and Generator Manufacturing" (North American Industry Classification System [NAICS] 33512). This industry comprises establishments primarily engaged in manufacturing electric motors (except internal combustion engine starting motors), power generators (except battery charging alternators for internal combustion engines), and motor generator sets (except turbine generator set units). It also includes establishments rewinding armatures on a factory basis.

As shown in Table 2-1, the variable production costs include materials (including energy), and labor. Of these categories, materials (including fuel and energy) represent about half of the total product value. Within the materials category, diesel and semidiesel engines account for approximately 2 percent of product value in 2002. Labor expenditures account for approximately 13 percent, and other costs such as capital, transportation, marketing, and markup represent the remaining 40 percent.

Table 2-1. Motor and Generator Manufacturing: 1997 to 2002 ($billion)

Year	Value of Shipments	Cost of Materials	Cost as a Share of Product Value (%)	Labor	Cost as a Share of Product Value (%)	Capital	Cost as a Share of Product Value (%)
2002	$9.1	$4.3	47%	$1.2	13%	$0.2	2%
2001	$9.4	$4.5	48%	$1.2	13%	$0.2	2%
2000	$10.0	$4.9	49%	$1.3	13%	$0.2	2%
1999	$10.8	$5.4	50%	$1.4	13%	$0.3	3%
1998	$11.6	$5.7	49%	$1.5	13%	$0.4	3%
1997	$12.2	$6.0	49%	$1.5	12%	$0.3	2%

Source: U.S. Bureau of the Census. 2004b. "Motor and Generator Manufacturing: 2002." *2002 Economic Census Manufacturing Industry Series*. EC02-311-335312(RV). Washington, DC: U.S. Bureau of the Census. Table 1.

The U.S. Economic Census classifies welding equipment under "Welding and soldering equipment manufacturing" (NAICS 333992). This U.S. industry comprises establishments primarily engaged in manufacturing welding and soldering equipment and accessories (except transformers), such as arc, resistance, gas, plasma, laser, electron beam, and ultrasonic welding equipment; welding electrodes; coated or cored welding wire; and soldering equipment (except handheld).

As shown in Table 2-2, the variable production costs include materials (including energy) and labor. Of these categories, materials (including fuel and energy) represent about 50 to 57 percent of the total product value. Within the materials category, the Census did not report diesel and semidiesel engine costs. Labor expenditures account for approximately 11 percent, and other costs such as capital, transportation, marketing, and markup represent the remaining 40 percent.

Table 2-2. Welding and Soldering Equipment Manufacturing: 1997 to 2002 ($billion)

Year	Value of Shipments	Cost of Materials	Cost as a Share of Product Value (%)	Labor	Cost as a Share of Product Value (%)	Capital	Cost as a Share of Product Value (%)
2002	$3.8	$1.9	50%	$0.4	11%	$0.1	3%
2001	$3.9	$2.1	54%	$0.4	10%	$0.1	3%
2000	$4.2	$2.3	55%	$0.4	10%	$0.1	2%
1999	$4.2	$2.3	55%	$0.4	9%	$0.1	2%
1998	$4.3	$2.3	53%	$0.4	9%	$0.1	2%
1997	$4.4	$2.5	57%	$0.5	11%	$0.1	2%

Source: U.S. Bureau of the Census. 2004d. "Welding and Soldering Equipment Manufacturing: 2002." *2002 Economic Census Manufacturing Industry Series*. EC02-311-333992(RV). Washington, DC: U.S. Bureau of the Census. Table 1.

2.1.1.2 Pumps and Compressors

The U.S. Economic Census classifies pumps and pumping equipment under "Pump and pumping equipment manufacturing" (NAICS 333911). This U.S. industry comprises establishments primarily engaged in manufacturing general purpose pumps and pumping equipment (except fluid power pumps and motors), such as reciprocating pumps, turbine pumps, centrifugal pumps, rotary pumps, diaphragm pumps, domestic water system pumps, oil well and oil field pumps and sump pumps.

As shown in Table 2-3, the variable production costs include materials (including energy), and labor. Of these categories, materials (including fuel and energy) represent about half of the total product value. Within the materials category, diesel and semidiesel engines accounted for approximately 0.5 percent of product value in 2002. Labor expenditures account for approximately 9 percent, and other costs such as capital, transportation, marketing, and markup represent the remaining 43 percent.

The U.S. Economic Census classifies compressors under "Air and gas compressor manufacturing" (NAICS 333912). This U.S. industry comprises establishments primarily engaged in manufacturing general purpose air and gas compressors, such as reciprocating compressors, centrifugal compressors, vacuum pumps (except laboratory), and nonagricultural spraying and dusting compressors and spray gun units.

Table 2-3. Pumps and Pumping Equipment Manufacturing: 1997 to 2002 ($billion)

Year	Value of Shipments	Cost of Materials	Cost as a Share of Product Value (%)	Labor	Cost as a Share of Product Value (%)	Capital	Cost as a Share of Product Value (%)
2002	$7.0	$3.4	49%	$0.6	9%	$0.2	3%
2001	$7.4	$3.6	49%	$0.6	8%	$0.2	3%
2000	$7.6	$3.7	49%	$0.6	8%	$0.2	3%
1999	$7.2	$3.5	49%	$0.6	8%	$0.2	3%
1998	$7.6	$4.0	53%	$0.7	9%	$0.2	3%
1997	$6.7	$3.3	49%	$0.7	10%	$0.2	3%

Source: U.S. Bureau of the Census. 2004c. "Pump and Pumping Equipment Manufacturing: 2002." *2002 Economic Census Manufacturing Industry Series*. EC02-311-333911(RV). Washington, DC: U.S. Bureau of the Census. Table 1.

As shown in Table 2-4, the variable production costs include materials (including energy), and labor. Of these categories, materials (including fuel and energy) represent 55 to 60 percent of the total product value. Within the materials category, diesel and semidiesel engines account for approximately 1.8 percent of product value in 2002. Labor expenditures account for approximately 8 percent, and other costs such as capital, transportation, marketing, and markup represent the remaining 35 percent.

Table 2-4. Air and Gas Compressor Manufacturing: 1997 to 2002 ($billion)

Year	Value of Shipments	Cost of Materials	Cost as a Share of Product Value (%)	Labor	Cost as a Share of Product Value (%)	Capital	Cost as a Share of Product Value (%)
2002	$4.8	$2.7	56%	$0.4	8%	$0.2	4%
2001	$5.6	$3.0	54%	$0.4	7%	$0.2	4%
2000	$6.2	$3.3	53%	$0.4	6%	$0.2	3%
1999	$5.7	$3.0	53%	$0.4	7%	$0.2	4%
1998	$5.7	$3.1	54%	$0.5	9%	$0.2	4%
1997	$5.6	$3.1	55%	$0.5	9%	$0.2	4%

Source: U.S. Bureau of the Census. 2004c. "Pump and Pumping Equipment Manufacturing: 2002." *2002 Economic Census Manufacturing Industry Series*. EC02-311-333911(RV). Washington, DC: U.S. Bureau of the Census. Table 1.

2.1.1.3 Irrigation Systems

The U.S. Economic Census classifies irrigation equipment under "Farm Machinery and Equipment Manufacturing" (NAICS 333111). This U.S. industry comprises establishments primarily engaged in manufacturing agricultural and farm machinery and equipment, and other turf and grounds care equipment, including planting, harvesting, and grass mowing equipment (except lawn and garden-type).

As shown in Table 2-5, the variable production costs include materials (including energy), and labor. Of these categories, materials (including fuel and energy) represent 52 to 57 percent of the total product value. Within the materials category, diesel and semidiesel engines accounted for approximately 2.2 percent of product value in 2002. Labor expenditures account for approximately 9 percent, and other costs such as capital, transportation, marketing, and markup represent the remaining 39 percent.

Table 2-5. Farm Machinery and Equipment Manufacturing: 1997 to 2002 ($billion)

Year	Value of Shipments	Cost of Materials	Cost as a Share of Product Value (%)	Labor	Cost as a Share of Product Value (%)	Capital	Cost as a Share of Product Value (%)
2002	$14.7	$7.7	52%	$1.3	9%	$0.3	2%
2001	$14.1	$7.6	54%	$1.3	9%	$0.3	2%
2000	$13.5	$7.7	57%	$1.4	10%	$0.3	2%
1999	$11.8	$6.4	54%	$1.3	11%	$0.3	3%
1998	$16.5	$8.5	52%	$1.5	9%	$0.4	2%
1997	$16.0	$8.4	53%	$1.6	10%	$0.5	3%

Source: U.S. Bureau of the Census. 2004a. "Farm Machinery and Equipment Manufacturing: 2002." *2002 Economic Census Manufacturing Industry Series*. EC02-311-333111(RV). Washington, DC: U.S. Bureau of the Census. Table 1.

2.1.2 Potential Changes in Material Inputs

Under the NSPS, subject nonemergency stationary CI internal combustion engines must be certified to meet Tier 4 emission standards for NO_x, NMHC, PM, and CO (Parise, 2005a, 2005b). To address emissions of these pollutants, several changes in the manufacturing design and/or material inputs have been considered. Among those are the following:

- catalyzed diesel particulate filters (CDPFs): Tier 4 emission standards for engines greater or equal 25 horsepower (hp) are based on the use of this control technology. It is estimated CDPFs will reduce PM emissions by more than 90 percent, and also reduce NMHC and CO emissions by a significant amount.
- NO_x adsorbers: Tier 4 emission standards for engines greater or equal to 75 hp are based on the use of this control technology. It is estimated NO_x adsorbers will reduce NO_x emissions by 90 percent.
- lower-sulfur fuel: the owners and operators of the subject stationary CI internal combustion engines will be required to use diesel fuel containing 500 parts per million (ppm) sulfur or less by October 1, 2007. This requirement will be lowered to 15 ppm (ultra-low sulfur diesel or ULSD) by October 1, 2010.

2.2 The Demand Side

The demand for diesel equipment is derived from consumer demand for the services and products the equipment provides. We describe uses and consumers of these products as well as provide examples of substitution possibilities in consumption. Results of econometric estimates of elasticities for downstream service and product markets are included as well.

2.2.1 Generators and Welding Equipment

Generator sets provide power for prime, standby, and peaking power industrial, commercial, and communications facilities. Prime power units typically have lower horsepower ratings while standby units have higher horsepower ratings. Potential substitutes including natural gas generation units and a recent industry study suggests over 1/3 of 1,000 hp or higher sets use fuels other than diesel (Rhein Associates, 2002). However, diesel-engine generators appear to be still preferred in remote/offsite agriculture and construction uses (EPA, 2004).

EPA's profile of nonroad welding machines found that similar substitution issues exist for on-site versus remote locations (EPA, 2004). On-site facility welding can be accomplished with electric (AC or battery-operated) units, an arrangement not possible for off-site uses. Gas welders provide a third option, one that is not dependent on a local infrastructure.

In Table 2-6, we use the latest detailed Benchmark Input-Output Data report by the Bureau of Economic Analysis (U.S. BEA, 2002) to identify industries that use generators and welding equipment. Note that these data include all types of generators and welding

Table 2-6. Generator Set and Welding Equipment Use by Industry: 1997

Commodity Code	IO-CodeDetail_I-O Description	Industry Code	IO-CodeDetail_I-O Description	Use Value	Direct Requirements Coefficients[a]
335312	Motor and generator manufacturing				
		333415	AC, refrigeration, and forced air heating	1,364.2	6.23%
		811300	Commercial machinery repair and maintenance	453.4	1.38%
		333911	Pump and pumping equipment manufacturing	451.4	6.97%
		335312	Motor and generator manufacturing	408.7	3.46%
		334119	Other computer peripheral equipment manufacturing	398.7	1.67%
333992	Welding and soldering equipment manufacturing				
		811300	Commercial machinery repair and maintenance	408.3	1.24%
		332312	Fabricated structural metal manufacturing	170.5	1.13%
		811400	Household goods repair and maintenance	140.9	0.57%
		333298	All other industrial machinery manufacturing	107.3	1.34%
		230220	Commercial and institutional buildings	61	0.03%

Note: The data include generators and welding equipment that is not affected by the proposed NSPS.

[a]These values show the amount of the commodity required to produce $1.00 of the industry's output.

Source: U.S. Bureau of Economic Analysis. 2002. 1997 Benchmark Input-Output Accounts: Detailed Make Table, Use Table and Direct Requirements Table. Tables 4 and 5.

equipment and are not restricted to stationary diesel-powered equipment affected by the NSPS. For all generators and welding and soldering equipment, NAICS 33415 (AC, refrigeration, and forced air heating) is the largest users of generators, and other industries that are relatively large demanders include pumping equipment manufacturing, generators and welders manufacturing, and machinery repair. NAICS 811300 (Commercial machinery repair and maintenance) is the largest user of welding and soldering equipment; other major users include fabricated metal manufacturing, household goods repair, and other industrial machinery manufacturing.

2.2.2 Stationary Pumps and Compressor Equipment

The construction industry is an important consumer of pump and compressor equipment; as a result, demand for this equipment fluctuates with construction activity. Oil field drilling and well servicing applications are primary consumers of high horsepower equipment such as drills and compressors. Demand in these areas is influenced by changes in fuel prices and changes in overall economic activity.

In Table 2-7, we use the latest detailed Benchmark Input-Output Data report by the Bureau of Economic Analysis (U.S. BEA, 2002) to identify industries that use pumps and compressor equipment. Again, these data include all types of pumps and compressor equipment and are not restricted to stationary diesel-powered equipment affected by the NSPS. Nonagricultural demanders of pumps and pumping equipment include railway transportation, nonfarm single family homes, and semiconductor machinery manufacturing. Major demanders of compressor equipment include construction of single-family homes and additions, and manufacturing of compressor equipment, motor vehicle parts, and plastic products.

2.2.3 Irrigation

Demand for irrigation equipment is driven by farm operators' supply decisions, optimal replacement considerations, and climate and weather conditions. The National Agriculture Statistics Service (NASS) 2003 Farm and Ranch Irrigation Survey (USDA-NASS, 2004) shows the top five states ranked by total acres irrigated are California, Nebraska, Texas, Arkansas, and Idaho. The survey showed that approximately 500,000 pumps were used on U.S. farms in 2003 with energy expenses totaling $1.5 billion dollars. Electricity is the dominant form of energy expense for irrigation pumps, accounting for 60 percent of energy expenses. Diesel fuel is second (18 percent), followed by natural gas (18 percent), and other forms of energy (4 percent). The report also notes that 411 pumps were powered by solar or other renewable energy sources. In 2003, farmers and ranchers spent approximately $13,000 per farm on irrigation investments.

Table 2-7. Pumps and Compressor Equipment Use by Industry: 1997

Commodity Code	IO-CodeDetail_I-O Description	Industry code	IO-CodeDetail_I-O Description	Use Value	Direct Requirements Coefficients
333911	Pump and pumping equipment manufacturing				
		482000	Rail transportation	508.4	1.34%
		230110	New residential 1-unit structures, nonfarm	208.1	0.12%
		333295	Semiconductor machinery manufacturing	173.7	1.64%
		230210	Manufacturing and industrial buildings	92.6	0.34%
		213111	Drilling oil and gas wells	77.7	0.82%
333912	Air and gas compressor manufacturing				
		230110	New residential 1-unit structures, nonfarm	211.9	0.12%
		333912	Air and gas compressor manufacturing	115.0	2.22%
		230130	New residential additions and alterations, nonfarm	56.1	0.10%
		336300	Motor vehicle parts manufacturing	50.0	0.03%
		32619A	Plastics plumbing fixtures and all other plastics products	50.0	0.08%

Note: The data includes pumps and compressor equipment that is not affected by the NSPS.

[a]These values show the amount of the commodity required to produce one dollar of the industry's output.

Source: U.S. Bureau of Economic Analysis. 2002. 1997 Benchmark Input-Output Accounts: Detailed Make Table, Use Table and Direct Requirements Table. Tables 4 and 5.

2.2.4 Empirical Data Elasticities

Stationary diesel equipment is used in the production of a variety of goods and services. Economic theory suggests the demand for stationary diesel equipment is strongly influenced by the elasticity of final demand for the product or service the equipment is used to produce. EPA’s nonroad diesel economic analysis (EPA, 2004) identified key markets where stationary diesel equipment was used and econometrically estimated demand elasticities for these markets. Demand elasticities measure the percent change in quantity demanded in response to a percent change in price. As shown in Table 2-8, final product/service demand is inelastic, that is, not very responsive to changes in prices. For example, a one percent

Table 2-8. Empirical Demand Elasticity Estimates: Final Product Markets Where Stationary Diesel Equipment is Used

	Stationary Gen Sets and Welders	Stationary Pumps and Compressors	Stationary Irrigation Systems
Demand Characterization	Derived demand	Derived demand	Derived demand
Final Product Market and Demand Elasticity (η^D)	Manufacturing –0.6	Manufacturing –0.6	Agriculture –0.2
	EPA (2004) Econometric estimate (inelastic)	EPA (2004) Econometric estimate (inelastic)	EPA (2004) Econometric estimate (inelastic)

increase in agricultural prices leads to only a 0.2 percent decline in demand for agricultural output.

2.3 Industry Organization

To estimate the economic impacts of a regulation, it is important to have an understanding of industry organization. We discuss key issues in this industry, identify firms and small businesses participating in the market, and discuss issues related to pricing behavior in these markets.

2.3.1 Diesel Engines: The Equipment Firm's "Make" or "Buy" Decision

Vertically integrated firms own a combination of "upstream" and "downstream" production operations; for example, vertically integrated diesel equipment manufactures make the engines used in equipment rather than buy diesel engines from independent diesel engine manufacturers. Although there are several reasons firms may choose this structure, two frequently cited benefits are reducing transaction costs associated with input purchases and taking advantage of technological economies that arise through integrated production structures (Viscusi, Vernon, and Harrington, 1992). A review of the Power Systems Research (PSR) data for 2000 shows that vertical operations are more likely to occur in diesel-powered generator set and irrigation system industries relative to the other directly affected markets. Approximately 30 to 40 percent of manufactured diesel engines in these equipment markets were consumed internally by integrated manufacturers in these applications.

2.3.2 *Defining the Products that Constitute the Market*

To assess market structure, we need a clear definition of the "market(s)" along geographic and product dimensions. There are two distinctive product characteristics we use to define the products. First, consumers are more likely to view products with similar horsepower ratings as close substitutes, so it seems reasonable to delineate the markets by horsepower categories defined in the engineering cost analysis and by EPA (2004). Second, after reviewing the EPA industry characterization for the Clean Air Nonroad Diesel Rule (EPA, 2004), the California Air Resources Board's (CARB's) Staff Report for the Airborne Toxic Control Measure for Stationary Compression-Ignition Engines (CARB, 2003), and a private industry study of the diesel engine markets (Rhein Associates, 2002), we have identified three broad nonemergency stationary diesel equipment applications where buyers and sellers would generally be unwilling to shift consumption/production among groups. These include generator sets and welding equipment, pumps and compressors, and irrigation systems. Market data associated with these applications are discussed in Section 2.4.

2.3.3 *Key Firms Currently Participating in these Markets*

EPA identified key firms in each of the markets using market share data from 2000 (PSR, 2004). As discussed below, sales are concentrated among a few top firms identified in each market (see Table 2-9).

2.3.3.1 Generators and Welders

Sales leaders in the diesel-powered generator set market include two Korean firms (Korean GenSets and Daewoo Heavy Industries & Machinery Ltd.) and Honda Motor Company. Large public firms Lincoln Electric and Illinois Tool Works dominate sales of diesel-powered welding equipment. Hoovers identifies Lincoln Electric as a leading manufacturer of arc-welding, cutting products, and welding supplies including arc-welding power sources, automated wire-feeding systems, and consumable electrodes for arc-welding. Its major competitor is Illinois Tool Works, a diversified company that makes products in the automotive, construction, paper products, and food and beverage industries (Hoovers, 2005).

2.3.3.2 Pumps and Compressors

Leaders in the pump sector include a small privately owned business, Pacer Pumps, and a public company, Gorman-Rupp Company. Gorman-Rupp makes pumps used in a variety of industries, including agriculture and construction work, sewage treatment,

Table 2-9. Firm Market Shares by Equipment Market: 2000

	Market Share
Pumps	
Pacer Pumps	13%
Gorman-rupp Company	11%
Godwin Pumps of America	9%
Air and Gas Compressors	
Ingersoll-rand	43%
Atlas Copco ab	17%
Sulliar Corp.	13%
Hydraulic Power Units	
Hydra-tech Pumps	26%
Griffin Dewatering Corporation	14%
Blount Inc.	14%
Generator Sets	
Korean Gen-sets	13%
Daewoo Heavy Ind.	11%
Honda Motor Company Ltd.	11%
Welders	
Illinois Tool Works Inc.	43%
Lincoln Electric	55%
Irrigation Sets	
Springfield Remanufacturing	28%
Deere & Company	27%
Tradewinds Power Corporation	19%

Source: Power Systems Registry (PSR). 2004. OELink™. <http://www.powersys.com/OELink.htm>.

petroleum refining, agriculture, and fire fighting, as well for HVAC and military applications (Hoovers, 2005). The top three pump makers accounted for only one-quarter of pump sales in 2000. Industrial machinery giant Ingersoll-Rand led sales in the air and gas compressor market in 2000. Atlas Copco AB and Sulliar Corporation (a division of Hamilton Sundstrand Corporation) are other key players in this market.

2.3.3.3 Irrigation Equipment

Sales leaders in this market include Springfield Remanufacturing, Deere and Company, and Tradewinds Power Corporation. Deere & Company is one of the two largest makers of farm equipment (Hoovers, 2005). Tradewinds Power is a small private firm that makes a range of engines for the power generation industry as well as power units, pump sets, and transmissions for industrial and irrigation use (Hoovers, 2005). Together, these three companies account for approximately 75 percent of the diesel-powered irrigation system market in 2000.

2.3.3.4 Diesel Engines

Engine production leaders for these markets include well-known domestic names Deere and Company, Caterpillar, and Cummins. Kubota Engine America, a subsidiary of Japanese Kubota Corporation, is another major seller in this market, primarily of small engines in industrial, agricultural, construction, and power generation equipment. Other Asian competitors are Korean companies Kukje Machinery Co. Ltd and Daewoo Heavy Industries & Machinery Ltd. European competitors include German companies Deutz AG and Motorenfabrik Hatz, which owns North American subsidiary Hatz Diesel of America, Inc. Small businesses in this industry include Wisconsin Motors (owned by V&L Tools). Wisconsin Motors produces diesel engines for a small niche market and served as a Small Entity Representative (SER) during the Small Business Advocacy Review Panel process for the Clean Air Nonroad Diesel Rule (EPA, 2004, p 11-8).

2.3.4 Description of Small and Large Firms

Small entities include small businesses, small organizations, and small governmental jurisdictions. For purposes of assessing the impacts of the CI NSPS, a small entity is defined as

- a small business whose parent company has fewer than 1,000 employees (for NAICS 335312 [Motor and Generator Manufacturing]) or 500 employees (for NAICS 333911 [Pump and Pumping Equipment Manufacturing], NAICS 333912 [Air and Gas Compressor Manufacturing], and NAICS 333992 [Welding and Soldering Equipment Manufacturing]).
- a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of fewer than 50,000.
- a small organization that is any not-for-profit enterprise, which is independently owned and operated and is not dominant in its field.

To identify sales and employment characteristics of affected parent companies, we use a company database developed for small business analysis of the Clear Air Nonroad Diesel Rule (EPA, 2004). Since the rule does not affect all companies included in the database, the analysis only includes companies that produce the following types of equipment:

- Pumps and compressors (Pump and Pumping Equipment Manufacturing [NAICS 333911] or Air and Gas Compressor Manufacturing [NAICS 333912])
- Welders and generators (Motor and Generator Manufacturing [NAICS 335312] or Welding and Soldering Equipment Manufacturing [NAICS 333992])

We identified 60 small companies and 44 large companies with sales data. Using the data, we found 62 companies manufacture products that are included in the Pump and Pumping Equipment Manufacturing (NAICS 333911) or Air and Gas Compressor Manufacturing (NAICS 333912) industries and 30 companies manufacture products included in the Motor and Generator Manufacturing (NAICS 335312) or Welding and Soldering Equipment Manufacturing (NAICS 333992) industries. The remaining 12 companies manufacture equipment in both PSR segments. The average small firm's annual sales are approximately $30 million compared to nearly $6 billion for large firms. The average small firm employed 100 people while the average large firm employed over 20,000 people.

2.3.5 Pricing Behavior in Equipment Markets

In the Clean Air Nonroad Diesel Rule, EPA argued that the competitive assumption is "widely accepted economic practice for this type of analysis (see, for example, EPA [2000], p. 126), especially in cases where existing analysis suggests that mitigating factors limit the potential for raising price above marginal cost" (EPA, 2004, p. 10-5). The mitigating factors cited in the nonroad rule include significant levels of domestic and international competition and significant excess capacity enabling competitors to quickly respond to changes in price. In addition, there were no indications of barriers to entry or evidence of high levels of strategic behavior in the price and quantity decisions of the firms. Our review of the available industry data suggests similar conditions are likely to be present in the markets included in this analysis.

2.4 Market Data

To perform the economic impact analysis, we compare baseline market conditions for affected markets with counterfactual conditions produced under a new policy. This comparison requires developing a dataset for generator sets and welders, pumps and compressors, and irrigation equipment markets for the year 2015, the baseline year of analysis. In this section, we describe elements of the dataset and include information on quantities and prices for these three markets together with historical and projected data.

2.4.1 Baseline Quantities

EPA has estimated that there will be approximately 16,000 new stationary nonemergency CI engines produced in the United States in 2015. This is 20 percent of the total population of stationary CI engines (which is 82,000). The other stationary CI engines are used for emergency applications (such as producing power when electric generation from the local utility is interrupted, pumping water in case of fire or flood). The majority (10,200, or 62 percent) of stationary nonemergency CI engines will be used in the generator sets and welders equipment market, with 32 percent of the engines used in the pumps and compressors market, and 6 percent used in the irrigation equipment market (see Table 2-10). Under the assumption that there is one-to-one correspondence between engines and equipment, it is reasonable to assume that these statistics reflect the equipment population as well.

Table 2-10. Baseline Quantities for Engines and Equipment: 2015

Stationary Nonemergency Generator Sets and Welders	Stationary Nonemergency Pumps and Compressors	Stationary Nonemergency Irrigation Systems	Grand Total
51–75 hp	**51–75 hp**	**50–100 hp**	
1,066	693	272	
76–100 hp	**76–100 hp**	**101-600 hp**	
1,532	1,343	707	
101–175 hp	**101–175 hp**		
2,479	1,111		
>176 hp	**>176 hp**		
5,132	2,011		
Total	**Total**	**Total**	
10,210	5,158	979	16,347

Source: Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI engine population by NAICS. April 20, 2005.

2.4.2 Baseline Prices

For the Clean Air Nonroad Diesel Rule, EPA collected price data for the nonroad diesel equipment from a variety of sources, including the U.S. General Services Administration and various Web sites. A relationship between price and horsepower was obtained using a linear regression technique (see Guerra [2005], p. 2). Using these linear equations and median horsepower for each market, we estimated national prices for stationary nonemergency CI equipment. As shown in Table 2-11, estimates range from

$7,200 to $86,200 and vary among applications. In each horsepower category, prices for small horsepower pumps and compressors and irrigation systems are typically higher than those for generator sets and welders.

2.4.3 Historical Data

Despite significant declines in 2000 sales, generator sets and welding markets grew at an average annual rate of 9 percent between 1990 and 2000. As shown in Table 2-12, this growth was led by low horsepower equipment (less than 100 hp). Irrigation equipment showed similar strong growth rates during the period (7 percent), followed by pumps and compressors.

Table 2-11. Baseline Equipment Prices: 2015

Stationary Nonemergency Generator Sets and Welders	Stationary Nonemergency Pumps and Compressors	Stationary Nonemergency Irrigation Systems
51–75 hp	**51–75 hp**	**50–100 hp**
$7,231	$13,960	$42,247
76–100 hp	**76–100 hp**	**101–600 hp**
$10,101	$19,499	$75,815
101–175 hp	**101–175 hp**	
$15,840	$30,578	
>176 hp	**>176 hp**	
$44,535	$86,192	

Note: Calculated computed using Guerra (2005) and midpoint value of horsepower range.

Table 2-12. Historical Unit Sales Data by Market: 1990–2000

	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Stationary Nonemergency Generator Sets and Welders											
50–75	762	1,637	658	466	279	361	303	282	336	354	304
76–100	993	1,355	525	434	315	342	289	238	206	249	164
101–175	1,773	2,179	1,247	1,081	886	1,122	1,137	1,133	928	934	774
>176	2,926	2,591	2,588	2,093	1,485	1,792	1,708	1,607	1,522	1,577	1,415
Total	6,454	7,762	5,019	4,074	2,965	3,617	3,437	3,260	2,991	3,114	2,656
Stationary Nonemergency Pumps and Compressors											
50–75	289	357	354	334	285	285	254	203	204	254	297
76–100	494	460	421	384	326	321	289	260	228	258	266
101–175	427	459	508	533	590	604	517	456	436	531	504
>176	993	939	875	784	823	809	658	566	487	606	712
Total	2,203	2,216	2,158	2,036	2,024	2,017	1,718	1,485	1,355	1,649	1,780
Stationary Nonemergency Irrigation Systems											
50–100	81	72	62	65	75	72	60	57	65	70	63
101–600	663	620	584	528	511	477	460	410	360	328	293
Total	744	692	646	592	585	549	521	468	425	399	356

Source: Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI engine population by NAICS. April 20, 2005.

2.4.4 Projections

Using 10-year growth data for engines (Sorrels, 2005), the Agency estimated that stationary nonemergency CI engine markets will continue to grow at historical rates (see Table 2-13). The total affected population is estimated to grow from 11,700 to 16,300 engines between 2005 and 2015.

Table 2-13. Projected Annual Unit Sales for Nonemergency CI Engines: Selected Years

Hp Range	2005	2010	2015
50–75	1,314	1,551	1,788
75–100	2,068	2,593	3,119
100–175	3,148	3,701	4,255
175–300	3,029	3,710	4,391
300–600	1,203	1,368	1,532
600–750	172	189	205
750–1,200	391	453	515
1,200–3,000	382	446	510
Over 3,000	32	32	32
Total	11,738	14,042	16,347

Source: Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI NSPS Cost Impacts 05-26-05. June 1, 2005.

SECTION 3

REGULATORY PROGRAM COST ESTIMATES

Under the NSPS, subject nonemergency stationary CI internal combustion engines must be certified to meet Tier 4 emission standards for NO_x, NMHC, PM, and CO (Parise, 2005a, 2005b). To address emissions of these pollutants, several changes in the manufacturing design and/or material inputs have been considered. Among those are the following:

- CDPFs: Tier 4 emission standards for engines greater than or equal to 25 hp are based on the use of this control technology. It is estimated CDPFs will reduce PM emissions by more than 90 percent and also reduce NMHC and CO emissions by a significant amount.
- NO_x adsorbers: Tier 4 emission standards for engines greater or equal to 75 hp are based on the use of this control technology. It is estimated NO_x adsorbers will reduce NO_x emissions by 90 percent.

The total estimated costs of the NSPS for stationary CI engines are presented in Table 3-1. The capital cost of control of the NSPS is estimated to be $67 million in 2015, the model year for which stationary CI internal combustion engines would have to meet final Tier 4 emission standards. The annualized cost of control of the NSPS is estimated to be $36 million in 2015. The total annualized cost including accumulated reporting costs in 2015 is estimated to be $57.1 million.

Table 3-1. Summary of Total Costs Associated with the NSPS

	Total Costs ($million)						
Type of Cost	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Capital control cost	31.0	40.1	42.4	62.7	66.8	68.6	70.3
Annual control cost	4.4	10.4	16.8	26.1	36.1	46.3	56.8
Reporting	10.2	12.5	15.0	17.5	20.0	23.0	25.6
Total annualized cost	15.4	23.8	32.7	44.5	57.1	70.1	83.4

SECTION 4

ECONOMIC IMPACT ANALYSIS: METHODS AND RESULTS

The EIA uses a combination of theory and simulation modeling to evaluate potential behavior changes associated with a new regulatory program. The goal is to estimate the impact of the regulatory program on producers and consumers. For this analysis, we chose to use a partial equilibrium (PE) modeling approach for the affected markets for two reasons. First, although these commodities may be an intermediate good used in the market, price changes that will occur in these markets will be small enough that production and consumption choices in related markets will be approximately unaffected. Similarly, changes in household income that could affect the demand for other products and services are expected to be small enough that they are not explicitly modeled.[1] In addition, an intermediate run approach is used in this EIA because it is likely that producers have flexibility to adjust selected factors of production but *some* of the factors (e.g., capital) still remain fixed. This lack of resource mobility captures potential transitory impacts on producers during the analysis period.

4.1 Analytical Approach

The CI NSPS and Clean Air Nonroad Diesel rule affect similar markets, so their impacts can be modeled in similar ways. Both rules increase the costs of manufacturing engines, the demand for which derives from the demand for the equipment in which the engines will be used. However, size and other differences between the rules led to the development of a separate model for the CI NSPS analysis. For example, the Nonroad Diesel Economic Impact Model (NDEIM) models derive the demand for equipment and engines from those "final" application markets; in the CI NSPS EPA simplified this approach and only models diesel equipment markets that use affected engines in their production process. EPA characterizes the response of equipment demand to changes in equipment prices with an

[1]Mas-Colell et al. (1995) and Vives (1987) provide a technical discussion of these issues.

elasticity parameter.[2] We discuss and compare NDEIM's characterization of equipment demand responses and the CI NSPS method below.

NDEIM's relationships explicitly link the demand for engines and equipment to the market behavior in an "application" market. A demand curve specified in terms of its downstream consumption is referred to as a derived demand curve (see Figure 4-1 for a graphical illustration of how a derived demand curve is identified). Consider an event in the equipment market that causes the price of equipment to increase by ΔP (such as an increase in the price of engines). This increase in the price of equipment will cause the supply curve in the application market to shift, leading to a decreased quantity of activity (ΔQ_C). The change in activity leads to a decrease in the quantity demanded for equipment (ΔQ_E). The new point ($Q_E - \Delta Q_E$, $P + \Delta P$) traces out the derived demand curve. The supply and demand function in the application market are needed to identify the derived demand in the construction equipment market.

An alternative approach to identifying the demand response is to derive an expression for the derived demand elasticity parameter using economic theory. Economist Alfred Marshall identified four factors that influence an industry's price elasticity of demand for a factor (Hicks, 1963; Layard and Walters, 1978). We restate these "rules" in terms of the industry elasticity of demand for equipment (ξ_{IE}) and the two factor production functions (equipment and labor). The (absolute) elasticity of demand for equipment in industry varies directly with

- the (absolute) elasticity of demand for the product or service the industry produces (η^D),
- the cost share of equipment (v_E) in production,
- the elasticity of supply of other factors (i.e., labor) (η^S), and
- the elasticity of substitution between equipment and other factors (σ_{EL}).

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[2]By doing this, we implicitly assume engine manufacturers fully pass on the control costs up the supply chain to the equipment market. The elasticity parameters and results of the numerical simulations in the nonroad economic impact analysis support the use of this simplification.

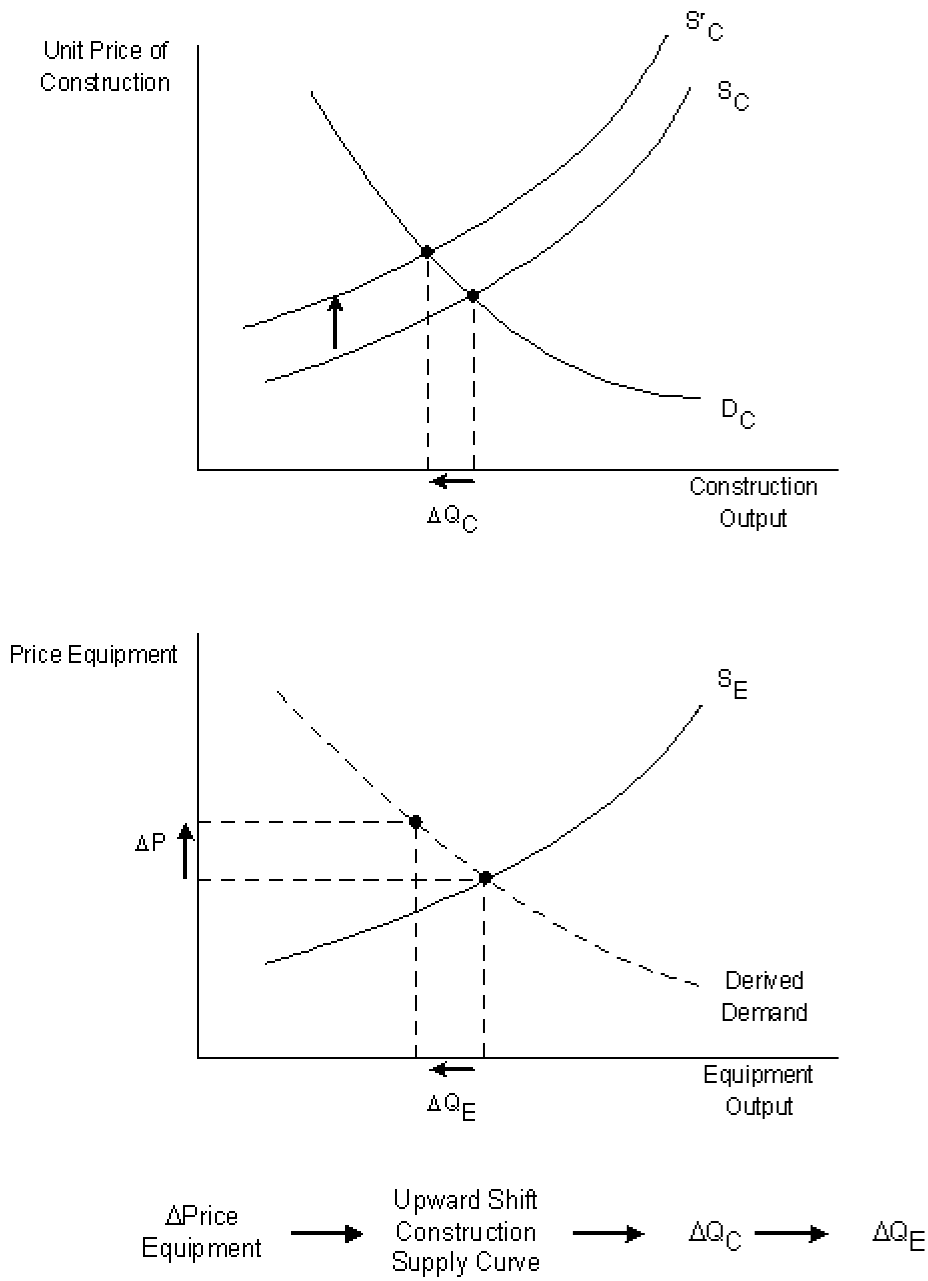


Figure 4-1. Derived Demand for Equipment from the Construction Industry

It can be shown that if the production function exhibits constant returns to scale with fixed factor proportions technology (i.e., $\sigma_{EL} = 0$)[3], price elasticity of demand for equipment can be expressed as a function of the selected variables included in Marshall's rules (Hicks, 1963; Layard and Walters, 1978):

$$\varepsilon_{IE} = \frac{v_E \times \eta^D}{1 - (1 - v_E) \times \frac{\eta^D}{\eta^S}} . \qquad (4.1)$$

This expression can be further simplified by assuming the supply of other factors is perfectly elastic ($\eta^S = \infty$). This simplification is appropriate because we expect the changes in production in the equipment market to be small enough that they do not influence prices in other factor markets:

$$\xi_{IE} = v_E \times \eta^D . \qquad (4.2)$$

Therefore, we can estimate this behavioral parameter with cost share data and final product/service demand elasticities.

4.2 Diesel Equipment Markets Affected by the CI NSPS

EPA identified three national competitive markets for the economic impact analysis—an approach consistent with the geographic definition and pricing behavior assumptions for nonroad diesel equipment markets within NDEIM. In selecting the competitive model, EPA argued that the competitive assumption is "widely accepted economic practice for this type of analysis (see, for example, EPA [2000], p. 126), especially in cases where existing analysis suggests that mitigating factors limit the potential for raising price above marginal cost" (EPA, 2004, p. 10-5). The mitigating factors cited in the nonroad rule include significant levels of domestic and international competition and significant excess capacity enabling competitors to quickly respond to changes in price. In addition, there were no indications of barriers to entry or evidence of high levels of strategic behavior in the price and quantity decisions of the firms. Our preliminary review of the available

[3]The fixed proportions technology assumption is reasonable for this industry. For interested readers, the expression for the more complicated formula that includes the elasticity of substitution is included in J.R. Hicks' *Theory of Wages*, pp. 243-244. A similar expression is reported in Layard and Walters (1978, p. 267).

industry data and literature suggests similar conditions are likely to be present in the markets included in this analysis.

We used two distinctive product characteristics to define the products that constitute the markets. First, consumers are more likely to view products with similar horsepower ratings as close substitutes, so it seems reasonable to delineate the markets by horsepower categories defined in the engineering cost analysis and by EPA (2004). Second, after reviewing the EPA industry characterization for the Clean Air Nonroad Diesel Rule (EPA, 2004), the California Air Resources Board's (CARB's) Staff Report for the Airborne Toxic Control Measure for Stationary Compression-Ignition Engines (CARB, 2003), and a private industry study of the diesel engine markets (Rhein Associates, 2002), EPA identified three broad nonemergency stationary diesel markets where buyers and sellers in the market would be unwilling to shift consumption/production among these products on a large scale.

To characterize behavioral responses in these three markets, EPA uses existing model elasticity parameters available from NDEIM model. The U.S. Bureau of Economic Analysis (2002) and U.S. Department of Agriculture (2004) provide data that allow us to approximate associated cost shares in final application markets. Table 4-1 provides the baseline data set for the economic impact analysis, and Section 4.3 describes the partial equilibrium model equations used for the economic impact analysis.

4.3 Overview of Partial Equilibrium Model

We illustrate our approach for estimating market-level impacts using a numerical simulation model. Our method involves specifying a set of nonlinear supply and demand relationships for the three diesel equipment markets identified in Table 4-1, simplifying the equations by transforming them into a set of linear equations, and then solving the equilibrium system of equations (see, for example, Fullerton and Metcalfe [2002]).

4.3.1 Market Supply

First, we consider the formal definition of the elasticity of supply with respect to changes in own price:

$$\varepsilon_s \equiv \frac{dQ_s / Q_s}{dp / p} . \qquad (4.3)$$

Table 4-1. Markets Included in Economic Impact Model

	Stationary Gen Sets and Welders	Stationary Pumps and Compressors	Stationary Irrigation Systems
Power Systems Research (PSR) application descriptions	Generator sets, welders	Air compressors, gas compressors, hydro power units, pressure washers, pumps	Irrigation systems
Geographic scope	National	National	National
Product groupings	4 horsepower categories	5 horsepower categories	2 horsepower categories
Firm behavior	Perfect competition	Perfect competition	Perfect competition
Baseline engine population	See Table 4-2a	See Table 4-2b	See Table 4-2c
Baseline year	2015	2015	2015
Supply elasticity	2.9 EPA (2004)	2.8 EPA (2004)	2.1 EPA (2004)
Demand characterization	Derived demand	Derived demand	Derived demand
Final product market and demand elasticity (η^D)	Manufacturing –0.6 EPA (2004) Econometric estimate (inelastic)	Manufacturing –0.6 EPA (2004) Econometric estimate (inelastic)	Agriculture –0.2 EPA (2004) Econometric estimate (inelastic)
Cost share (v_E)	7 %	1 %	2 %
Estimated derived demand elasticity (ξ_{IE})	–0.042	–0.006	–0.004

Table 4-2a. Baseline Data: Nonemergency Stationary Diesel Generator Sets and Welders, 2015

Application	51–75 hp	76–100 hp	101–175 hp	>176 hp
Quantity (units)	1,066	1,532	2,479	5,132
Price ($/unit)	$7,231	$10,101	$15,840	$44,535

Sources: U.S. Environmental Protection Agency. 2004. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*. EPA 420-R-04-007. Available from <http://www.epa.gov/nonroad-diesel/2004fr.htm>.

Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI engine population by NAICS. April 20, 2005.

Table 4-2b. Baseline Data: Nonemergency Stationary Diesel Pumps and Compressors, 2015

Application	51–75 hp	76–100 hp	101–175 hp	>176 hp
Quantity (units)	693	1,343	1,111	2,011
Price ($/unit)	$13,960	$19,499	$30,578	$86,192

Sources: U.S. Environmental Protection Agency. 2004. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*. EPA 420-R-04-007. Available from <http://www.epa.gov/nonroad-diesel/2004fr.htm>.

Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI engine population by NAICS. April 20, 2005.

Table 4-2c. Baseline Data: Nonemergency Stationary Diesel Irrigation Systems, 2015

Market Variable	50–100 hp	101–600 hp
Quantity (units)	272	707
Price ($/unit)	$42,247	$75,815

Sources: U.S. Environmental Protection Agency. 2004. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*. EPA 420-R-04-007. Available from <http://www.epa.gov/nonroad-diesel/2004fr.htm>.

Sorrels, Larry, EPA, e-mail to Ruth Mead, ERG and Katherine Heller and Brooks Depro, RTI International. CI engine population by NAICS. April 20, 2005.

Next, we can use "hat" notation to transform Eq. (4.3) to proportional changes and rearrange terms:

$$\hat{Q}_s = \theta_s \hat{p} \tag{4.4}$$

where

$\hat{Q}_s$ = percentage change in the quantity of market supply,

θ_s = market elasticity of supply, and

$\hat{p}$ = percentage change in market price.

By using this approach, we have taken the elasticity definition and turned it into a linear *behavioral* equation that characterizes market supply in the three diesel equipment markets. To introduce the cost of controls associated with the regulatory program, we assume the per-unit cost (c) leads to a proportional shift in the marginal cost of production. Under the assumption of perfect competition (price equals marginal cost), we can approximate this shift at the initial equilibrium point as follows:

$$\hat{MC} = \frac{c}{MC_o} = \frac{c}{p_o}. \tag{4.5}$$

4.3.2 Market Demand

We can specify a demand equation for each diesel engine equipment market as follows:

$$\hat{Q}_d = \xi_{IE} \hat{p} \tag{4.6}$$

where

$\hat{Q}_d$ = percentage change in the quantity of market demand,

ξ_{IE} = market elasticity of demand, and

$\hat{p}$ = percentage change in market price.

4.3.3 Equilibrium Solution

Lastly, we specify the market equilibrium conditions in three diesel equipment markets. In response to the exogenous increase in production costs, the new equilibrium satisfies the condition that the change in supply equals the change in demand:

$$\hat{Q}_s = \hat{Q}_d \cdot \tag{4.7}$$

We now have three linear equations in three unknowns ($\hat{p}$, $\hat{Q}_d$, and $\hat{Q}_s$), and we can solve for the proportional price change in terms of the elasticity parameters (ε_s and η_d) and the proportional change in marginal cost:

$$\hat{p} = \frac{\theta_s}{\theta_s - \hat{\zeta}_{IB}} \cdot \hat{MC} \cdot \tag{4.8}$$

Given this solution, we can solve for the proportional change in market quantity using the demand equation.

4.4 Results

The model projects the NSPS will increase prices from 2 to 9.4 percent (see Table 4-3). Generator set and welding equipment markets experience the highest relative change in baseline price (9.4 percent). Domestic production declines by small amounts (less than 0.5 percent) because the (absolute) elasticity of demand for the final product or service that uses affected equipment and the cost share of equipment in production of these goods and services is small.

The national compliance cost estimates are often used to approximate the social cost of the rule. The engineering analysis estimated annualized costs of $57.1 million. In cases where the engineering costs of compliance are used to estimate social cost, the burden of the regulation is typically measured as falling solely on the affected producers, who experience a profit loss exactly equal to these cost estimates. Thus, the entire loss is a change in producer surplus with no change (by assumption) in consumer surplus, because no change in market price is estimated. This is typically referred to as a “full-cost absorption” scenario in which all factors of production are assumed to be fixed and firms are unable to adjust their output levels when faced with additional costs.

Table 4-3. Summary of Economic Impacts: 2015

	Market-Level Impacts	
	% Change in Price	% Change in Quantity
Generator Sets and Welders	9.4%	–0.40%
Pumps and Compressors	3.7%	–0.02%
Irrigation Systems	2.0%	–0.01%
	Welfare Impacts	
Change in Consumer Surplus	–$37.629	
Change in Producer Surplus	–$0.436	
Recordkeeping costs not addressed in market model	–$19.009	
Change in Total Surplus	–$57.074	

In contrast, EPA's economic analysis builds on the engineering cost analysis and incorporates economic theory related to producer and consumer behavior to estimate changes in market conditions. Owners of affected plants are economic agents that can make adjustments, such as changing production rates or altering input mixes, that will generally affect the market environment in which they operate. As producers change their production levels in response to a regulation, consumers are typically faced with changes in prices that cause them to alter the quantity that they are willing to purchase. These changes in price and output from the market-level impacts are used to estimate the total surplus losses/gains for two types of stakeholders: chemical consumers and owners of chemical plants.

The numerical simulation suggests the changes in price and quantity are relatively small; thus, the economic approach and engineering cost approach yield approximately the same estimate of the total change in surplus ($57.1 million). However, the advantage of the economic approach is that it illustrates how the costs flow through the economic system and identifies transitory impacts on stakeholders. As shown in Table 4-3, equipment consumers unambiguously see reductions in surplus as the result of higher prices and reduced consumption ($37.6 million). The monitoring, recordkeeping, recording, and reporting costs in 2015 total $20.2 million. They include $2.06 million for prime engines (included in the model) and $19.009 million for initial notification ($5,768), certification ($845,000), and recording hours of nonemergency operation of emergency engines ($18.158 million). The $19.0 million in costs are largely borne by emergency engine operators and thus are not included in the model; instead, they are entered as a line item in the calculation of social costs of the rule (see Table 4-3).

Table 4-4 presents detailed economic impact estimates for generator and welder equipment. Prices are projected to increase from 6.3 percent to 10.3 percent across the horsepower ranges, and quantities sold are projected to decline by less than 0.5 percent. For this segment of the industry, purchasers of the generator and welder equipment are projected to incur three-quarters of the social costs ($28.9 million), while producers of the generator and welder equipment are projected to lose less than $0.5 million.

Table 4-4. Detailed Results for Generator and Welder Equipment: 2015

	Market-Level Impacts	
HP Range	**% Change in Price**	**% Change in Quantity**
51-75 hp	6.3%	–0.27%
76-100 hp	9.4%	–0.40%
101-175 hp	8.9%	–0.37%
>176 hp	10.3%	–0.43%
	Welfare Impacts	
Change in Consumer Surplus	–$28.949	
Change in Producer Surplus	–$0.417	
Change in Total Surplus	–$29.366	

Table 4-5 presents detailed economic impact estimates for pump and compressor equipment. Prices are projected to increase from 2.4 percent to 4.9 percent across the horsepower ranges, and quantities sold are projected to decline by less than 0.03 percent. For this segment of the industry, purchasers of the pump and compressor equipment are projected to incur the majority of the social costs ($7.4 million), while producers of the pump and compressor equipment are projected to lose $0.02 million.

Table 4-6 presents detailed economic impact estimates for irrigation equipment. Prices are projected to increase from 2.0 percent to 2.2 percent across the horsepower ranges, and quantities sold are projected to decline by 0.01 percent. Like the other two segments of the industry, purchasers of the irrigation equipment are projected to incur the majority of the

Table 4-5. Detailed Results for Pump and Compressor Equipment: 2015

HP Range	Market-Level Impacts	
	% Change in Price	% Change in Quantity
51-75 hp	3.3%	–0.02%
76-100 hp	4.9%	–0.03%
101-175 hp	4.7%	–0.03%
>176 hp	2.4%	–0.01%
	Welfare Impacts	
Change in Consumer Surplus	–$7.376	
Change in Producer Surplus	–$0.016	
Change in Total Surplus	–$7.391	

Table 4-6. Detailed Results for Irrigation Equipment: 2015

HP Range	Market-Level Impacts	
	% Change in Price	% Change in Quantity
51-100 hp	2.2%	–0.01%
101-600 hp	2.0%	–0.01%
	Welfare Impacts	
Change in Consumer Surplus	$ (1.305)	
Change in Producer Surplus	$ (0.002)	
Change in Total Surplus	$ (1.307)	

social costs ($1.3 million), while producers of the irrigation equipment are projected to lose less than $0.01 million.

The NSPS will reduce emissions of SO_2 by requiring the use of lower-sulfur fuel. In the baseline year of analysis (2015), new stationary CI equipment subject to the NSPS will be required to use ULSD fuel (i.e., must consume fuel meeting a 15 ppm sulfur standard). In the absence of regulation, these engines might still have been using high-sulfur fuel. As a result of regulation, demand for ULSD fuel will increase and demand for high-sulfur No. 2 distillate will decline relative to an unregulated baseline. Estimated demand for low-sulfur diesel fuel in 2015 is 63.2 billion gallons. This number includes demand for diesel fuels used in highway, nonroad, locomotive, and marine categories (see Table 4-7). Estimated prime engine fuel demand in 2015 is 1.73 billion gallons; therefore, the expected increase in demand for low-sulfur diesel fuel equals 2.74 percent. On the other hand, decrease in demand for high-sulfur diesel fuel will be a substantial share of the remaining production of high-sulfur diesel fuel. Estimated 2015 high-sulfur fuel production is 7.538 billion gallons, and the ratio of prime engine fuel demand to high-sulfur fuel supply equals 22.94 percent (see Table 4-7).

Table 4-7. Shift of Diesel Fuel Supply and Demand Quantities in 2015 (billion gallons)

Fuel Use Category	Estimated Demand for Low-Sulfur Diesel Fuel[a]	Estimated Supply for High-Sulfur Diesel Fuel[a]
Highway	47.58	—
Nonroad	10.34	—
Locomotive	3.13	—
Marine	2.16	—
Heating oil	—	7.54
Total	63.21	7.54
Estimated stationary prime-engine fuel demand[b]	1.73	1.73
Ratio	2.74%	22.94%

[a]From Table 7.1.4-13, p7-61, Final Reg Supp Doc.

[b]E-mail from Larry Sorrels to ERG and RTI, "Analysis of availability of ultra low sulfur diesel." June 7, 2005.

SECTION 5

SMALL BUSINESS IMPACT ANALYSIS

This regulatory action will potentially affect the economic welfare of owners of facilities that will own or operate new CI internal combustion engines. The ownership of these facilities ultimately is in the hands of private individuals who may be owners/operators that directly conduct the business of the firm (i.e., single proprietorships or partnerships) or, more commonly, investors or stockholders that employ others to conduct the business of the firm on their behalf (i.e., privately held or publicly traded corporations). The individuals or agents that manage these facilities have the capacity to conduct business transactions and make business decisions that affect the facility. The legal and financial responsibility for compliance with a regulatory action ultimately rests with these agents; however, the owners must bear the financial consequences of the decisions. Environmental regulations like this rule potentially affect all businesses, large and small, but small businesses may have special problems in complying with such regulations, because they may have less specialized environmental expertise or limited access to capital for investing in compliance equipment.

The Regulatory Flexibility Act (RFA) of 1980 requires that special consideration be given to small entities affected by federal regulation. The RFA was amended in 1996 by the Small Business Regulatory Enforcement Fairness Act (SBREFA) to strengthen the RFA's analytical and procedural requirements. Prior to enactment of SBREFA, EPA exceeded the requirements of the RFA by requiring the preparation of a regulatory flexibility analysis for every rule that would have any impact, no matter how minor, on any number, no matter how few, of small entities. Under SBREFA, however, the Agency decided to implement the RFA as written and that a regulatory flexibility analysis will be required only for rules that will have a *significant* impact on a *substantial* number of small entities (SISNOSE). In practical terms, the amount of analysis of small entities' impacts has not changed, for SBREFA required EPA to increase involvement of small entity stakeholders in the rulemaking process. Thus, the Agency has made additional efforts to consider small entity impacts as part of the rulemaking process.

5.1 Description of Small Entities Affected

Small entities include small businesses, small organizations, and small governmental jurisdictions. For purposes of assessing the impacts of the CI NSPS, a small entity is defined as

- a small business whose parent company has fewer than 1,000 employees (for NAICS 335312 [Motor and Generator Manufacturing]) or 500 employees (for NAICS 333911 [Pump and Pumping Equipment Manufacturing], NAICS 333912 [Air and Gas Compressor Manufacturing], and NAICS 333992 [Welding and Soldering Equipment Manufacturing]);
- a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of fewer than 50,000; and
- a small organization that is any not-for-profit enterprise, which is independently owned and operated and is not dominant in its field.

5.2 Small Business Screening Analysis

In the next step of the analysis, we assessed how the regulatory program may influence the profitability of ultimate parent companies by comparing pollution control costs to total sales. To do this, we divided an ultimate parent company's total annual compliance cost by its reported revenue (see the following equation):

$$CSR = \frac{\sum_{i}^{n} TACC}{TR_j} \tag{5.1}$$

where

CSR	=	cost-to-sales ratio,
TACC	=	total annualized compliance costs,
i	=	indexes the number of affected plants owned by company j,
n	=	number of affected plants, and
TRj	=	total revenue from all operations of ultimate parent company j.

This method assumes the affected a company cannot shift pollution control costs to consumers (in the form of higher market prices). Instead, the company experiences a one-for-one reduction in profits.

To identify sales and employment characteristics of affected parent companies, we used a company database developed for small business analysis of the Clean Air Nonroad Diesel Rule (EPA, 2004). Since the rule does not affect all companies included in the database, the analysis only includes companies that produced the following types of equipment segments:

- pumps and compressors (Pump and Pumping Equipment Manufacturing [NAICS 333911] or Air and Gas Compressor Manufacturing [NAICS 333912]) and
- welders and generators (Motor and Generator Manufacturing [NAICS 335312] or Welding and Soldering Equipment Manufacturing [NAICS 333992]).

The statistics included in the database come from PSR and other publicly available resources such as the following:

- ***Business & Company Resource Center***. A single database for company profiles, company brand information, rankings, investment reports, company histories, chronologies, full-text articles, investment reports, industry overviews, and financial and trade association data. http://www.gale.com/servlet/Item DetailServlet?region=9&imprint=000&titleCode=GAL49&type=1&id=115085.
- ***Hoover's Online***. This electronic database is an excellent source of information on U.S. public and private companies. Users can search for companies by name, ticker symbol, or keyword. It provides corporate ownership, sales, net income, and employment. Links are also provided to the company's Web site and those of top competitors (if available), SEC filings in EDGAR Online, investor research reports, and news and commentary. http://www.hoovers.com/.
- ***ReferenceUSA***. The ReferenceUSA database contains, in module format, detailed information on more than 12 million U.S. businesses. Information is compiled from the following public sources: more than 5,600 Yellow Page and Business White Page telephone directories; annual reports, 10-Ks, and other Securities and Exchange Commission (SEC) information; Continuing Medical Education (CME) directories; federal, state, provincial, and municipal government data; Chamber of Commerce information; leading business magazines, trade publications, newsletters, major newspapers, industry and specialty directories; and postal service information, including both U.S. and Canadian National Change of Address updates. One disadvantage of this database is that it only reports sales and employment ranges. For this analysis, we developed a point estimate for these values (typically the median). http://www.referenceusa.com/.

- ***Dun & Bradstreet's Million Dollar Directory***. The D&B Million Dollar Directory provides information on over 1,260,000 U.S. leading public and private businesses. Company information includes industry information with up to 24 individual eight-digit Standard Industrial Classification (SIC) codes, size criteria (employees and annual sales), type of ownership, and principal executives and biographies. http://www.dnb.com/ dbproducts/ description/ 0,2867,2-223-1012-0-223-142-177-1,00.html.

We identified 60 small companies and 44 large companies with sales data. Using the data, we found 62 companies manufacture products that are included in the Pump and Pumping Equipment Manufacturing (NAICS 333911) or Air and Gas Compressor Manufacturing (NAICS 333912) industries, and 30 companies manufacture products included in the Motor and Generator Manufacturing (NAICS 335312) or Welding and Soldering Equipment Manufacturing (NAICS 333992) industries. The remaining 12 companies manufacture equipment in both PSR segments.

The results of the screening analysis, presented in Table 5-1, show that two small firms have estimated CSRs between 1 percent and 3 percent of sales and one firm has a CSR greater than 3 percent. The remaining 57 small firms have estimated CSRs below 1 percent. The average (median) CSR for small firms is 0.3 percent (0.1 percent), and the average and median CSR for all large firms with data is less than 0.02 percent (0.003 percent).

Table 5-1. Summary Statistics for SBREFA Screening Analysis

	Small		Large	
	Number	Share (%)	Number	Share (%)
Companies with Parent Sales Data	60	100%	44	100%
Compliance costs are < 1% of sales	57	95%	44	100%
Compliance costs are ≥ 1 to 3% of sales	2	3%	—	0%
Compliance costs are ≥ 3% of sales	1	2%	—	0%
Cost-to-Sales Ratios (%)				
Average	0.3%		0.0192%	
Median	0.1%		0.0025%	
Maximum	4.7%		0.2%	
Minimum	0.0%		0.0%	

5.3 Assessment

The RFA generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative

Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions. The economic impacts of the NSPS are expected to be insignificant, and the Agency has determined that there is no significant impact (economic) on a substantial number of small entities (or SISNOSE).

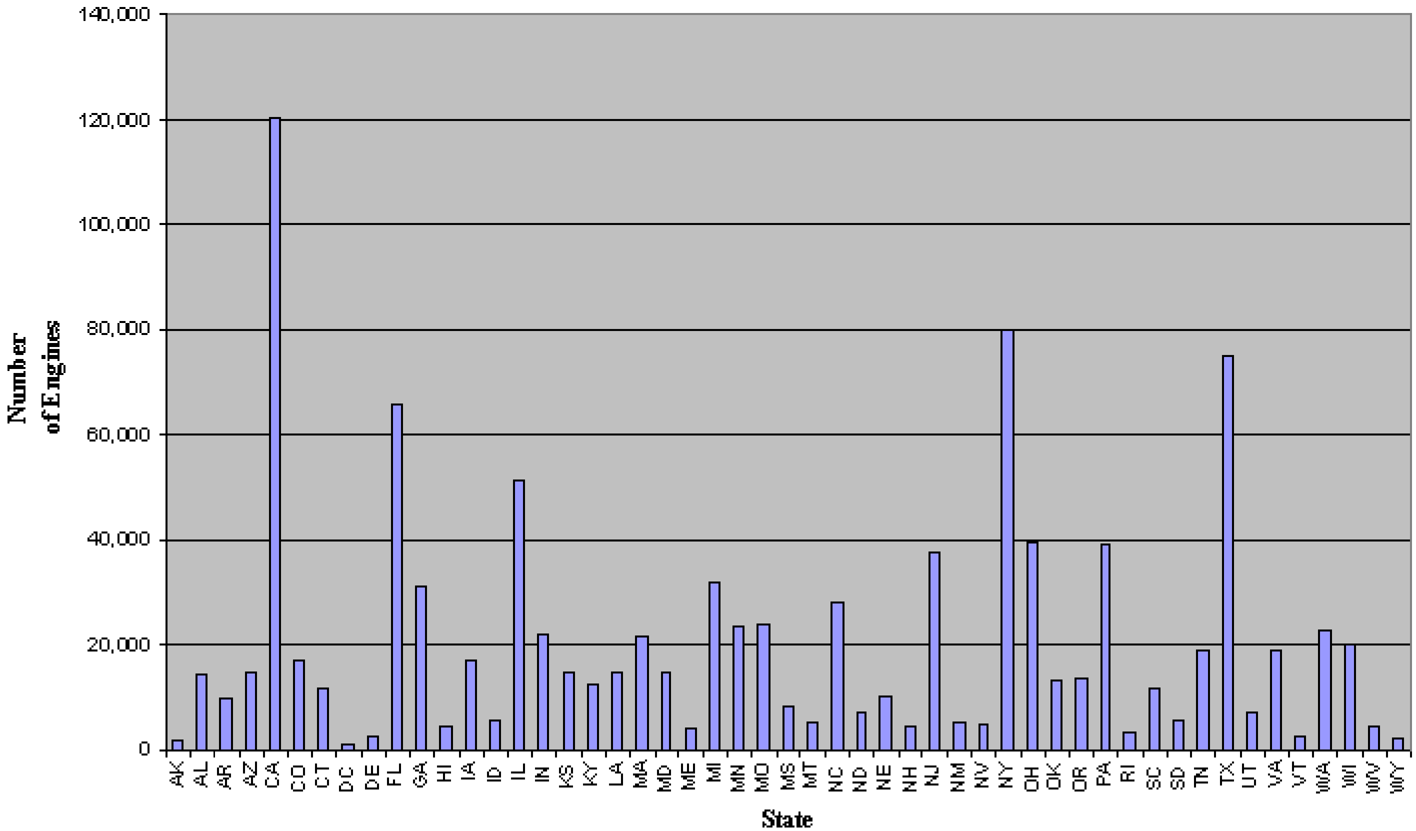
SECTION 6

HUMAN HEALTH BENEFITS OF EMISSION REDUCTIONS

6.1 Calculation of Human Health Benefits

For the purposes of estimating the benefits of reducing emissions from stationary diesel compression ignition engines through this rulemaking, EPA is using the approach and methodology laid out in EPA's 2004 economic analysis supporting the regulation of emissions from nonroad diesel engines (Final Regulatory Impact Analysis (RIA): Control of Emissions from Nonroad Diesel Engines, May 2004). We chose this analysis as the basis since most of the elements in that rule are similar to those covered here. Both the engine type, the controls applied, and the pollutants reduced are similar to those covered by the Nonroad Diesel engine rule. In addition, EPA believes that these types of engines are broadly distributed across the country similar in distribution to nonroad diesel engines. Figure 6-1 shows the distribution of these engines by State.

Figure 6-1: Nonroad Engines in the U.S. by State



These four factors lead us to believe is appropriate to use the benefits transfer approach and values in the Nonroad Diesel engine rule regulatory impacts analysis (RIA) for estimating the benefits of this rule. The benefits transfer method used to estimate benefits for the final Nonroad Diesel engine rule is similar to that used to estimate benefits in the analysis of the Large SI/Recreational Vehicles standards (see U.S. EPA 2002, Docket A-2000-01, Document VB-4). The methodology is laid out in Chapter 9 of the Nonroad Diesel engine RIA.

EPA did not perform an air quality modeling assessment of the emission reductions resulting from the installation of controls on these engines due to time and resources constraints and the limited value of that analysis for the purposes of developing the regulatory approach. This limited EPA's ability to perform a benefits analysis for this rulemaking since our benefits model requires either air quality modeling or monitoring data. However, as mentioned above, the similarities of the engines being regulated under this rulemaking and those in the Nonroad Diesel rulemaking allow us to use the benefit per ton values derived from the Nonroad Diesel RIA in this analysis.

To develop the estimate of the benefits of the emission reductions from this rulemaking, we used dollar benefits per ton of emissions reduced estimates for each pollutant based on the results of the benefits analysis in the Nonroad diesel RIA. We then multiply this by the number of tons of each pollutant reduced to get the overall benefits value. These results are summarized in Table 6-1 below. It is important to note that the dollar benefits per ton estimates used here reflect specific geographic patterns of emissions reductions and specific air quality and benefits modeling assumptions. Use of these $/ton values to estimate benefits associated with different emission control programs (e.g. for reducing emissions from large stationary sources like EGUs) may lead to higher or lower benefit estimates than if benefits were calculated based on direct air quality modeling. Great care should be taken in applying these estimates to emission reductions occurring in any specific location, as these are all based on national or broad regional emission reduction programs and therefore represent average benefits per ton over the entire U.S. The benefits per ton for emission reductions in specific locations may be very different than the national average.

Table 6-1: Estimate of Monetized Benefits in 2015 ($2000)* Presuming CI Engines are Spatially Distributed Similar to Nonroad Engines

	$ benefits/ton	Amount of emissions reduced (tons)	Monetized benefits
Pollutant			
NOx	$8,000	35,000	$280 million
SOx	$23,000	9,300	$220 million
Direct PM	$300,000**	2,900	$860 million
Total health benefits			$1.36 billion

* The results in the table are presented assuming a discount rate of three percent. Assuming a discount rate of seven percent reduces the total benefits to $1.28 billion.

** This $/ton value is higher than that found in other EPA rulemakings such as the heavy duty onroad engines. This reflects the fact that nonroad engines, such as construction equipment, are frequently located in highly populated urban areas and thus more people benefit per ton of emissions reduced.

6.2 Characterization of Uncertainty in the Benefits Estimates

In any complex analysis, there are likely to be many sources of uncertainty. Many inputs are used to derive the final estimate of economic benefits, including emission inventories, air quality models (with their associated parameters and inputs), epidemiological estimates of 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.

In addition to uncertainty, the annual benefit estimates presented in this analysis are also inherently variable due to the truly random processes that govern pollutant emissions and ambient air quality in a given year. Factors such as hours of equipment use and weather display constant variability regardless of our ability to accurately measure them. As such, 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. In addition, as with all benefits transfer applications, the benefits per ton for specific emissions tons reduced will be dependent on the geographic location of those emissions reductions and the relative atmospheric conditions compared to the geographic distribution of nonroad diesel engines and the atmospheric conditions assumed in the Nonroad Diesel analysis. Specifically, the transfer method we used leads to an average benefit per ton that is based on the average population exposed to emissions from nonroad engines. If populations exposed to ambient pollution resulting from emissions from CI engines are less dense than the average population exposed to ambient pollution resulting from nonroad engines, then the benefits per ton associated with those emissions will be lower than that derived from the Nonroad rule. Likewise, if populations exposed are more dense than those exposed to ambient pollution from Nonroad engines, then benefits per ton will be higher.

Above we present a primary estimate of the total 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, key assumptions underlying the primary estimate for the premature mortality which accounts for 90 percent of the total benefits we were able to quantify include the following:

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

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

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

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

The recent NAS report (NAS 2002) on estimating public health benefits of air pollution regulations recommended that EPA begin to move the assessment of uncertainties from its ancillary analyses into its primary analyses by conducting probabilistic, multiple-source uncertainty analyses. As part of a collaboration between EPA's Office of Air and Radiation (OAR) and the Office of Management and Budget (OMB) on the Nonroad Diesel Rule, we conducted a pilot expert elicitation intended to more fully characterize uncertainty in the estimate of mortality resulting from exposure to PM. The final expert elicitation is expected to be finished and peer reviewed this Fall.

For this RIA we did not go through the detailed uncertainty assessment used in the Regulatory Impact Analysis for the Clean Air Interstate Rule (CAIR RIA) (March 2005) because we lack the necessary air quality input data to run the benefits model. However, the results of the Monte Carlo analyses of the health and welfare benefits presented in Appendix B of that RIA can provide some evidence of the uncertainty surrounding the benefits results presented in this analysis.

6.3 General Approach

In our recent assessment of the Clean Air Interstate Rule (CAIR) we describe our progress toward improving our approach of characterizing the uncertainties in our economic benefits estimates, with particular emphasis on the concentration response (C-R) function relating premature mortality to exposures to ambient PM2.5. We presented two approaches to generating probabilistic distributions designed to illustrate the potential influence of some aspects of the uncertainty in the C-R function in a PM benefits analysis. The first approach generated a probabilistic estimate of statistical uncertainty based on standard errors reported in the underlying studies used in the benefit modeling framework. The second approach used the results from the pilot expert elicitation designed to characterize certain aspects of uncertainty in the ambient PM2.5/mortality relationship.

In addition to the two approaches to characterize uncertainty for PM mortality, we incorporated information on uncertainties of other endpoints in the benefits model. We did not attempt to assign probabilities to all of the uncertain parameters in the model because of a lack of resources and reliable methods. We simply generate estimates of the distributions of dollar benefits for PM health effects and for total dollar benefits. For non-mortality endpoints, we provide a likelihood distribution for the total benefits estimate, based solely on the statistical uncertainty surrounding the estimated C-R functions and the assumed distributions around the unit values.

Our estimate of the likelihood distribution for total benefits should be viewed as incomplete because of the wide range of sources of uncertainty that we have not incorporated. The 5th and 95th percentile points of our estimate are based on statistical error, and cross-study variability provides some insight into how uncertain our estimate is with regard to those sources of uncertainty. However, it does not capture other sources of uncertainty regarding other inputs to the model, including emissions, air quality, baseline population incidence, projected exposures, or the model itself, including aspects of the health science not captured in the studies, such as the likelihood that PM is causally related to premature mortality and other serious health effects. Thus, a likelihood description based on the standard error would provide a misleading picture about the overall uncertainty in the estimates.

Both the uncertainty about the incidence changes[4] and uncertainty about unit dollar values can be characterized by *distributions*. Each "likelihood distribution" characterizes our beliefs about what the true value of an unknown variable (e.g., the true change in incidence of a given health effect in relation to PM exposure) is likely to be, based on the available information from relevant studies.[5] Unlike a sampling distribution (which describes the possible values that an *estimator* of an unknown variable might take on), this likelihood distribution describes our beliefs about what values the unknown variable itself might be. Such likelihood distributions can be constructed for each underlying unknown variable (such as a particular pollutant coefficient for a particular location) or for a function of several underlying unknown variables (such as the total dollar benefit of a regulation). In either case, a likelihood distribution is a characterization of our beliefs about what the unknown variable (or the function of unknown variables) is likely to be, based on all the available relevant information. A likelihood description based on such distributions is typically expressed as the interval from the 5th percentile point of the likelihood distribution to the 95th percentile point. If all uncertainty had been included, this range would be the "credible range" within which we believe the true value is likely to lie with 90 percent probability.

6.4 Monte-Carlo Based Uncertainty Analysis

The uncertainty about the total dollar benefit associated with any single endpoint combines the uncertainties from these two sources (the C-R relationship and the valuation)

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[4]Because this is a national analysis in which, for each endpoint, a single C-R function is applied everywhere, there are two sources of uncertainty about incidence: statistical uncertainty (due to sampling error) about the true value of the pollutant coefficient in the location where the C-R function was estimated and uncertainty about how well any given pollutant coefficient approximates ß*.

[5] Although such a "likelihood distribution" is not formally a Bayesian posterior distribution, it is very similar in concept and function (see, for example, the discussion of the Bayesian approach in Kennedy (1990), pp. 168-172).

and is estimated with a Monte Carlo method. In each iteration of the Monte Carlo procedure, a value is randomly drawn from the incidence distribution, another value is randomly drawn from the unit dollar value distribution; the total dollar benefit for that iteration is the product of the two.[6] When this is repeated for many (e.g., thousands of) iterations, the distribution of total dollar benefits associated with the endpoint is generated.

Using this Monte Carlo procedure, a distribution of dollar benefits can be generated for each endpoint. As the number of Monte Carlo draws gets larger and larger, the Monte Carlo-generated distribution becomes a better and better approximation of a joint likelihood distribution (for the considered parameters) making up the total monetary benefits for the endpoint. After endpoint-specific distributions are generated, the same Monte Carlo procedure can then be used to combine the dollar benefits from different (nonoverlapping) endpoints to generate a distribution of total dollar benefits.

The estimate of total benefits may be thought of as the end result of a sequential process in which, at each step, the estimate of benefits from an additional source is added. Each time an estimate of dollar benefits from a new source (e.g., a new health endpoint) is added to the previous estimate of total dollar benefits, the estimated total dollar benefits increases. However, our bounding or likelihood description of where the true total value lies also increases as we add more sources. The physical effects estimated in this analysis are assumed to occur independently. It is possible that, for any given pollution level, there is some correlation between the occurrence of physical effects, due to say avoidance behavior or common causal pathways and treatments (e.g., stroke, some kidney disease, and heart attack are related to treatable blood pressure). Estimating accurately any such correlation, however, is beyond the scope of this analysis, and instead it is simply assumed that the physical effects occur independently.

For the CAIR RIA, we conducted two different Monte Carlo analyses, one based on the distribution of reductions in premature mortality characterized by the mean effect

[6] This method assumes that the incidence change and the unit dollar value for an endpoint are stochastically independent.

estimate and standard error from the epidemiology study of PM-associated mortality associated with the primary estimate (Pope et al., 2002), and one based on the results from a pilot expert elicitation project (IEc, 2004). In both analyses, the distributions of all other health endpoints are characterized by the reported mean and standard deviations from the epidemiology literature. Distributions for unit dollar values are based on reported ranges or distributions of values in the economics literature and are summarized in Table B-1 of Appendix B of the CAIR RIA. Summary results of the Monte Carlo analyses based on the Pope et al. (2002) distribution and based on the pilot expert elicitation are presented in the next section.

6.5 Results of the CAIR RIA Monte Carlo Analyses

Results of the Monte Carlo simulations are presented in Table 6-2. The table provides the estimated means of the distributions and the estimated 5th and 95th percentiles of the distributions. The contribution of mortality to the mean benefits and to both the 5th and 95th percentiles of total benefits is substantial, with mortality accounting for 93 percent of the mean estimate, and even the 5th percentile of mortality benefits dominating the 95th percentile of all other benefit categories. Thus, the choice of value and the shape for likelihood distribution for VSL should be examined closely and is key information to provide to decision makers for any decision involving this variable.

Table 6-2: Results of Monte Carlo Uncertainty Assessment from CAIR RIA

	5th percentile	mean	95th percentile
Statistical uncertainty based approach	$26 Billion	$100 Billion	$210 Billion
Expert elicitation uncertainty based approach	$3 Billion	$74 Billion	$240 Billion

For the statistical based approach, the 95th percentile of total benefits is approximately twice the mean, while the 5 th percentile is approximately one-fourth of the mean. The overall range from 5th to 95th represents about one order of magnitude. For the expert elicitation based approach, the 95th percentile of total benefits is approximately three times the mean, while the 5 th percentile is approximately one-twentieth of the mean. The overall range from 5th to 95th is somewhat wider than that of the statistical based approach.

Prior to taking the next step and applying these results to the benefits estimates from this rulemaking, it is important to note that there are numerous caveats and limitations associated these uncertainty approaches which are not reflected in this write-up. Readers are strongly encouraged to review the detailed discussion in Appendix B of the CAIR RIA for a detailed discussion of these approaches.

As a means of assessing the uncertainty associated with the estimate of the monetized benefits of this rulemaking we applied the ratios from the above table to the benefit estimates presented earlier. Thus, to estimate the 5th percentile of the statistical uncertainty based approach we multiplied the ratio of the 5th percentile to the mean (26/100) by the estimated benefits of this rule ($1.36 Billion). Using these values as a guide, we assumed that the distribution of values for this rulemaking would be similar. Table 6-3 summarizes the results.

Table 6-3: Estimated Monetized Health Benefits Compared to Two Approaches for Estimating the Uncertainty Range

	5th percentile	mean	95th percentile
Estimated monetized benefits**	NC*	$1.36 Billion	NC*
Statistical uncertainty based approach	$360 Million	NC*	$2.85 Billion
Expert elicitation uncertainty based approach	$68 Million	NC*	$4.4 Billion

* NC - Not Calculated

** 3 percent discount rate

6.6 Benefits By Engine Size Category

We analyzed the distribution of monetized benefits across engine size categories. This analysis assumes that the average $ benefits per ton based on the Nonroad Diesel RIA analysis is representative of the average benefits that would accrue to reductions in emissions for each individual engine size category. This introduces additional uncertainty in the analysis. As such, this analysis should be viewed as providing the most information when used in a relative sense, e.g., comparing relative magnitudes across categories, rather than in an absolute sense, as little confidence should be placed on the specific estimates of benefits for any one category of engine size. As with all benefits transfer applications, the benefits per ton for any specific grouping of engine sizes will be dependent on the geographic location of those engines and the relative atmospheric conditions compared to the geographic distribution of nonroad diesel engines and the atmospheric conditions assumed in the Nonroad Diesel analysis.

The results of this analysis shown below in Table 6-4 suggest that there are net benefits for every engine size category. In addition, the benefit-cost ratio exceeds 8 for all engine size categories, although the benefit-cost ratios tend to be larger for the larger engine size categories. It should be noted that the impacts listed in Table 6-4 are associated with prime engines. We believe that emergency engines, which make up about 80 percent of the engines covered by this rule, will have minimal incremental costs and benefits. We assume that emergency engines will be compliant with certain non-road diesel requirements, thereby meeting the requirements of this rule.

Table 6-4. Benefits of Emission Reductions in 2015 by Engine Size Category

	Emission Reductions by Pollutant (tons)			Benefits (3%, million 2000$)	Benefits (7%, million 2000$)	Annualized Costs (2000$)	Net Benefits	Net Benefits	Benefits/ Costs	Benefits/ Costs
Engine Size(hp)	PM2.5	NOx	SO_2				3%	7%	3%	7%
50-75	64	-	270	25.3	23.8	2.9	22.4	21.0	8.8	8.3
75-100	324	1620	542	112.0	114.8	6.5	105.5	108.4	17.3	17.8
100-175	498	2780	1184	181.0	186.5	11.0	170.0	175.5	16.5	17.0
175-300	738	5044	1983	275.4	288.6	12.5	262.9	276.0	22.0	23.0
300-600	497	3345	1437	187.8	196.2	6.7	181.0	189.5	27.9	29.2
600-750	101	673	372	40.0	41.6	1.2	38.8	40.4	32.5	33.8
750-1200	187	1069	997	80.9	82.4	3.8	77.1	78.6	21.2	21.6
1200-3000	399	20421	2116	210.5	315..3	10.8	199.7	304.5	19.4	29.1
>3000	62	3210	351	33.3	49.8	1.6	31.7	48.1	20.3	30.3

6.7 Benefit-Cost Comparison

Recall that the costs of this rulemaking are estimated to be $57 million in 2015. Regardless of the uncertainty characterization approach used, the benefits of this rule exceed the costs, even when the cost is compared to the 5th percentile estimate of the expert elicitation approach. Thus, EPA believes that the benefits of this rulemaking will exceed the costs. The reader should refer to the CAIR RIA for a full detailed discussion of the uncertainties considered in EPA's benefit analyses.

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