OAR-2002-0059
II-A-12

EPA Contract Number 68-D-99-024
RTI Project Number 7647-001-013

Economic Analysis of the Internal Combustion Engines MACT Standard

Final Report

July 2000

Prepared for

Lisa Conner
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Innovative Strategies and Economics Group (ISEG)
(MD-15)
Research Triangle Park, NC 27711

Prepared by

Robert H. Beach
Michael P. Gallaher
Brooks M. Depro
Alan C. O'Connor
Research Triangle Institute
Center for Economics Research
Research Triangle Park, NC 27709

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

2SLB	spark ignition, two-stroke lean burn
4SLB	spark ignition, four-stroke lean burn
4SRB	spark ignition, four-stroke rich burn
A/F	air-to-fuel
AIRS	Aerometric Information Retrieval System
API	American Petroleum Institute
CAA	Clean Air Act
CEMS	Continuous Emission Monitoring System
CI	compression ignition
CO	carbon monoxide
CSRs	cost-to-sales ratios
EIA	economic impact analysis
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
HAPs	hazardous air pollutants
hp	horsepower
IC	internal combustion
ICCR	Industrial Combustion Coordinated Rulemaking
ISEG	Innovative Strategies and Economics Group
MACT	maximum achievable control technology
NEMS	National Energy Modeling System
NESHAP	National Emission Standard for Hazardous Air Pollutants

NSCR	nonselective catalytic reduction
O&M	operating and maintenance costs
OAQPS	Office of Air Quality Planning and Standards
OTAG	Ozone Transport Assessment Group
RFA	Regulatory Flexibility Act
RICE	reciprocating internal combustion engine
SBA	Small Business Administration
SBREFA	Small Business Regulatory Enforcement Fairness Act of 1996
SIC	Standard Industrial Classification

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (referred to as EPA or the Agency) is developing regulations under Section 112 of the Clean Air Act (CAA) for stationary reciprocating internal combustion engines (referred to as RICE or engines). These engines are primarily used by the natural gas industry and tend to be concentrated in the major gas-producing states and along gas pipelines. The proposed regulations are designed to reduce emissions of hazardous air pollutants (HAPs) generated by the combustion of fossil fuels in engines. The primary HAPs emitted by RICE include formaldehyde, acetaldehyde, acrolein, and methanol. This report presents the results of an economic impact analysis (EIA) in which a market model is used to analyze the impacts of the proposed air pollution rule on society.

1.1 Agency Requirements for an EIA

Congress and the Executive Office have imposed statutory and administrative requirements for conducting economic analyses to accompany regulatory actions. Section 317 of the CAA specifically requires estimation of the cost and economic impacts for specific regulations and standards proposed under the authority of the Act. In addition, Executive Order (EO) 12866 requires a more comprehensive analysis of benefits and costs for proposed *significant* regulatory actions.[1] Other statutory and administrative requirements include examination of the composition and distribution of benefits and costs. For example, the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement and Fairness Act of 1996 (SBREFA), requires EPA to consider the economic impacts of regulatory actions on small entities. The Office of Air Quality Planning and Standards (OAQPS) has developed the *OAQPS Economic Analysis Resource Document*, which provides detailed instructions and expectations for economic analyses performed by this office that support such rulemakings (EPA, 1999a).

add to Statutory Requirements section & Intro.

[1]Office of Management and Budget (OMB) guidance under EO 12866 stipulates that a full benefit-cost analysis is required only for economically significant actions (i.e.. when the regulatory action has an annual effect on the economy of $100 million or more).

1.2 Scope and Purpose

The CAA's purpose is to protect and enhance the quality of the nation's air resources (Section 101(b)). Section 112 of the CAA Amendments of 1990 establishes the authority to set national emissions standards for HAPs. This report evaluates the economic impacts of pollution control requirements placed on RICE under these amendments. These control requirements are designed to reduce releases of HAPs into the atmosphere.

To reduce emissions of HAPs, the Agency establishes maximum achievable control technology (MACT) standards. The term "MACT floor" refers to the minimum control technology on which MACT standards can be based. For existing major sources[2], the MACT floor is the average emissions limitation achieved by the best performing 12 percent of sources (if there are 30 or more sources in the category or subcategory). For new sources, the MACT floor must be no less stringent than the emissions control achieved in practice by the best controlled similar source. The MACT can also be chosen to be more stringent than the floor, considering the costs and the health and environmental impacts.

Under the proposed regulation, there are eight subcategories of engines affected. These categories are: (1) spark ignition, two-stroke lean burn (2SLB); (2) spark ignition, four-stroke lean burn (4SLB); (3) spark ignition, four-stroke rich burn (4SRB); (4) compression ignition (CI); (5) emergency power units; (6) stationary RICE that combust digester gas or landfill gas as a primary fuel; (7) stationary RICE with a manufacturer's nameplate rating of less than or equal to 500 brake horsepower; and (8) stationary RICE located at area sources of pollution. Only the first four categories of engines are subject to emission controls. The CI engines may be either two-stroke lean burn or four-stroke lean burn. The distinction between CI engines and the other engine types is that CI engines are powered by diesel fuel and the other engine types are powered by natural gas.[3] Because different control technologies are available for the different types of engines and the different types may produce varying levels of emissions, the MACT requirements for these engine categories were developed separately.

---

[2]A major source is defined as a stationary source or group of stationary sources located within a contiguous area and under common control that emits, or has the potential to emit considering control, 10 tons or more of any one HAP or 25 tons or more of any combination of HAPs.

[3]Despite the fact that CI engines may be of either two-stroke lean burn or four-stroke lean burn design, 2SLB and 4SLB are used to refer only to spark ignition engines throughout this report for simplicity. All engines burning diesel fuel are placed in the CI category.

Almost all of the existing 2SLB, 4SLB, and CI engines are uncontrolled. Therefore, the MACT floor for these engines is considered to be no control. Because the average of the top 12 percent of existing 4SRB use nonselective catalytic reduction (NSCR) systems, the MACT floor for 4SRB RICE was chosen as the level of HAP emissions reduction achieved by using NSCR. For this regulation, the MACT for all existing engines is chosen to be the MACT floor for that engine type, meaning that the only existing engines subject to controls are the 4SRB RICE.

The MACT floor for new 4SRB engines (i.e., based on the best controlled similar source) is the same as for existing 4SRB engines, the level of control achieved by NSCR. Because there are a small number of 2SLB, 4SLB, and CI engines that operate with oxidation catalyst systems in place, the MACT floor for new engines of these types is the level of control that these existing controlled engines achieve. Once again, the MACT floor was chosen as the required level of control on new engines for all engine types (although the actual amount of emission reduction achieved through these controls varies by engine type). The costs for individual units to comply with the MACT standards are inputs into the EIA presented in this report.

To estimate the social cost and economic impacts associated with the regulation, the entrance of new RICE is projected through the year 2005. The annualized cost of required control devices is estimated for 12 model engines, and these costs are linked to the existing and projected new units. The impacts on affected markets as a result of these costs is then estimated.

1.3 Organization of the Report

The remainder of this report is divided into five sections that describe the methodology and present results of this analysis:

- Section 2 provides background information on RICE technologies, profiles the existing RICE units and reviews the costs of compliance associated with the proposed regulation. Projections of the future population of engines in 2005 are also presented.
- Section 3 profiles the industries with the largest number of affected facilities. Included are profiles of the crude petroleum and natural gas extraction industry (SIC 13) and the natural gas pipeline industry (SIC 4922).

- Section 4 describes the methodology for assessing the economic impacts of the proposed NESHAP and presents the results of the economic analysis, including market, industry, and social cost impacts.
- Section 5 provides the Agency's analysis of the regulation's impact on small businesses.
- Section 6 describes the key assumptions used in performing the analysis.

In addition to these sections, Appendix A details the economic model used to predict the economic impacts of the NESHAP, and Appendix B presents the results of sensitivity analyses on key model assumptions.

SECTION 2

RICE TECHNOLOGIES AND UNIT PROFILE

EPA identified 2,645 existing engines at 834 facilities (potentially affected by this rule), mostly in either the oil and gas extraction industry or the natural gas transmission industry. This includes all of the identified engines in the database greater than 500 hp. The data for these units, which were used to generate the effects of the proposed regulation on the affected RICE population, were developed from the EPA Inventory Database V.4—Internal Combustion (IC) Engines (referred to as the Inventory Database). The list of engines in this database was itself developed from information in the Aerometric Information Retrieval System (AIRS) and Ozone Transport Assessment Group (OTAG) databases and state and local permit records. As part of the Industrial Combustion Coordinated Rulemaking (ICCR) Federal Advisory Committee Act (FACA) process, industry and environmental stakeholders reviewed the engines units in the EPA Inventory Database. Because the only existing RICE affected by the rules are 4SRB, most of the engines in the database would not have any control costs. Only 889 of the engines in the database are expected to incur any control costs. In addition, stakeholders contributed to the Inventory Database by identifying and including omitted units. This section provides background information on RICE technologies, the units and facilities in the Inventory Database, and engines population estimates. Included is a discussion of pollutants associated with these units and the cost of installing control technologies.

2.1 Engines Technologies

The IC engines affected by the regulation are of three design categories as discussed in Section 1: 2SLB, 4SLB, and 4SRB. In an IC engine, a mixture of air and fuel is burned in engine cylinders. A series of pistons and a crankshaft convert the energy of the expanding gases into mechanical work. Apart from the number of strokes, two or four, engines are differentiated by their air-to-fuel (A/F) ratio. As defined by the Gas Research Institute (2000), the relative proportions of air and fuel are expressed as the mass of air to that of fuel and is called the A/F ratio. The A/F ratio is called "stoichiometric" if the mixture contains the minimum amount of air that supplies sufficient oxygen to complete combustion of the fuel. Rich burn engines operate near the fuel-air stoichiometric limit with excess oxygen levels less than 4 percent. Lean burn engines operate with significantly higher excess oxygen levels (GRI, 2000). The majority of the information contained in this section is from the Gas Research Institute's publication, "Engine Design, Operation, and Control in the Natural Gas Industry" (2000).

2.1.1 Two-Stroke Engines

A two-stroke engine completes the power cycle in one revolution of the crankshaft. The crankshaft in an IC engine is attached to the pistons. When the pistons move up and down, the crankshaft turns and converts the reciprocating motion of the pistons into rotary motion. The first stroke begins with the piston at the top of the cylinder. At this time, the engine's combustion chamber contains a compressed mixture of fuel and air. The mixture is ignited by a spark that causes a sudden increase in temperature and pressure that forces the piston downward, transferring power to the crankshaft. As the piston travels downward, air and exhaust ports are uncovered, allowing combustion gases to exit and fresh air to enter. During the second stroke, the air and exhaust ports close and fuel is injected into the cylinder. As the piston returns to its starting position, the upward motion compresses the fuel and air mixture. When the piston reaches the top of the cylinder, the compressed fuel and air mixture is ignited again and the cycle begins again.

Because fresh air is used to clear combustion gases from the cylinder, two-stroke engines operate with an A/F ratio greater than stoichiometric and are, therefore, all of the "lean-burn" design type. A/F ratios for 2SLB engines range between 20:1 and 60:1. Their exhaust temperatures are normally between 550 and 800°F. All 2SLB engines are direct-injected (i.e., fuel is injected directly into the cylinder) (GRI, 2000).

2.1.2 Four-Stroke Engines

A four-stroke engine completes the power cycle in two revolutions of the crankshaft. The first stroke is the intake stroke during which the intake valve opens and the exhaust valve closes. The downward motion of the piston draws air (direct injected) or a mixture of air and fuel (premixed) into the cylinder. During the second stroke, the intake valve closes, and the fuel is injected (direct injected) into the cylinder as the piston moves upward to compress the air and fuel mixture. As the piston finishes its upward stroke, a spark ignites the mixture, causing a sudden increase in temperature and pressure. The increased pressure drives the piston downward (i.e., the third stroke), delivering power to the crankshaft. During the fourth stroke. the exhaust valve opens and the piston moves upwards to force the exhaust gases out of the cylinder. The regulation will affect two types of spark ignition, four-stroke engines: 4SLB and 4SRB.

Four-Stroke Lean Burn. Compared to the 2SLB engine, the 4SLB engine reduces the presence of high fuel concentration and temperature gradients in the cylinder by mixing the air and fuel during the second stroke. Compared to a 4SRB engine, the increased A/F ratio in 4SLB engines reduces combustion and exhaust temperatures. A/F ratios for this engine configuration are similar to those of 2SLB engines.

Four-Stroke Rich Burn. 4SRB engines have A/F ratios near stoichiometric, meaning that in these engines the proportion of fuel relative to air is greater than in lean-burn engines. All turbo-charged engines that do not introduce fresh air to sweep combustion gases out of the cylinder after ignition are 4SRB engines (GRI, 2000). A/F ratios for these engines typically range between 16:1 and 20:1. Exhaust temperature is higher in rich-burn engines than in lean-burn engines.

2.1.3 Compression Ignition Units

CI units almost always operate as lean burn engines. They can be configured as either 2SLB or 4SLB; the distinction is that CI engines are fueled by distillate fuel oil (diesel oil), not by natural gas. Fuel consumption is an important determinant in the type of emissions from these units; combustion of natural gas and combustion of diesel oil may each have separate types and proportions of emissions. Because of this difference in fuel consumption, the type of control equipment, and thus cost, varies from natural gas-fueled units, even if those using diesel are of the same engine configuration and horsepower (hp).

2.2 Emissions

The proposed regulation aims to reduce HAP emissions. HAPs of concern include formaldehyde, acetaldehyde, acrolein, and methanol. Without the regulation, annual HAP emissions are estimated to be 49,967 tons each year by 2005. The proposed regulation will decrease emissions to 36,185 tons, for a total reduction of 13,782 tons (Ali, 2000). Table 2-1 contains the HAP emissions factors for each engine configuration in pounds per hour. Emissions are greatest for 2SLB engines, which, on average, emit 1.08 lbs. per hour of HAPs, and least for CI engines, which emit 0.03 lbs. per hour.

Table 2-1. HAP Emissions Factors by Engine Configuration (lbs/hour)[a]

Engine Configuration	Emissions Factor (lbs/hour)
2SLB	1.0791
4SLB	1.0108
4SRB	0.0707
CI	0.0344

[a] The HAP emissions factors presented are the sum of the factors for formaldehyde, acetaldehyde, acrolein, and methanol.

2.3 Control Costs

The primary method identified by EPA for controlling emissions from 2SLB, 4SLB, and CI engines is the use of oxidation catalyst systems. However, few existing 2SLB, 4SLB, and CI engines currently use these systems to control their emissions. Less than 1 percent of 2SLB and CI engines are controlled, and only about 3 percent of 4SLB engines are controlled. All of these numbers are well below the 12 percent criteria for a MACT floor in each subcategory, so the MACT floor in these categories was considered to be no control. An above-the-floor MACT option of requiring oxidation catalyst systems was considered for these subcategories of engines, but it was determined that the incremental cost of this alternative would be excessive (EPA, 2000a).

Unlike the situation for the other engine configurations, more than 12 percent of existing 4SRB stationary RICE control emissions. The method used to control emissions from 4SRB engines is known as nonselective catalytic reduction (NSCR). Because more than 12 percent of existing engines in this category are controlled, the MACT floor for existing 4SRB engines is considered to be the level of HAP emissions reduction achieved by using NSCR systems. Although less than 12 percent of existing 2SLB, 4SLB, and CI engines are controlled with oxidation catalyst systems, there are a few stationary RICE operating with these systems in each of these subcategories. Therefore, the MACT floor for new sources in these subcategories is defined as the level of HAP emissions control achieved using oxidation catalyst systems. For new 4SRB engines, the MACT floor is the same as for existing engines. The required control for new 4SRB engines is the level of HAP emissions reduction achieved using NSCR systems (EPA, 2000).

Each unit in the Inventory Database was grouped into one of 12 categories, or model types, based on its engine configuration, horsepower, and fuel type. For each of those model types, the annualized cost of installing pollution control equipment to achieve the floor level of control and the associated administrative, operating, monitoring, and maintenance costs for that equipment were estimated. This allowed annual cost estimates to be available for each unit in the Inventory Database. Once the unit-level cost elements were available, they were summed using ownership information to determine costs at the facility- and parent firm-levels.

The annual cost of control and monitoring for these units ranges between $20,000 and $254,000. Table 2-2 lists the model types, characteristics, and costs[1] for the 12 unit categories as well as the number of units from the Inventory Database that fall into those categories.[2] Affected engines that have capacities between 500 and 1,000 hp generally have costs less than $30,000 per year. Affected engines that have capacities between 1,000 and 5,000 hp have control and monitoring costs between $65,000 and $90,000 per year. Affected engines with capacities greater than 5,000 hp have annual control and monitoring costs greater than $200,000 per year. Based on the proportion of each model number included in the Inventory Database, the mean cost expected per affected new engine is $57,288 and the median is $65,959.[3]

2.4 Profile of RICE Units and Facilities in Inventory Database

2.4.1 Unit Characterization

Engines in the Inventory Database range in capacity from 500 to 8,000 hp. Despite the presence of units with horsepower capacity of 5,000 or more, the vast majority of units are less than 1,500 hp (see Figure 2-1). About 80 percent of the Inventory units, 2,088

[1]Costs are calculated based on values in Ali (2000).

[2]Not all existing engines listed will incur these costs. The only existing engines in the database subject to controls are 4SRB engines (models 7, 8, and 9).

[3]However, the Agency expects a different growth pattern than one proportional to the Inventory Database. Expected growth is outlined and cost per engine based on that projection is provided in Section 2.5.

Table 2-2. Total Annual Control Cost, Number of Units, and Unit Characteristics of Engines in the Inventory Database by Model Number

Model Number	Number[a] of Units	Engine Configuration	Fuel Type	Hp Range	Annual Control Cost	Annual Monitoring Cost	Average Total Annual Cost
1	259	2SLB	Natural gas	500 to 1,000	$16,500	$5,959	$22,459
2	500	2SLB	Natural gas	1,000 to 5,000	$66,000	$5,959	$71,959
3	57	2SLB	Natural gas	5,000 to 10,000	$165,000	$58,800	$223,800
4	170	4SLB	Natural gas	500 to 1,000	$15,000	$5,959	$20,959
5	608	4SLB	Natural gas	1,000 to 5,000	$60,000	$5,959	$65,959
6	37	4SLB	Natural gas	5,000 to 10,000	$150,000	$58,800	$208,800
7	650	4SRB	Natural gas	500 to 1,000	$20,250	$6,496	$26,746
8	238	4SRB	Natural gas	1,000 to 5,000	$81,000	$6,496	$87,496
9	1	4SRB	Natural gas	5,000 to 10,000	$202,500	$21,618	$224,118
10	63	CI	Diesel	500 to 1,000	$19,500	$5,959	$25,459
11	60	CI	Diesel	1,000 to 5,000	$78,000	$5,959	$83,959
12	2	CI	Diesel	5,000 to 10,000	$195,000	$58,800	$253,800

[a] These are the number of units of each model type included in the Inventory Database. However, only the 4SRB engines (models 7, 8, and 9) in the database are subject to controls because the MACT floor for existing 2SLB, 4SLB, and CI engines is no control.

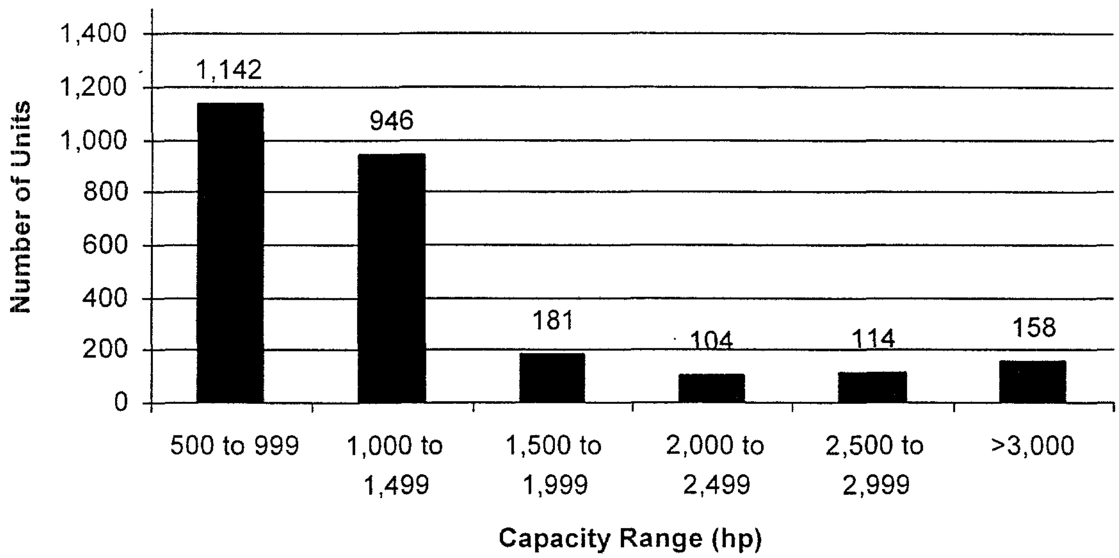


Figure 2-1. Capacity Ranges for Engines in the Inventory Database

engines, have capacities less than 1,500 hp. More than half of those engines have less than 1,000 hp. Only 557 units are greater than 1,500 hp.

About two-thirds of the units in the Inventory Database are described as lean-burn units (see Figure 2-2). All of the rich-burn units are four-stroke; the lean-burn units are split fairly evenly between two-stroke and four-stroke configurations. Also, 95 percent of the units use natural gas for fuel (only about 5 percent are CI units).

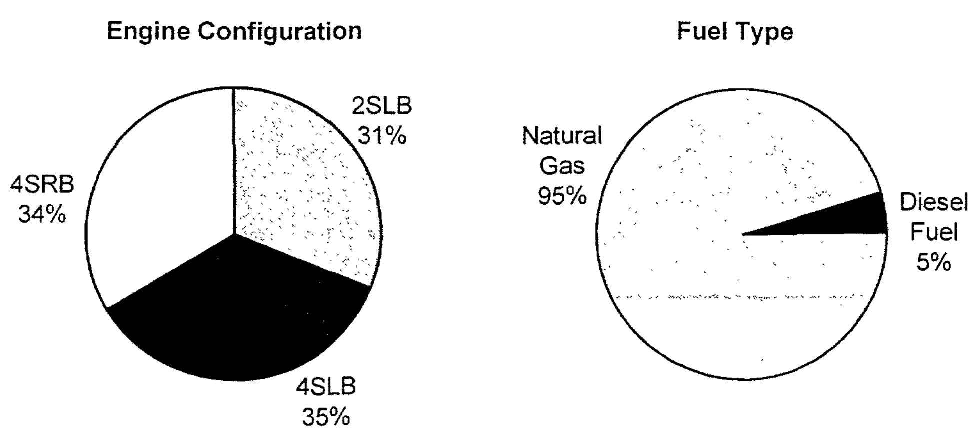


Figure 2-2. Characteristics of Engines in the Inventory Database

2.4.2 Facility Characterization

The 2,645 units identified in the Inventory Database are located at 834 facilities. Table 2-3 presents the distribution of units and facilities by industry grouping. Most of the Inventory Database units are concentrated in two industries: oil and gas extraction and electric and gas services. Table 2-4 provides unit and facility counts by four-digit SIC code for these two industries. According to their four-digit SIC codes, most of the units are located at compression stations on natural gas pipelines or at oil and gas fields and plants. The only other industries with relatively sizable numbers of units at the two-digit SIC code level are the mining and quarrying industry and health services, such as clinics and hospitals.

2.5 Projected Growth of RICE

The Agency estimates that, without the rule, by the end of 2005 the U.S. will have 20,306 new IC engines with horsepower greater than 500. These estimates are based on the expected growth in the number of engines in each of the 12 model categories listed in Table 2-5. Table 2-5 lists several unit counts: units in the Inventory Database, existing affected units, and projected unit growth over 5 years. The latter two categories are also broken out by the total number of units and the number of units that would have been controlled regardless of the rule.

Existing 2SLB engines (model numbers 1, 2, and 3) are not affected by the rule. As new 2SLB units come online, however, they will be required to install the requisite control equipment and operators will have to adhere to monitoring requirements. It is estimated that 500 new 2SLB engines of greater than 500 hp will have come into operation by the end of 2005, none of which are expected to be greater than 1,000 hp.

Existing 4SLB engines (model numbers 4, 5, and 6) are also not affected by this rule. In the absence of this rule, it is expected that 3 percent of new units would come online controlled in the future based on the percentage of units currently controlled (Ali, 2000). Therefore, only the remaining 97 percent (2,060 of 2,124 units) will have control costs associated with the rule. The cost of controlling the additional remaining 3 percent was not included in the rule's cost because it would have been borne by industry regardless of the rule; the rule will not affect those business decisions. However, all 2,124 new 4SLB engines will incur monitoring costs. It is expected that very few of these units will be greater than 5,000 hp.

Table 2-3. Number of Units and Facilities and Average Number of Units per Facility by Industry in the Inventory Database

SIC	Industry Description	Number of Units	Number of Facilities	Average Number of Units Per Facility
02	Agricultural Services	1	1	1.0
10	Metal Mining	1	1	1.0
13	Oil & Gas Extraction	1,146	311	3.7
14	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	32	27	1.2
16	Heavy Construction	1	1	1.0
20	Food & Kindred Products	15	4	3.8
21	Textile Mill Products	9	1	9.0
26	Pulp & Paper	1	1	1.0
28	Chemicals & Allied Products	16	4	4.0
29	Petroleum Refining & Related Industries	11	7	1.6
30	Rubber & Misc. Plastics	3	2	1.5
32	Stone, Clay, Glass, & Concrete Products	1	1	1.0
33	Primary Metals Industries	3	1	3.0
45	Transportation by Air	1	1	1.0
46	Pipelines, Except Natural Gas	8	4	2.0
49	Electric, Gas, & Sanitary Services	1,311	436	3.0
50	Durable Goods Wholesale Trade	1	1	1.0
55	Automotive Dealers & Gas Stations	4	1	4.0
63	Insurance Carriers	5	3	1.7
65	Real Estate	1	1	1.0
73	Business Services	13	1	13.0
80	Health Services	36	20	1.8
82	Educational Services	1	1	1.0
92	Justice, Public Order, & Safety	4	1	4.0
Unknown		20	2	10.0
Total		2,645	834	3.2

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63. II-K-4b2 through -4b5. Research Triangle Park. North Carolina. September 16-17.

Table 2-4. Units and Facilities in the Oil and Gas Extraction (SIC 13) and Electric, Gas, and Sanitary Services (SIC 49) Industries in the Inventory Database

SIC	Description	Number of Units	Number of Facilities
1311	Crude Petroleum & Natural Gas	543	193
1321	Natural Gas Liquids	601	117
1382	Oil & Gas Field Exploration Services	3	1
1389	Oil & Gas Field Services, N.E.C.	1	1
Subtotal		1,148	312
4911	Electric Services	31	12
4922	Natural Gas Transmission	1,268	416
4924	Natural Gas Distribution	1	1
4941	Water Supply	1	1
4952	Sewerage Systems	2	1
4953	Refuse Systems	2	1
Subtotal		1,305	432
Total		2,453	744

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

The only existing engines that are affected by the rule are 4SRB engines (model numbers 7, 8, and 9). Those engines that are not already controlled, 3,339 units, will have to install control equipment. All existing 4SRB engines (4,573 units) must comply with the monitoring component of the rule. For new sources, the Agency estimates that 27 percent (1,157 units) would come online controlled without the rule based on the current population of 4SRB engines (Ali, 2000). Thus, control costs for these units are not included in the total cost of the rule. However, all 4,283 units projected to enter into operation by the end of 2005 will incur monitoring costs. Most existing units are less than 1,000 hp, but the majority of new units are expected to be between 1,000 and 5,000 hp.

Table 2-5. Weights and 2005 Total Population Estimates

Model Number	Engine Configuration	Units in Inventory Database	Total Existing Affected Units[a]	Existing Affected Uncontrolled Units	Total 5-year Growth in Affected Units	5-year Growth in Affected Uncontrolled Units[b]	Total Affected Units (2005)	Unit Weights (Total Affected Units/Inventory Database [2005])
1	2SLB	259	0	0	500	500	500	1.931
2	2SLB	500	0	0	0	0	0	—
3	2SLB	57	0	0	0	0	0	—
4	4SLB	170	0	0	2,124	2,060	2,124	12.494
5	4SLB	608	0	0	3,412	3,308	3,412	5.612
6	4SLB	37	0	0	12	10	12	0.324
7	4SRB	650	3,353	2,448	1,858	1,356	5,211	8.017
8	4SRB	238	1,215	887	2,417	1,764	3,632	15.261
9	4SRB	1	5	4	8	6	13	13.000
10	CI	63	0	0	5,985	5,985	5,985	95.000
11	CI	60	0	0	3,990	3,990	3,990	66.500
12	CI	2	0	0	0	0	0	—
Total		2,645	4,573	3,339	20,306	18,979	24,879	

[a] The only existing engines affected by this rule are 4SRB engines, some of which are already controlled in the absence of this rule. Monitoring costs due to the rule apply to all of the 4SRB engines, even those already controlled.

[b] It is assumed that 27 percent of new 4SRB and 3 percent of new 4SLB engines would be controlled in the absence of this regulation. Therefore, the costs of controls for these engines are not included in the total cost of the regulation. However, the monitoring costs incurred by all of these engines due to the rule are included in calculating the total cost.

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

Similar to 2SLB and 4SLB engines, only new CI engines (model numbers 10, 11, and 12) will be affected by this rule. Existing CI engines do not have to add any controls. None of these engines are projected to be controlled in the absence of regulation. Therefore, all 9,975 units estimated to enter into operation by the end of 2005 will be subject to both control and monitoring costs under the regulation. About 60 percent of these units are expected to be under 1,000 hp; no units are expected to be greater than 5,000 hp.

Although growth estimates by engine configuration and horsepower are available, estimates of the growth in the number of units by industry are not. To assess the distribution of the engines estimated to be operating in 2005 across industries, unit-level weights were attached by model number to each engine in the Inventory Database. These weights, which are listed in Table 2-5, allow each unit in the Inventory Database to represent a number (or fraction) of units that are predicted to be in use by the end of 2005. The weights were then summed by two-digit SIC code to estimate the distribution of 24,879 units by industry.

A principal effect of using this weighting process is that the dominance of the oil and gas extraction and electric and gas services industries was diminished because other industries had units with configurations associated with greater growth projections, and thus weights, which increased their estimated number of future units. The total number of affected units in 2005 by industry is presented in Table 2-6. The third column lists the number of units in the Inventory Database. The fourth column presents the estimated population based on the unit configuration weights. Whereas the units used in either oil and gas extraction (SIC 13) or electric and gas services (SIC 49) account for 93 percent of the units in the Inventory Database, they only account for 68 percent of the estimated population in 2005 using the weights in Table 2-5. The weighting system gave added prominence to industries such as mining and quarrying, real estate, and health services that use mainly CI engines because CI engines are underrepresented in the database relative to the estimated population of these engines.

Based on the unit projections in Table 2-6, the engineering control costs of this regulation would be $1,114.7 million in 2005. These costs are inputs into the market model used in Section 4 to estimate the changes in price and quantity taking place in each affected market as a result of the regulation as well as the social costs of the rule. The magnitude and distribution of the regulatory costs' impact on the economy depend on the relative size of the

Table 2-6. Engineering Costs by SIC Code

SIC	Industry Description	Number of Units in Inventory Database	Estimated 2005 Affected Population	Engineering Costs (1998$)
02	Agricultural Services	1	8	170,587
10	Metal Mining	1	95	2,418,605
13	Oil & Gas Extraction	1,146	7,162	295,406,008
14	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	32	2,483	96,402,266
16	Heavy Construction	1	0	0
20	Food & Kindred Products	15	156	9,402,703
21	Textile Mill Products	9	77	2,555,362
26	Pulp & Paper	1	67	5,583,274
28	Chemicals & Allied Products	16	431	21,692,922
29	Petroleum Refining & Related Industries	11	370	13,455,194
30	Rubber & Misc. Plastics	3	91	6,095,706
32	Stone, Clay, Glass, & Concrete Products	1	95	2,418,605
33	Primary Metals Industries	3	17	1,079,665
45	Transportation by Air	1	8	170,587
46	Pipelines, Except Natural Gas	8	306	8,422,194
49	Electric, Gas, & Sanitary Services	1,311	9,750	471,576,378
50	Durable Goods Wholesale Trade	1	95	2,418,605
55	Automotive Dealers & Gas Stations	4	32	682,349
63	Insurance Carriers	5	216	17,090,995
65	Real Estate	1	95	2,418,605
73	Business Services	13	23	1,174,792
80	Health Services	36	2,906	132,291,790
82	Educational Services	1	67	5,503,274
92	Justice, Public Order, & Safety	4	323	16,003,757
Unknown		20	8	170,587
Total		2,645	24,879	1,114,684,811

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

impact on individual markets (relative shift of the market supply curves) and the behavioral responses of producers and consumers in each market (as measured by the elasticity of supply and the elasticity of demand).

SECTION 3

PROFILES OF AFFECTED INDUSTRIES

This section contains profiles of the industries most directly affected by the proposed regulation of RICE. Most existing engines that would be subject to the regulation are concentrated in two industries, petroleum and natural gas extraction (SIC 13) and natural gas transmission (SIC 4922). Together, they account for over 90 percent of the engines identified by EPA in the Inventory Database that would fall under this rule. (The remaining units are spread across various industries, most notably mining and quarrying of nonmetallic minerals, health services, and various manufacturing industries, such as food and kindred products and chemicals and allied products.) Most new engines that would be affected by this regulation are also projected to be in these industries.

The oil and natural gas industry is divided into five distinct sectors: (1) exploration, (2) production, (3) transportation, (4) refining, and (5) marketing. The NESHAP considers controls on the use of RICE, which are used in this industry primarily to power compressors used for crude oil and natural gas extraction and natural gas pipeline transportation. Therefore, this section contains background information on the petroleum and natural gas extraction industry and the natural gas transmission industry to help inform the regulatory process.

3.1 Crude Petroleum and Natural Gas (SIC 13)

The crude petroleum and natural gas industry encompasses the oil and gas extraction process from the exploration for oil and natural gas deposits through the transportation of the product from the production site. The primary products of this industry are natural gas, natural gas liquids, and crude petroleum.

3.1.1 Introduction

The U.S. is home to half of the major oil and gas companies operating around the globe. Although small firms account for nearly 45 percent of U.S. crude oil and natural gas output, the domestic oil and gas industry is dominated by 20 integrated petroleum and natural gas refiners and producers, such as Exxon Mobil, BP Amoco, and Chevron (Lillis, 1998).

Despite the presence of many large global players, the industry experiences a more turbulent business cycle than most other major U.S. industries. Because oil is an international commodity, the U.S. production of crude oil is affected by the world crude oil price, the price of alternative fuels, and existing regulations. Domestic oil production has been falling in recent years. Total U.S. crude oil production is expected to fall to 5.78 million barrels per day in 2000, the lowest annual U.S. crude oil output since 1950 (EIA, 2000). Because the industry imports 60 percent of the crude oil used as an input into refineries, it is susceptible to fluctuations in crude oil output and prices, which may be influenced by the Organization of Petroleum Exporting Countries (OPEC).[1]

In contrast, natural gas markets in the U.S. are competitive and relatively stable. Domestic natural gas production has been on an upward trend since the mid-1980s. Almost all natural gas used in the U.S. comes from domestic and Canadian sources.

Within SIC 13, there are five major industry groups (see Table 3-1):

- SIC 1311 (NAICS 211111): Crude petroleum and natural gas. Firms in this industry are primarily involved in the operation of oil and gas fields. These firms may also explore for crude oil and natural gas, drill and complete wells, and separate crude oil and natural gas components from natural gas liquids and produced fluids.

- SIC 1321 (NAICS 211112): Natural gas liquids (NGL). NGL firms separate NGLs from crude oil and natural gas at the site of production. Propane and butane are examples of NGLs.

- SIC 1381 (NAICS 213111): Drilling oil and gas wells. Firms in this industry drill oil and natural gas wells on a contract or fee basis.

- SIC 1382 (NAICS 213112/54136): Oil and gas field exploration services. Firms in this industry perform geological, geophysical, and other exploration services.

- SIC 1389 (NAICS 213112): Oil and gas field services, not elsewhere classified. Companies in this industry perform services on a contract or fee basis that are not classified in the above industries. Services include drill-site preparations, such as

[1]OPEC is a cartel consisting of most of the world's largest petroleum-producing countries that attempts to increase the profits of member countries.

Table 3-1. Crude Petroleum and Natural Gas Industries Likely to Be Affected by the Regulation

SIC	NAICS	Description
1311	211111	Crude Petroleum and Natural Gas
1321	211112	Natural Gas Liquids
1381	213111	Drilling Oil and Gas Wells
1382	213112	Oil and Gas Exploration Services
	54136	Geophysical Surveying and Mapping Services
1389	213112	Oil and Gas Field Services, N.E.C.

building foundations and excavating pits, and maintenance.

In 1997, more than 6,800 crude oil and natural gas extraction companies (SIC 1311) generated $75 billion in revenues (see Table 3-2). Revenues for 1997 were approximately 5 percent higher than revenues in 1992, although the number of companies and employees declined 11.5 and 42.5 percent, respectively.

Table 3-2 shows the NGL extraction industry (SIC 1321) experienced a decline in the number of companies, establishments, and employees. The industry's revenues declined nearly 8.0 percent between 1992 and 1997, from $27 billion per year to $24.8 billion per year.

Revenues for SIC 1381, drilling oil and gas wells, more than doubled between 1992 and 1997. In 1992, the industry employed 47,700 employees at 1,698 companies and generated $3.6 billion in annual revenues. By the end of 1997, the industry's annual revenues were $7.3 billion, a 106 percent improvement. Although the total number of companies and establishments decreased from 1992 levels, industry employment increased 13 percent to 53,685.

The recent transition from the SIC system to the North American Industrial Classification System (NAICS) changed how some industries are organized for information collection purposes and thus how certain economic census data are aggregated. Some SIC codes were combined, others were separated, and some activities were classified under one NAICS code and the remaining activities classified under another. The oil and gas field

Table 3-2. Summary Statistics, Crude Oil and Natural Gas Extraction and Related Industries

SIC	Industry	Number of Companies	Number of Establishments	Revenues ($1997 10^3)	Employees
1311	Crude Oil and Natural Gas Extraction				
	1992	7,688	9,391	71,622,600	174,300
	1997	6,802	7,781	75,162,580	100,308
1321	Natural Gas Liquid Extraction				
	1992	108	591	26,979,200	12,000
	1997	89	529	24,828,503	10,549
1381	Drilling Oil and Gas Wells				
	1992	1,698	2,125	3,552,707	47,700
	1997	1,371	1,638	7,317,963	53,865
1382/89	Oil and Gas Field Services				
	1997	6,385	7,068	11,547,563	106,339

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining Industry Series*. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series*. Washington, DC: U.S. Department of Commerce.

services industry is an example of an industry code that was reclassified. Under NAICS, SIC 1382, Oil and Gas Exploration Services, and SIC 1389, Oil and Gas Services Not Elsewhere Classified, were combined. The geophysical surveying and mapping services portion of SIC 1382 was reclassified and grouped into NAICS 54136. The adjustments to SIC 1382/89 have made comparison between the 1992 and 1997 economic censes difficult at this time. The U.S. Census Bureau has yet to publish a comparison report. Thus, for this industry only 1997 census data are presented. For that year, nearly 6,400 companies operated under SIC 1382/89 (NAICS 213112), employing more than 100,000 people and generating $11.5 billion in revenues.

3.1.2 Supply Side Characteristics

Characterizing the supply side of the industry involves describing the production processes, the types of output, major by-products, costs of production, and capacity utilization.

3.1.2.1 Production Processes

Domestic production occurs within the contiguous 48 U.S., Alaska, and at offshore facilities. There are four major stages in oil and gas extraction: exploration, well development, production, and site abandonment (EPA, 1999b). Exploration is the search for rock formations associated with oil and/or natural gas deposits. Nearly all oil and natural gas deposits are located in sedimentary rock. Certain geological clues, such as porous rock with an overlying layer of low-permeability rock, help guide exploration companies to a possible source of hydrocarbons. While exploring a potential site, the firm conducts geophysical prospecting and exploratory drilling.

After an economically viable field is located, the well development process begins. Well holes, or well bores, are drilled to a depth of between 1,000 and 30,000 feet, with an average depth of about 5,500 feet (EPA, 1999b). The drilling procedure is the same for both onshore and offshore sites. A steel or diamond drill bit, which may be anywhere between 4 inches and 3 feet in diameter, is used to chip off rock to increase the depth of the hole. The drill bit is connected to the rock by several pieces of hardened pipe known collectively as the drill string. As the hole is drilled, casing is placed in the well to stabilize the hole and prevent caving. Drilling fluid is pumped down through the center of the drill string to lubricate the equipment. The fluid returns to the surface through the space between the drill string and the rock formation or casing. Once the well has been drilled, rigging, derricks, and other production equipment are installed. Onshore fields are equipped with a pad and roads; ships, floating structures, or a fixed platform are procured for offshore fields.

Production is the process of extracting hydrocarbons through the well and separating saleable components from water and silt. Oil and natural gas are naturally occurring co-products, and most production sites produce a combination of oil and gas; however, some wells produce little natural gas, while others may produce only natural gas. Once the hydrocarbons are brought to the surface, they are separated into a spectrum of products. Natural gas is separated from crude oil by passing the hydrocarbons through one or two decreasing pressure chambers. Crude oil is always delivered to a refinery for processing and excess water is removed, at which point the oil is about 98 percent pure, a purity sufficient for storage or transport to a refinery (EPA, 1999b). Natural gas may be processed at the field or at a natural gas processing plant to remove impurities. The primary extracted streams and recovered products associated with the oil and natural gas industry include crude oil, natural gas, condensate, and produced water. The products are briefly described below.

Crude oil can be classified as paraffinic, naphthenic, or intermediate. Paraffinic (or heavy) crude is used as an input to the manufacture of lube oils and kerosene. Naphthenic (or light) crude is used as an input to the manufacture of gasoline and asphalt. Intermediate crudes are those that do not fit into either category. The classification of crude oil is determined by a gravity measure developed by the American Petroleum Institute (API). API gravity is a weight per unit volume measure of a hydrocarbon liquid. A heavy crude is one with an API gravity of 20° or less, and a light crude, which flows freely at atmospheric temperature, usually has an API gravity in the range of the high 30s to the low 40s (EPA, 1996).

Natural gas is a mixture of hydrocarbons and varying quantities of nonhydrocarbons that exist either in gaseous phase or in solution with crude oil from underground reservoirs. Natural gas may be classified as either wet or dry gas. Wet gas is unprocessed or partially processed natural gas produced from a reservoir that contains condensable hydrocarbons. Dry gas is natural gas whose water content has been reduced through dehydration, or natural gas that contains little or no commercially recoverable liquid hydrocarbons.

Condensates are hydrocarbons that are in a gaseous state under reservoir conditions (prior to production), but which become liquid during the production process. Condensates have an API gravity in the 50° to 120° range (EPA, 1996). According to historical data, condensates account for about 4.5 to 5 percent of total crude oil production.

Produced water is recovered from a production well or is separated from the extracted hydrocarbon streams. More than 90 percent of produced water is reinjected into the well for disposal and to enhance production by providing increased pressure during extraction. The remainder is released into surface water or disposed of as waste.

In addition to the products discussed above, other various hydrocarbons may be recovered through the processing of the extracted streams. These hydrocarbons include mixed natural gas liquids, natural gasoline, propane, butane, and liquefied petroleum gas.

Natural gas is conditioned using a dehydration and a sweetening process, which removes hydrogen sulfide and carbon dioxide, so that it is of high enough quality to pass through transmission systems. The gas may be conditioned at the field or at one of the 623 operating gas-processing facilities located in gas-producing states, such as Texas, Louisiana, Oklahoma, and Wyoming. These plants also produce the nation's NGLs, propane and butane (NGSA et al., 2000c).

Site abandonment occurs when a site lacks the potential to produce economic quantities of natural gas or when a production well is no longer economically viable. The well(s) are plugged using long cement plugs and steel plated caps, and supporting production equipment is disassembled and moved offsite.

3.1.2.2 Types of Output

The oil and gas industry's principal products are crude oil, natural gas, and NGLs (see Tables 3-3 and 3-4). Refineries process crude oil into several petroleum products. These products include motor gasoline (40 percent of crude oil); diesel and home heating oil (20 percent); jet fuels (10 percent); waxes, asphalts, and other nonfuel products (5 percent); feedstocks for the petrochemical industry (3 percent); and other lesser products (EIA, 1999a).

Natural gas is produced from either oil wells (known as "associated gas") or wells that are drilled for the primary objective of obtaining natural gas (known as "nonassociated gas") (see Table 3-4). Methane is the predominant component of natural gas (about 85 percent), but ethane (about 10 percent), propane, and butane are also significant components (see Table 3-3). Propane and butane, the heavier components of natural gas, exist as liquids when cooled and compressed. These latter two components are usually separated and processed as natural gas liquids (EPA, 1999b). A small amount of the natural gas produced is consumed as fuel by the engines used in extracting and transporting the gas, and the remainder is transported through pipelines for use by residential, commercial, industrial, and electric utility users.

3.1.2.3 Major By-products

In addition to the various products of the oil and natural gas extraction process described above, there are some additional by-products generated during the extraction process. Oil and natural gas are composed of widely varying constituents and proportions depending on the site of extraction. The removal and separation of individual hydrocarbons during processing is possible because of the differing physical properties of the various

Table 3-3. U.S. Supply of Crude Oil and Petroleum Products (10^3 barrels), 1998

Commodity	Field Production	Refinery Production	Imports
Crude Oil	2,281,919		3,177,584
Natural Gas Liquids	642,202	245,918	82,081
Ethane/Ethylene	221,675	11,444	6,230
Propane/Propylene	187,369	200,815	50,146
Normal Butane/Butylene	54,093	29,333	8,612
Isobutane/Isobutylene	66,179	4,326	5,675
Other	112,886		11,418
Other Liquids	69,477		211,266
Finished Petroleum Products	69,427	5,970,090	437,515
Finished Motor Gasoline	69,427	2,880,521	113,606
Finished Aviation Gasoline		7,118	43
Jet Fuel		556,834	45,143
Kerosene		27,848	466
Distillate Fuel Oil		1,249,881	76,618
Residual Fuel Oil		277,957	100,537
Naptha		89,176	22,388
Other Oils		78,858	61,554
Special Napthas		24,263	2,671
Lubricants		67,263	3,327
Waxes		8,355	613
Petroleum Coke		260,061	263
Asphalt and Road Oil		181,910	10,183
Still Gas		239,539	
Miscellaneous Products		20,506	103
Total	3,063,025	6,216,008	3,908,446

Source: Energy Information Administration. 1999b. *Petroleum Supply Annual 1998, Volume I.* Washington, DC: U.S. Department of Energy.

Table 3-4. **U.S. Natural Gas Production, 1998**

Gross Withdrawals	Production (10^6 cubic feet)
From Gas Wells	17,558,621
From Oil Wells	6,365,612
Less Losses and Repressuring	5,216,477
Total	18,707,756

Source: Energy Information Administration. 1999b. *Natural Gas Annual 1998.* Washington, DC: U.S. Department of Energy.

components. Each component has a distinctive weight, boiling point, vapor pressure, and other characteristics, making separation relatively simple. Most natural gas is processed to separate hydrocarbon liquids that are more valuable as separate products, such as ethane, propane, butane, isobutane, and natural gasoline. Natural gas may also include water, hydrogen sulfide, carbon dioxide, nitrogen, helium, or other diluents/contaminants. The water present is either recovered from the well or separated from the hydrocarbon streams being extracted. More than 90 percent of the produced water is reinjected into the well to increase pressure during extraction. If hydrogen sulfide, which is poisonous and corrosive, is present, it is removed and further processed to recover elemental sulfur for commercial sale. In addition, processing facilities may remove carbon dioxide to prevent corrosion and to use for injection into the well to increase pressure and enhance oil recovery, recover helium for commercial sale, and may remove nitrogen to increase the heating value of the gas (Natural Gas Information and Educational Resources, 2000). Finally, the engines that provide pumping action at wells and push crude oil and natural gas through pipes to processing plants, refineries, and storage locations produce HAPs. HAPs produced in engines include formaldehyde, acetaldehyde, acrolein, and methanol.

3.1.2.4 Costs of Production

The 42 percent decrease in the number of people employed by the crude oil and natural gas extraction industry between 1992 and 1997 was matched by a corresponding 40 percent decrease in the industry's annual payroll (see Table 3-5). During the same period, industry outlays for supplies, such as equipment and other supplies, increased over 32 percent, and capital expenditures nearly doubled. Automation, mergers, and corporate downsizing have made this industry less labor-intensive (Lillis, 1998).

Table 3-5. Costs of Production, Crude Oil and Natural Gas Extraction and Related Industries

SIC	Industry	Employees	Payroll ($1997 10^3)	Cost of Supplies Used, Purchased Machinery Installed, Etc. ($1997 10^3)	Capital Expenditures ($1997 10^3)
1311	Crude Oil and Natural Gas Extraction				
	1992	174,300	$8,331,849	$16,547,510	$10,860,260
	1997	100,308	$4,968,722	$21,908,191	$21,117,850
1321	Natural Gas Liquid Extraction				
	1992	12,000	$509,272	$23,382,770	$609,302
	1997	10,549	$541,593	$20,359,528	$678,479
1381	Drilling Oil and Gas Wells				
	1992	47,700	$1,358,784	$1,344,509	$286,509
	1997	53,865	$1,918,086	$7,317,963	$2,209,300
1382/89	Oil and Gas Field Services				
	1997	106,339	$3,628,416	$3,076,039	$1,165,018

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining, Industry Series*. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series*. Washington, DC: U.S. Department of Commerce.

Unlike the crude oil and gas extraction industry, the NGL extraction industry's payroll increased over 6 percent even though total industry employment declined 12 percent. The industry's expenditures on capital projects, such as investments in fields, production facilities, and other investments, increased 11.4 percent between 1992 and 1997. The cost of supplies did, however, decrease 13 percent from $23.3 billion in 1992 to $20.3 billion in 1997.

Employment increased in SIC 1381, Drilling Oil and Gas Wells. In 1992, the industry employed 47,700 people, increasing 13 percent to 53,685 in 1997. During a period where industry revenues increased over 100 percent, the industry's payroll increased 41 percent and the cost of supplies increased 182 percent.

3.1.2.5 Imports and Domestic Capacity Utilization

U.S. annual oil and gas production is a small percentage of total U.S. reserves. In 1998, oil producers extracted approximately 1.5 percent of the nation's proven crude oil reserves (see Table 3-6). A slightly lesser percentage of natural gas was extracted (1.4 percent), and an even smaller percentage of NGLs was extracted (0.9 percent). The U.S. produces approximately 40 percent (2,281 million barrels) of its annual crude oil consumption, importing the remainder of its crude oil from Canada, Latin America, Africa, and the Middle East (3,178 million barrels). Approximately 17 percent (3,152 billion cubic feet) of U.S. natural gas supply is imported. Most imported natural gas originates in Canadian fields in the Rocky Mountains and off the Coast of Nova Scotia and New Brunswick.

Table 3-6. Estimated U.S. Oil and Gas Reserves, Annual Production, and Imports, 1998

Category	Reserves	Annual Production	Imports
Crude Oil (10^6 barrels)	152,453	2,281	3,178
Natural Gas (10^9 cubic feet)	1,330,930	18,708	3,152
Natural Gas Liquids (10^6 barrels)	26,792	246	NA

Sources: Energy Information Administration. 1999d. *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1998 Annual Report.* Washington, DC: U.S. Department of Energy.

Energy Information Administration. 1999b. *Petroleum Supply Annual 1998, Volume I.* Washington DC: U.S. Department of Energy.

3.1.3 Demand Side Characteristics

Characterizing the demand side of the industry involves describing product characteristics. Crude oil, or unrefined petroleum, is a complex mixture of hydrocarbons that is the most important of the primary fossil fuels. Refined petroleum products are used for petrochemicals, lubrication, heating, and fuel. Petrochemicals derived from crude oil are the source of chemical products such as solvents, paints, plastics, synthetic rubber and fibers, soaps and cleansing agents, waxes, jellies, and fertilizers. Petroleum products also fuel the engines of automobiles, airplanes, ships, tractors, trucks, and rockets. Other applications include fuel for electric power generation, lubricants for machines, heating, and asphalt (Berger and Anderson, 1978). Because the market for crude oil is global and its price influenced by OPEC, slight increases in the cost of producing crude oil in the U.S. will have little effect on the prices of products that use crude oil as an intermediate good. Production cost increases are likely to be absorbed mainly by the producer, with little of the increased cost passed along to consumers.

Natural gas is a colorless, flammable gaseous hydrocarbon consisting for the most part of methane and ethane. Natural gas is used by residential, commercial, industrial, and electric utility users. Total consumption of natural gas in the U.S. was 21,262 billion cubic feet in 1998. Industrial consumers accounted for the largest share of this total, consuming 8,686 billion cubic feet, while residential, commercial, and electric utility consumption was 4,520 billion cubic feet, 3,005 billion cubic feet, and 3,258 billion cubic feet, respectively. The remainder of U.S. consumption was by natural gas producers in their plants and on their gas pipelines. The largest single application for natural gas is as a domestic or industrial fuel. Natural gas is also becoming increasingly important for generating electricity. Although these are the primary uses, other specialized applications have emerged over the years, such as a nonpolluting fuel for buses and other motor vehicles. Carbon black, a pigment made by burning natural gas with little air and collecting the resulting soot, is an important ingredient in dyes, inks, and rubber compounding operations. Also, much of the world's ammonia is manufactured from natural gas; ammonia is used either directly or indirectly in urea, hydrogen cyanide, nitric acid, and fertilizers (Tussing and Tippee, 1995).

The primary substitutes for oil and natural gas are coal, electricity, and each other. Consumers of these energy products are expected to respond to changes in the relative prices between these four energy markets by changing the proportions of these fuels they consume. For example, if the price of natural gas were to increase relative to other fuels, then it is likely that consumers would substitute oil, coal, and electricity for natural gas. This effect of changing prices is commonly referred to as fuel-switching. The extent to which consumers change their fuel usage depends on such factors as the availability of alternative fuels and the capital requirements involved. If they own equipment that can run on multiple fuels, then it may be relatively easy to switch fuel usage as prices change. However, if existing capital cannot easily be modified to run on an alternative fuel, then it is less likely for a consumer to change fuels in the short run. If the relative price of the fuel currently in use remains elevated in the long run, some additional consumers will switch fuels as they replace existing capital with new capital capable of using relatively cheaper fuels. For example, if the price of natural gas were to increase greatly relative to the price of electricity for residential consumers, most consumers are unlikely to replace their natural gas furnaces immediately due to the high cost of doing so. However, new construction would be less likely to include natural gas furnaces, and if the price of natural gas were to remain relatively high compared with electricity in the long run, residential consumers would be more likely to replace their natural gas furnaces with electric heat pumps as their existing furnaces wear out.

3.1.4 Organization of the Industry

Many oil and gas firms are merging to remain competitive in both the global and domestic marketplaces. By merging with their peers, these companies may reduce operating expenses and reap greater economies of scale than they would otherwise. Recent mergers, such as BP Amoco and Exxon Mobil, have reduced the number of companies and facilities operating in the U.S. Currently, there are 20 domestic major oil and gas companies, and only 40 major global companies in the world (Conces, 2000). Most U.S. oil and gas firms are concentrated in states with significant oil and gas reserves, such as Texas, Louisiana, California, Oklahoma, and Alaska.

Tables 3-7 through 3-10 present the number of facilities and value of shipments by facility employee count for each of the four SIC 13 industries. In 1997, 6,802 oil and gas extraction companies operated 7,781 facilities, an average of 1.14 facilities per company (see Table 3-7). Facilities with more than 100 employees produced more than 55 percent of the industry's value of shipments. Although the number of companies and the number of facilities operating in 1992 were both greater then than in 1997, the distribution of shipment values by employee size was similar to that of 1992.

Facilities employing fewer than 50 people in the NGLs extraction industry accounted for 64 percent, or $15.8 billion, of the industry's total value of shipments in 1997 (see Table 3-8). Four hundred eighty-seven of the industry's 529 facilities are in that employment category. This also means that a relatively small number of larger facilities produce 36 percent of the industry's annual output, in terms of dollar value. The number of facilities with zero to four employees and the number with 50 or more employees decreased during the 5-year period, accounting for most of the 10.5 percent decline in the number of facilities from

Table 3-7. Size of Establishments and Value of Shipments, Crude Oil and Natural Gas Extraction Industry (SIC 1311), 1997 and 1992

	1997		1992	
Average Number of Employees in Facility	**Number of Facilities**	**Value of Shipments ($1997 10^3)**	**Number of Facilities**	**Value of Shipments ($1997 10^3)**
0 to 4 employees	5,249	$5,810,925	6184	$5,378,330
5 to 9 employees	1,161	$3,924,929	1402	$3,592,560
10 to 19 employees	661	$4,843,634	790	$4,504,830
20 to 49 employees	412	$10,538,529	523	$8,820,100
50 to 99 employees	132	$8,646,336	203	$5,942,130
100 to 249 employees	105		154	$11,289,730
250 to 499 employees	40		68	$8,135,850
500 to 999 employees	14	$41,318,227	46	$14,693,630
1,000 to 2,499 employees	5		18	$9,265,530
2,500 or more employees	2		3	D
Total	7,781	$75,162,580	9.391	$71,622,600

D = undisclosed
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining, Industry Series: Crude Petroleum and Natural Gas Extraction.* EC97N-2111A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series: Crude Petroleum and Natural Gas.* MIC92-I-13A. Washington, DC: U.S. Department of Commerce.

1992 to 1997. The average number of facilities per company was 5.5 and 5.9 in 1992 and 1997, respectively.

As mentioned earlier, the oil and gas well drilling industry's 1997 value of shipments were 106 percent larger than 1992's value of shipments. However, the number of companies primarily involved in this industry declined by 327 over 5 years, and 487 facilities closed during the same period (see Table 3-9). The distribution of the number of facilities by

Table 3-8. Size of Establishments and Value of Shipments, Natural Gas Liquids Industry (SIC 1321), 1997 and 1992

Average Number of Employees in Facility	1997 Number of Facilities	1997 Value of Shipments ($1997 10^3)	1992 Number of Facilities	1992 Value of Shipments ($1997 10^3)
0 to 4 employees	143	$1,407,192	190	$2,668,000
5 to 9 employees	101	$1,611,156	92	$1,786,862
10 to 19 employees	122	$4,982,941	112	$5,240,927
20 to 49 employees	121	$7,828,439	145	$10,287,200
50 to 99 employees	35	$5,430,448	36	$4,789,849
100 to 249 employees	3	D	14	$2,205,819
250 to 499 employees	3	D	2	D
500 to 999 employees	1	D	0	—
1,000 to 2,499 employees	0	—	0	—
2,500 or more employees	0	—	0	—
Total	529	$24,828,503	591	$26,979,200

D = undisclosed
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Economic Census, Mining, Industry Series: Natural Gas Liquid Extraction*. EC97N-2111b. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Mineral Industries, Industry Series: Natural Gas Liquids*. MIC92-I-13B. Washington, DC: U.S. Department of Commerce.

employment size shifted towards those that employed 20 or more people. In 1997, those facilities earned two-thirds of the industry's revenues.

In 1997, 6,385 companies operated 7,068 oil and gas field services facilities, an average of 1.1 facilities per company. The Inventory Database includes 1,599 facilities in SIC 13. Most facilities employed four or fewer employees; however, those facilities with 20 or more employees accounted for the majority of the industry's revenues (see Table 3-10).

Table 3-9. **Size of Establishments and Value of Shipments, Drilling Oil and Gas Wells Industry, 1997 and 1992**

	1997		1992	
Average Number of Employees in Facility	**Number of Facilities**	**Value of Shipments ($1997 10^3)**	**Number of Facilities**	**Value of Shipments ($1997 10^3)**
0 to 4 employees	825	$107,828	1,110	$254,586
5 to 9 employees	215	$231,522	321	$182,711
10 to 19 employees	197	$254,782	244	$256,767
20 to 49 employees	200	$1,008,375	233	$572,819
50 to 99 employees	95	$785,804	120	$605,931
100 to 249 employees	75	$1,069,895	70	$816,004
250 to 499 employees	10	$435,178	19	$528,108
500 to 999 employees	14	$1,574,139	5	$97,254
1,000 to 2,499 employees	6	D	3	$238,427
2,500 or more employees	1	D	—	—
Total	1,638	$7,317,963	2,125	$3,552,707

D = undisclosed
Sums do not add to totals due to independent rounding.

Sources: U.S. Department of Commerce, Bureau of the Census. 1999c. *1997 Economic Census, Mining, Industry Series: Drilling Oil and Gas Wells*. EC97N-2131A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995c. *1992 Census of Mineral Industries, Industry Series: Oil and Gas Field Services*. MIC92-I-13C. Washington, DC: U.S. Department of Commerce.

3.1.5 Markets and Trends

Between 1990 and 1998, crude oil consumption increased 1.4 percent per year, and natural gas consumption increased 2.0 percent per year. The increase in natural gas consumption came mostly at the expense of coal consumption (EPA, 1999b). The Energy Information Administration (EIA) anticipates that natural gas consumption will continue to

Table 3-10. Size of Establishments and Value of Shipments, Oil and Gas Field Services (SIC 1382/89), 1997 and 1992

Average Number of Employees at Facility	1997	
	Number of Facilities	Value of Shipments ($1997 10^3)
0 to 4 employees	4,122	$706,396
5 to 9 employees	1,143	$571,745
10 to 19 employees	835	$904,356
20 to 49 employees	629	$1,460,920
50 to 99 employees	211	$1,480,904
100 to 249 employees	84	$1,175,766
250 to 499 employees	21	$754,377
500 to 999 employees	13	$1,755,689
1,000 to 2,499 employees	9	D
2,500 or more employees	1	D
Total	7,068	$11,547,563

D = undisclosed
Sums do not add to totals due to independent rounding.

Source: U.S. Department of Commerce, Bureau of the Census. 1999d. *1997 Economic Census, Mining, Industry Series: Support Activities for Oil and Gas Operations*. EC97N-2131B. Washington, DC: U.S. Department of Commerce.

grow at a similar rate through the year 2020 to 32 trillion cubic feet/year. Prices are expected to grow steadily, increasing overall by about 0.6 percent annually (EIA, 1999a). They also expect crude oil consumption to grow at an annual rate of less than 1 percent over the same period (EIA, 1999a). For ease of comparison, the quantities used for all energy markets modeled for this EIA are defined in terms of quadrillions of Btus and prices are defined as dollars per million Btus. In 2005, the year used for this analysis, the EIA (2000) projects 24.57 quadrillion Btus of natural gas will be consumed at an average price of $4.23/million Btus, and 41.21 quadrillion Btus of petroleum products will be consumed at an average price of $8.22/million Btus.

3.2 Natural Gas Pipeline Industry

The natural gas pipeline industry (SIC 4922/NAICS 4862) comprises establishments primarily engaged in the pipeline transportation of natural gas from processing plants to local distribution systems. Also included in this industry are natural gas storage facilities, such as depleted gas fields and aquifers.

3.2.1 Introduction

The natural gas industry can be divided into three segments, or links: production, transmission, and distribution. Natural gas pipeline companies are the second link, performing the vital function of linking gas producers with the local distribution companies and their customers. Pipelines transmit natural gas from gas fields or processing plants through high compression steel pipe to their customers. By the end of 1998, there were more than 300,000 miles of transmission lines (OPS, 2000).

The interstate pipeline companies that linked the producing and consuming markets functioned mainly as resellers or merchants of gas until about the 1980s. Rather than acting as common carriers (i.e., providers only of transportation), pipelines typically bought and resold the gas to a distribution company or to some other downstream pipelines that would later resell the gas to distributers. Today, virtually all pipelines are common carriers, transporting gas owned by other firms instead of wholesaling or reselling natural gas (Tussing and Tippee, 1995).

According to the U.S. Bureau of the Census, the natural gas pipeline industry's revenues totaled $19.6 billion in 1997. Pipeline companies operated 1,450 facilities and employed 35,789 people (see Table 3-11). The Inventory Database contains 1,401 facilities in SIC 4922, so the majority of pipeline companies are included. The industry's annual payroll is nearly $1.9 billion.

The recent transition from the SIC system to the NAICS changed how some industries are organized for information collection purposes and thus how certain economic census data are aggregated. Some SIC codes were combined, others were separated, and some activities were classified under one NAICS code and the remaining activities classified under another. The natural gas transmission (pipelines) industry is an example of an industry code that was reclassified. Under NAICS, SIC 4922, natural gas transmission (pipelines), and a portion of SIC 4923, natural gas distribution, were combined. The adjustments have made comparison between the 1992 and 1997 economic censes difficult at this time. The U.S. Census Bureau

Table 3-11. Summary Statistics for the Natural Gas Pipeline Industry (NAICS 4862), 1997

Establishments	1,450
Revenue ($\$10^3$)	\$19,626,833
Annual Payroll ($\$10^3$)	\$1,870,950
Paid Employees	35,789

Source: U.S. Department of Commerce, Bureau of the Census. 2000. *1997 Economic Census, Transportation and Warehousing: Geographic Area Series*. EC97T48A-US. Washington, DC: Government Printing Office.

has yet to publish a comparison report. Thus, for this industry only 1997 census data are presented.

3.2.2 Supply Side Characteristics

Characterizing the supply side involves describing services provided by the industry, by-products, the costs of production, and capacity utilization.

3.2.2.1 Service Description

Natural gas is delivered from gas processing plants and fields to distributers via a nationwide network of over 300,000 miles of transmission pipelines (NGSA et al., 2000a). The majority of pipelines are composed of steel pipes that measure from 20 to 42 inches in diameter and operate 24 hours a day. Natural gas enters pipelines at gas fields, storage facilities, or gas processing plants and is "pushed" through the pipe to the city gate or interconnections, the point at which distribution companies receive the gas. Pipeline operators use sophisticated computer and mechanical equipment to monitor the safety and efficiency of the network.

Reciprocating internal combustion engines compress and provide the pushing force needed to maintain the flow of gas through the pipeline. When natural gas is transmitted, it is compressed to reduce the volume of gas and to maintain pushing pressure. The gas pressure in pipelines is usually between 300 and 1,300 psi, but lesser and higher pressures may be used. To maintain compression and keep the gas moving, compressor stations are located every 50 to 100 miles along the pipeline. Most compressors are large reciprocating engines powered by a small portion of the natural gas being transmitted through the pipeline.

There are over 8,000 gas compressing stations along U.S. gas pipelines, each equipped with one or more engines. The combined output capability of U.S. compressor engines is over 20 million horsepower (NGSA et al., 2000a). Nearly 5,000 engines have individual output capabilities from 500 to over 8,000 horsepower. The replacement cost of this subset of larger engines is estimated by the Gas Research Institute to be $18 billion (Whelan, 1998).

Before or after natural gas is delivered to a distribution company, it may be stored in an underground facility. Underground storage facilities are most often depleted oil and/or gas fields, aquifers, or salt caverns. Natural gas storage allows distribution and pipeline companies to serve their customers more reliably by withdrawing more gas from storage during peak-use periods and reduces the time needed to respond to increased gas demand (NGSA et al., 2000b). In this way, storage guarantees continuous service, even when production or pipeline transportation services are interrupted.

3.2.2.2 Major By-products

There are no major by-products of the natural gas pipeline industry itself. However, the engines that provide pumping action at plants and push crude oil and natural gas through pipelines to customers and storage facilities produce HAPs. As noted previously, HAPs produced in engines include formaldehyde, acetaldehyde, acrolein, and methanol.

3.2.2.3 Costs of Production

Between 1996 and 2000, pipeline firms committed over $14 billion to 177 expansion and new construction projects. These projects added over 15,000 miles and 36,178 million cubic feet per day (MMcf/d) capacity to the transmission pipeline system. Because there are compression stations about every 50 to 100 miles along gas pipelines, the addition of 15,000 miles of pipeline implies that 150 to 300 compression stations were added. There are varying numbers of engines at different stations, but the average is three engines per compression station in the Inventory Database. Thus, approximately 450 to 900 new engines were added along pipelines over the period 1996 through 2000. Table 3-12 summarizes the investments made in pipeline projects during the past 5 years. Building new pipelines is more expensive than expanding existing pipelines. For the period covered in the table, the average cost per project mile was $862,000. However, the costs for pipeline expansions averaged $542,000, or 29 cents per cubic foot of capacity added. New pipelines averaged $1,157,000 per mile at 48 cents per cubic foot of capacity.

Table 3-12. Summary Profile of Completed and Proposed Natural Gas Pipeline Projects, 1996 to 2000

	All Type Projects						New Pipelines		Expansions	
Year	Number of Projects	System Mileage	New Capacity (Mmcf/d)	Project Costs ($$10^6$)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)	Average Cost per Mile ($$10^3$)	Costs per Cubic Foot Capacity (cents)
1996	26	1,029	2,574	$552	$448	21	$983	17	$288	27
1997	42	3,124	6,542	$1,397	$415	21	$554	22	$360	21
1998	54	3,388	11,060	$2,861	$1,257	30	$1,301	31	$622	22
1999	36	3,753	8,205	$3,135	$727	37	$805	46	$527	31
2000	19	4,364	7,795	$6,339	$1,450	81	$1,455	91	$940	57
Total	177	15,660	36,178	$14,285	$862	39	$1,157	48	$542	29

Note: Sums may not add to totals because of independent rounding.

Source: Energy Information Administration. 1999a. *Natural Gas 1998: Issues and Trends*. Washington, DC: U.S. Department of Energy.

Pipelines must pay for the natural gas that is consumed to power the compressor engines. The amount consumed and the price paid have fluctuated in recent years. In 1998, pipelines consumed 635,477 MMcf of gas, paying, on average, $2.01 per 1,000 cubic feet. Thus, firms spent approximately $1.28 billion in 1998 for the fueling of RICE used on pipelines. Pipelines used less natural gas in 1998 than in previous years; the price paid for that gas fluctuated between $1.49 and $2.29 between 1994 and 1997 (see Table 3-13). For companies that transmit natural gas through their own pipelines the cost of the natural gas consumed is considered a business expense.

Table 3-13. Energy Usage and Cost of Fuel, 1994-1998

Year	Pipeline Fuel (MMcf)	Average Price ($ per 1,000 cubic feet)
1994	685,362	1.70
1995	700,335	1.49
1996	711,446	2.27
1997	751,470	2.29
1998	635,477	2.01

Source: Energy Information Administration. 1999b. *Natural Gas Annual 1998*. Washington, DC: US Department of Energy.

3.2.2.4 Capacity Utilization

During the past 15 years, interstate pipeline capacity has increased significantly. In 1990, the transmission pipeline system's capacity was 74,158 Mmcf/day (see Table 3-14). By the end of 1997, capacity reached 85,847 Mmcf/day, an increase of approximately 16 percent. The system's usage, however, has increased at a faster rate than capacity. The average daily flow was 60,286 Mmcf/day in 1997, a 22 percent increase over 1990's rates. Currently, the system operates at approximately 72 percent of capacity.

3.2.2.5 Imports

Approximately 17 percent of the U.S. natural gas supply is imported, primarily from Canadian fields. In many economic analyses, the imported supply is treated separately from the domestic supply because of the difference in the impact of domestic regulation.

Table 3-14. Transmission Pipeline Capacity, Average Daily Flows, and Usage Rates, 1990 and 1997

	1990	1997	Percent Change
Capacity (Mmcf per day)	74,158	85,847	16
Average Flow (Mmcf per day)	49,584	60,286	22
Usage Rate (percent)	68	72	4

Source: Energy Information Administration. 1999a. *Natural Gas 1998: Issues and Trends*. Washington, DC: US Department of Energy.

However, it is assumed that the imported gas will still be subject to control costs when it is transported through pipelines in the U.S. Thus, the imported supply is not differentiated because the regulation will affect it in a similar manner to domestically supplied gas since they use the same distribution method.

3.2.3 Demand Side Characteristics

Most pipeline customers are local distribution companies that deliver natural gas from pipelines to local customers. Many large gas users will buy from marketers and enter into special delivery contracts with pipelines. However, local distribution companies (LDCs) serve most residential, commercial, and light industrial customers. LDCs also use compressor engines to pump natural gas to and from storage facilities and through the gas lines in their service area.

While economic considerations strongly favor pipeline transportation of natural gas, liquified natural gas (LNG) emerged during the 1970s as a transportation option for markets inaccessible to pipelines or where pipelines are not economically feasible. Thus, LNG is a substitute for natural gas transmission via pipelines. LNG is natural gas that has been liquified by lowering its temperature. LNG takes up about 1/600 of the space gaseous natural gas takes up, making transportation by ship possible. However, virtually all of the natural gas consumed in the U.S. reaches its consumer market via pipelines because of the relatively high expense of transporting LNG and its volatility. Most markets that receive LNG are located far from pipelines or production facilities, such as Japan (the world's largest LNG importer), Spain, France, and Korea (Tussing and Tippee, 1995).

3.2.4 Organization of the Industry

Much like other energy-related industries, the natural gas pipeline industry is dominated by large investor-owned corporations. Smaller companies are few because of the real estate, capital, and operating costs associated with constructing and maintaining pipelines (Tussing and Tippee, 1995). Many of the large corporations are merging to remain competitive as the industry adjusts to restructuring and increased levels of competition. Increasingly, new pipelines are built by partnerships: groups of energy-related companies share capital costs through joint ventures and strategic alliances (EIA, 1999a). Ranked by system mileage, the largest pipeline companies in the U.S. are El Paso Energy (which recently merged with Southern Natural Gas Co.), Enron, Williams Cos., Coastal Corp., and Duke Energy (see Table 3-15). El Paso Energy and Coastal intend to merge in mid-2000.

3.2.5 Markets and Trends

During the past decade, interstate pipeline capacity has increased 16 percent. Many existing pipelines underwent expansion projects, and 15 new interstate pipelines were constructed. In 1999 and 2000, proposals for pipeline expansions and additions called for a $9.5 billion investment, an increase of 16.0 billion cubic feet per day of capacity (EIA, 1999a).

The EIA (1999a), a unit of the Department of Energy, expects natural gas consumption to grow steadily, with demand forecasted to reach 32 trillion cubic feet by 2020. The expected increase in natural gas demand has significant implications for the natural gas pipeline system.

The EIA (1999a) expects the interregional pipeline system, a network that connects the lower 48 states and the Canadian provinces, to grow at an annual rate of 0.7 percent between 2001 and 2020. However, natural gas consumption is expected to grow at more than twice that annual rate, 1.8 percent, over that same period. The majority of the growth in consumption is expected to be fueled by the electric generation sector. According to the EIA, a key issue is what kinds of infrastructure changes will be required to meet this demand and what the financial and environmental costs will be of expanding the pipeline network.

Table 3-15. Five Largest Natural Gas Pipeline Companies by System Mileage, 2000

Company	Headquarters	Sales ($1999 10^6)	Employment (1999)	Miles of Pipeline
El Paso Energy Corporation Incl. El Paso Natural Gas Co. Southern Natural Gas Co. Tennessee Gas Pipe Line Co.	Houston, TX	$10,581	4,700	40,200
Enron Corporation Incl. Northern Border Pipe Line Co. Northern Natural Gas Co. Transwestern Pipeline Co.	Houston, TX	$40,112	17,800	32,000
Williams Companies, Inc. Incl. Transcontinental Gas Pipe Line Northwest Pipe Line Co. Texas Gas Pipe Line Co.	Tulsa, OK	$8,593	21,011	27,000
The Coastal Corporation Incl. ANR Pipeline Co. Colorado Interstate Gas Co.	Houston, TX	$8,197	13,000	18,000
Duke Energy Corporation Incl. Panhandle Eastern Pipeline Co. Algonquin Gas Transmission Co. Texas Eastern Transmission Co.	Charlotte, NC	$21,742	21,000	11,500

Sources: Heil, Scott F., Ed. 1998. *Ward's Business Directory of U.S. Private and Public Companies 1998, Volume 5.* Detroit, MI: Gale Research Inc.

Sales, employment, and system mileage: Hoover's Incorporated. 2000. Hoover's Company Profiles. Austin, TX: Hoover's Incorporated. <http://www.hoovers.com/>.

SECTION 4

ECONOMIC IMPACT ANALYSIS

The proposed rule to control emissions of HAPs from RICE will affect many U.S. industries because these engines are primarily used as inputs in extracting and transporting fuels (oil and natural gas). Therefore, the proposed regulations will increase the cost of producing these fuels and will lead to an increase in energy costs to industrial, commercial, and residential customers. In addition to the effect on energy prices, many industrial facilities use RICE as part of their production process and will face direct control costs on these engines. The response of producers to these additional costs determines the economic impacts of the regulation. Specifically, the cost of the regulation may induce some owners to change their current operating rates or even to close their operations (either the entire facility or individual product lines). These choices affect, and in turn are affected by, the market prices for fuels and the market prices in the final product markets. This section describes the methodology, data, and model used to estimate the economic impacts of the proposed regulation for the year 2005 and provides the EIA results.

4.1 Economic Impact Methodology

This section summarizes the Agency's approach to modeling the responses of fuel markets to the imposition of the proposed regulation. In conducting an economic analysis and determining the economic impacts, the analyst should recognize the alternatives available to each producer in response to the regulation and the context of these choices. The Agency evaluated the economic impacts of this NESHAP using a market-based approach that gives producers the choice of whether to continue producing these products and, if so, to determine the optimal level consistent with market signals.

The Agency's approach is soundly based on standard microeconomic theory, employs a comparative statics approach, and assumes certainty in relevant markets. Supply curves were developed for each energy market (see Appendix A), and prices and quantities were determined in perfectly competitive markets for each fuel market and each industrial product market.

4.1.1 Background on Economic Modeling Approaches

In general, the EIA methodology needs to allow EPA to consider the effects of the different regulatory alternatives. Several types of economic impact modeling approaches have been developed to support regulatory development. These approaches can be viewed as varying along two modeling dimensions:

- the scope of economic decisionmaking accounted for in the model and
- the scope of interaction between different segments of the economy.

Each of these dimensions was considered in determining the approach for this study. The advantages and disadvantages of different modeling approaches are discussed below.

4.1.1.1 Modeling Dimension 1: Scope of Economic Decisionmaking

Models incorporating different levels of economic decisionmaking can generally be categorized as *with* behavior responses and *without* behavior responses (accounting approach). Table 4-1 provides a brief comparison of the two approaches. The nonbehavioral approach essentially holds fixed all interactions between facility production and market forces. It assumes that firms absorb all control costs and consumers do not face any of the costs of regulation. Typically, engineering control costs are weighted by the number of affected units to develop "engineering" estimates of the total annualized costs. These costs are then compared to company or industry sales to determine the regulation's impact.

In contrast, the behavioral approach is grounded in economic theory related to producer and consumer behavior in response to changes in market conditions. Owners of affected facilities are economic agents that can, and presumably will, 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 behavior in response to regulation, consumers are typically faced with changes in prices that cause them to alter the quantity that they are willing to purchase. In essence, this approach models the expected reallocation of society's resources in response to a regulation. The changes in price and production from the market-level impacts are used to estimate the distribution of social costs between consumers and producers.

Table 4-1. Comparison of Modeling Approaches

EIA With Behavioral Responses

- Incorporates control costs into production function
- Includes change in quantity produced
- Includes change in market price
- Estimates impacts for
  - ✓ affected producers
  - ✓ unaffected producers
  - ✓ consumers
  - ✓ foreign trade

EIA Without Behavioral Responses

- Assumes firm absorbs all control costs.
- Typically uses discounted cash flow analysis to evaluate burden of control costs
- Includes depreciation schedules and corporate tax implications
- Does *not* adjust for changes in market price
- Does *not* adjust for changes in plant production

4.1.1.2 Modeling Dimension 2: Interaction Between Economic Sectors

Because of the large number of markets potentially affected by the regulation on RICE, an issue arises concerning the level of sectoral interaction to model. In the broadest sense, all markets are directly or indirectly linked in the economy; thus, all commodities and markets are to some extent affected by the regulation. For example, controls on RICE may indirectly affect almost all markets for goods and services to some extent because the cost of fuel (an input in the provision of most goods and services) is likely to increase with the regulation in effect. However, the impact of rising fuel prices will differ greatly between different markets depending on how important fuel is as an input in that market.

The appropriate level of market interactions to be included in the EIA is determined by the scope of the regulation across industries and the ability of affected firms to pass along the regulatory costs in the form of higher prices. Alternative approaches for modeling interactions between economic sectors can generally be divided into three groups:

- Partial equilibrium model: Individual markets are modeled in isolation. The only factor affecting the market is the cost of the regulation on facilities in the industry being modeled.
- General equilibrium model: All sectors of the economy are modeled together. General equilibrium models operationalize neoclassical microeconomic theory by modeling not only the direct effects of control costs, but also potential input substitution effects, changes in production levels associated with changes in market prices across all sectors, and the associated changes in welfare economywide. A disadvantage of general equilibrium modeling is that substantial time and resources are required to develop a new model or tailor an existing model for analyzing regulatory alternatives.
- Multiple-market partial equilibrium model: A subset of related markets are modeled together, with intersectoral linkages explicitly specified. To account for the relationships and links between different markets without employing a full general equilibrium model, analysts can use an integrated partial equilibrium model. The multiple-market partial equilibrium approach represents an intermediate step between a simple, single-market partial equilibrium approach and a full general equilibrium approach. This approach involves identifying and modeling the most significant subset of market interactions using an integrated partial equilibrium framework. In effect, the modeling technique is to link a series of standard partial equilibrium models by specifying the interactions between supply functions and then solving for prices and quantities across all markets simultaneously. In instances where separate markets are closely related and there are strong interconnections, there are significant advantages to estimating market adjustments in different markets simultaneously using an integrated market modeling approach.

4.1.2 Selected Modeling Approach for RICE Analysis

To conduct the analysis for the RICE MACT, the Agency used a market modeling approach that incorporates behavioral responses in a multiple-market partial equilibrium model as described above. This approach allows for a more realistic assessment of the distribution of impacts across different groups than the nonbehavioral approach, which may be especially important in accurately assessing the impacts of a significant rule affecting numerous industries. Because of the size and complexity of this regulation, it is important to use a behavioral model to examine the distribution of costs across society. Because the regulations on RICE affect energy costs, an input into many production processes, complex market interactions need to be captured to provide an accurate picture of the distribution of regulatory costs. Because of the large number of affected industries under this MACT, an appropriate model should include multiple markets and the interactions between them. Multiple-market partial equilibrium analysis provides a manageable approach to incorporate interactions between energy markets and final product markets into the EIA to accurately estimate the regulation's impact.

The model used for this analysis includes industrial (manufacturing), commercial, residential, transportation, and energy markets affected by the controls placed on engines. The manufacturers are divided into 24 different final product markets.[1] The energy markets are divided into natural gas, petroleum products, coal, and electricity. The commercial, residential, and transportation markets are each treated as a single representative demander in the fuel markets.

Figure 4-1 presents an overview of the key market linkages included in the economic impact model we propose to use for analyzing the RICE MACT. The analysis' emphasis is on the energy supply chain, including the extraction and transportation of natural gas and petroleum, the generation of electricity, and the consumption of energy by producers of final products and services. The industries most directly affected by the RICE MACT are those involved in extracting and transporting natural gas. However, changes in the equilibrium price and quantity of natural gas affect all of the other energy markets. As shown in Figure 4-1, wholesale electricity generators consume natural gas, petroleum products, and coal to generate electricity that is then used to produce final products and services. In addition, many final product markets use natural gas and petroleum products directly as an input into their production process. This analysis explicitly models the linkages between these market segments.

RICE are used to extract and transport natural gas and petroleum products used by a wide range of industrial, commercial, residential, and transportation sectors in the U.S. economy. As a result, control costs associated with the proposed regulation will directly affect the cost of

[1]These markets are defined at the two-digit SIC code level. This allows for a fairly disaggregated examination of the regulation's impact on producers. However, if the costs of the regulation are concentrated on a particular subset of one of these markets, then treating the cost as if it fell on the entire two-digit SIC code may still underestimate the impacts on the subset of producers that are affected by the regulation.

- extraction and transportation of natural gas and petroleum products using RICE to generate compression and
- using RICE directly as part of a production process, such as for rock crushing in the mining sector.

There are several categories of RICE, as described in Section 2. The categories that fall under the proposed regulation are spark ignition 2SLB, spark ignition 4SLB, spark ignition 4SRB, and CI RICE.[2] Most industries that use engines use multiple categories. 2SLB, 4SLB, and 4SRB engines are all used primarily in either oil and gas extraction or on natural gas pipelines. They are also distributed across many other industrial and commercial SIC codes, although in relatively small numbers. The CI engines in the Inventory Database fall mainly in the hospital services industry and in other commercial businesses.

In addition to the direct impact of control costs on entities installing new RICE and existing entities using 4SRB, indirect impacts are passed along the energy supply chain through changes in prices. For example, production costs will increase for mining companies using RICE as a result of the direct control costs on RICE as well as the resulting increase in the price of natural gas and electricity used as energy inputs in the production process.

Also included in the impact model is feedback of changes in output in the final product markets into the demand for Btus in the fuel markets. The change in facility output is determined by the size of the Btu cost increase (typically variable cost per output), the facility's production function (slope of facility-level supply curve), and the characteristics of the facility's downstream market (other market suppliers and market demanders). For example, if consumers' demand for a final product is not very sensitive to price, then producers can pass the majority of the cost of the regulation through to consumers and the facility output may not change appreciably. However, if only a small proportion of market output is produced at facilities affected by the regulation, then competition will prevent the affected facilities from raising their prices significantly.

One possible feedback pathway that this analysis does *not* plan on modeling is technical changes in the manufacturing process. For example, if the cost of Btus increases, a facility may use measures to increase manufacturing efficiency or capture waste heat. Facilities could also possibly change the input mix that they use, substituting other inputs for

---

[2]Although CI engines can be either 2SLB or 4SLB, these two categories have been combined for this analysis, and the acronyms 2SLB and 4SLB are reserved for spark ignition engines of these configurations.

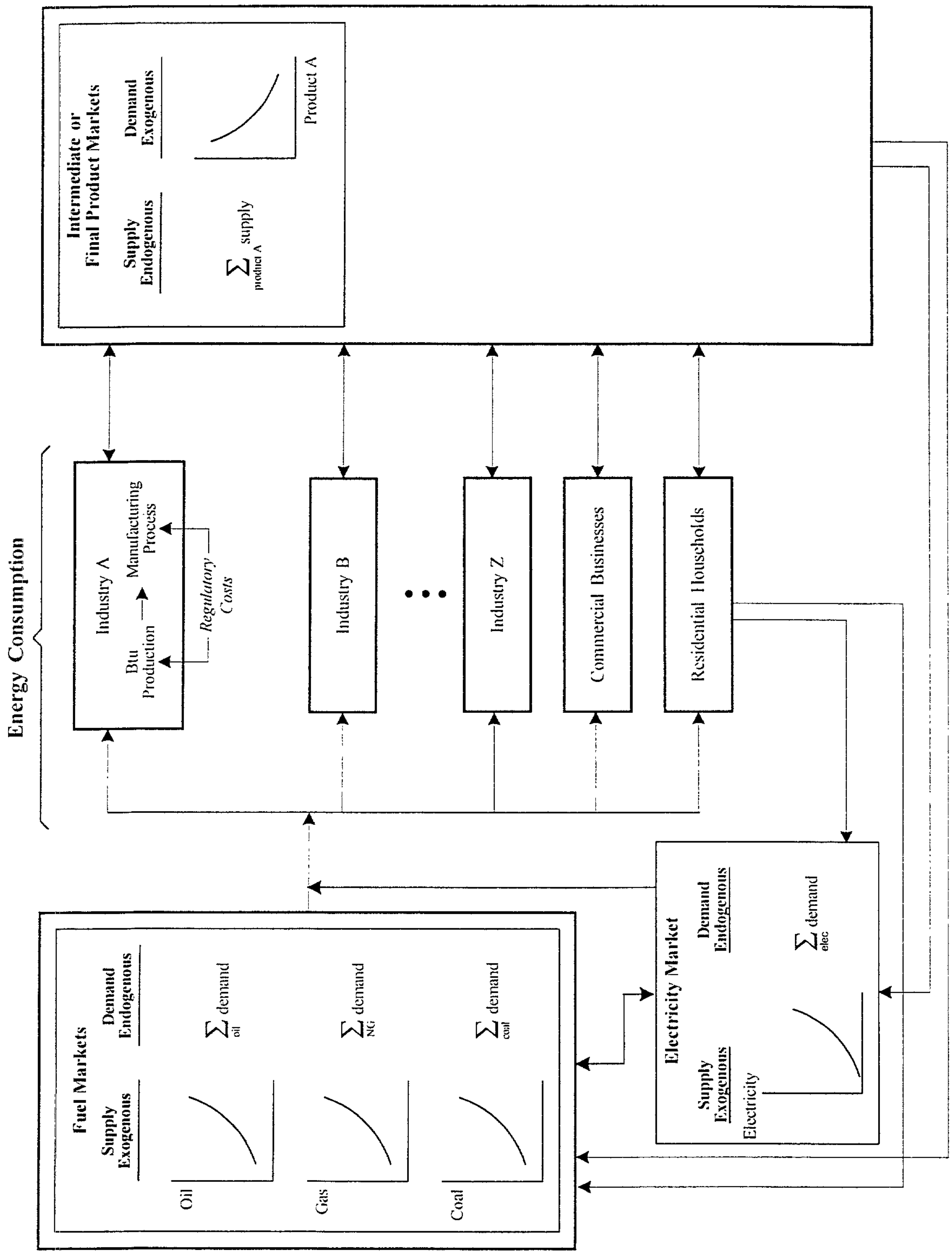


Figure 4-1. Links Between Energy and Final Product Markets

fuel. These facility-level responses will also act to reduce pollution, but including these responses is beyond the scope of this analysis.

The intermarket linkages connecting the fuel markets and final product markets are described in the sections below.

4.1.3 Directly Affected Markets

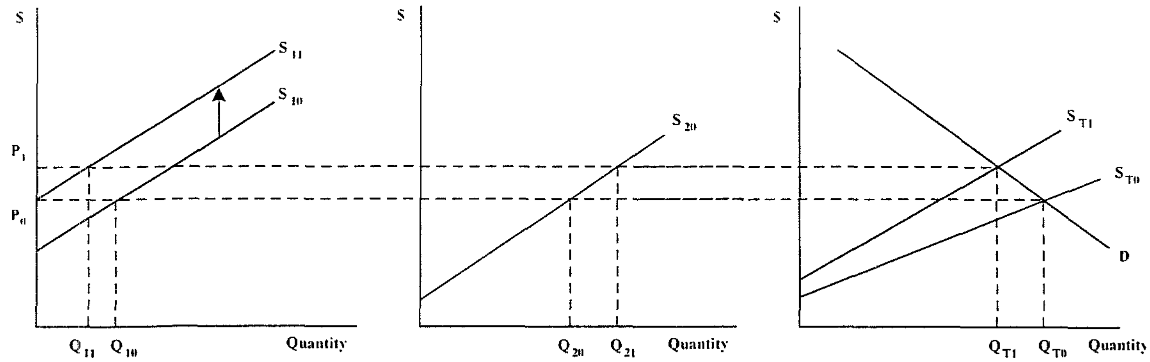
Markets where RICE are used as an input to production are considered to be directly affected. Producers using engines will be required to add costly controls to any new engines that they acquire and to existing 4SRB engines. They also must incur monitoring costs to ensure that the controls are working properly. Therefore, the regulation will increase their production costs and cause these directly affected firms to reduce the quantity that they are willing to supply at any given price.

4.1.3.1 Market for Natural Gas

Because the majority of RICE are used in either extracting oil and natural gas or transporting natural gas, the energy market most directly affected by the proposed regulations is the natural gas industry. Because it will be more costly to produce natural gas under the new regulations, firms involved in producing natural gas are expected to supply less gas to the market at any given price than they did prior to the new rule. These decreases at the facility level will lead to a decrease in industry supply. The magnitude of the upward shift in the supply curve and the price elasticities of supply and demand are the two factors that determine the impacts on the natural gas market. Because 25 percent of 4SRB and 3 percent of 4SLB engines are projected to be controlled in the absence of the proposed regulation, these engines are considered to be unaffected by the regulation. Figure 4-2 illustrates the shifts in the supply curves for a representative energy market.

4.1.3.2 Market for Petroleum Products

The market for petroleum products is also included in the economic impact model for RICE. For petroleum products, a single composite product is used to model market adjustment. A composite product was used in this market because engines are used in the extraction of crude petroleum; as a result, the increased production costs were not assigned to specific end products, such as fuel oil #2 or reformulated gasoline. This will tend to understate the impacts for petroleum products where extraction costs as a percentage of



(a) Producers bearing control costs (affected)

(b) Producers bearing no control costs (unaffected)

(c) Total Market

P_0	=	market price without regulation
P_1	=	market price with regulation
S_{10}	=	supply function for affected firms without regulation
S_{11}	=	supply function for affected firms with regulation
Q_{10}	=	quantity sold for affected firms without regulation
Q_{11}	=	quantity sold for affected firms with regulation
S_{20}	=	supply function for unaffected firms both with and without regulation
Q_{20}	=	quantity sold for unaffected firms without regulation
Q_{21}	=	quantity sold for unaffected firms with regulation
S_{T0}	=	total market supply function without regulation
S_{T1}	=	total market supply function with regulation
Q_{T0}	=	total market quantity sold without regulation
Q_{T1}	=	total market quantity sold with regulation

Figure 4-2. Market Effects of Regulation-Induced Costs

production costs are greater than average and overstate impacts for products where extraction costs as a percentage of production costs are less than average.

Control costs associated with RICE will increase the cost of petroleum extraction. The cost impacts are assumed to be distributed over all domestically consumed petroleum products. This is because it is assumed that affected units will be distributed across all firms involved in the production of these products. The supply curve for petroleum products will shift upward by the proportional increase in total production costs caused by the control costs on RICE.

4.1.3.3 Final Product and Service Markets

Final product and service markets are also directly affected by the regulation. Many manufacturing facilities use engines in their production processes. Commercial entities use engines as generators, especially in the health services field. In addition to the direct costs of the regulation, final product and service markets are indirectly affected through price increases in the energy markets.

Directly affected producers of final products and services are segmented into industrial and commercial sectors defined at the two-digit SIC code level. A partial equilibrium analysis was conducted for each of the manufacturing sectors to model the supply and demand for final products in these sectors. Changes in production levels and fuel switching due to the regulation's impact on the price of Btus were then linked back into the energy markets.

Impact on Industrial Sector. The impact of the regulation on manufacturers in this sector is modeled as an increase in the cost of Btus used in the production process. In this context, Btus refer to the generic energy requirements that are used to generate process heat, process steam, or shaft power. Compliance costs associated with the regulation will increase the cost of Btu production in the manufacturing sectors. The cost of Btu production for industry increases due to both direct control costs on engines owned by manufacturers and increases in the price of fuels. Because Btus are an input into the production process, these price increases lead to an upward shift in the facility (and industry) supply curves as shown in Figure 4-2, leading to a change in the equilibrium market price and quantity.

The changes in equilibrium supply and demand in each final product and service market are modeled to estimate the regulation's impact on each manufacturing sector. In a perfectly competitive market, the point where supply equals demand determines the market price and quantity, so market price and quantity are determined by solving the model for the price where the quantity supplied and the quantity demanded are equal. The size of the regulation-induced shifts in the supply curve are a function of the total direct control costs associated with new engines and existing 4SRB engines and the indirect fuel costs (determined by the change in fuel price and intensity of use) in each final product and service market. The proportional shift in the supply curve is determined by the ratio of total control costs (both direct and indirect) to production costs.

This impact on the price of Btus facing industrial users feeds back to the fuel market in two ways (see Figure 4-3). The first is through the company's input decision concerning the fuel(s) that will be used for its manufacturing process. As the cost of Btus increases, firms may switch fuels and/or change production processes to increase energy efficiency and reduce the number of Btus required per unit of output. Fuel switching impacts are modeled

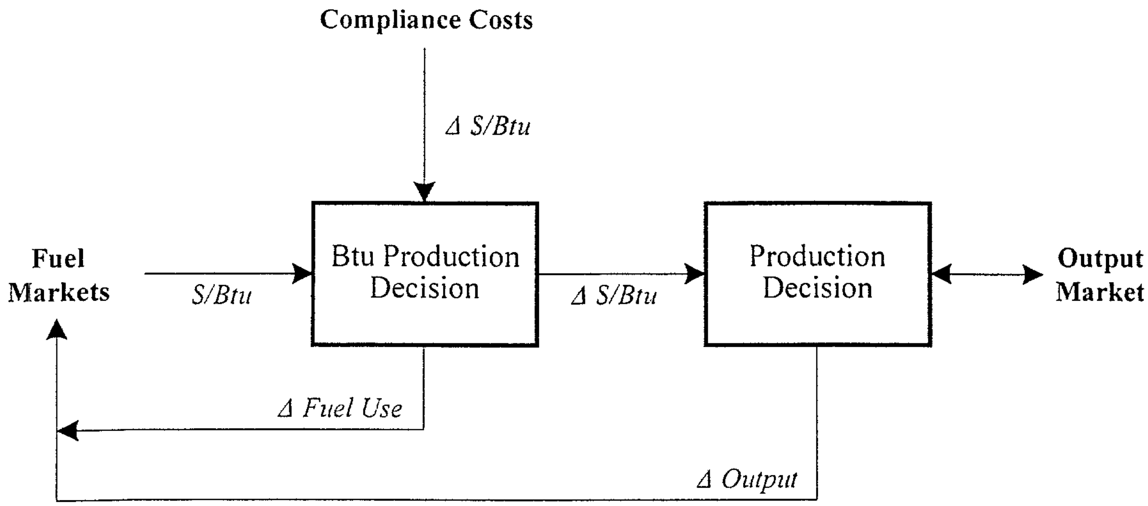


Figure 4-3. Fuel Market Interactions with Facility-Level Production Decisions

using cross-price elasticities of demand between energy sources. For example, a cross-price elasticity of demand between natural gas and electricity of 0.5 implies that a 1 percent increase in the price of electricity will lead to a 0.5 percent increase in the demand for natural gas. Own-price elasticities of demand are used to estimate the change in the use of fuel by demanders. For example, a demand elasticity of –0.175 for electricity implies that a 1 percent increase in the price of electricity will lead to a 0.175 percent decrease in the quantity of electricity demanded.

The second feedback pathway to the energy markets is through the facility's change in output. Because Btus are an input into the production process, price increases lead to an upward shift in the facility supply curves (not modeled individually). This leads to an upward shift in the industry supply curve when the shifts at the facility level are aggregated across facilities. A shift in the industry supply curve leads to a change in the equilibrium market price and quantity. In a perfectly competitive market, the point where supply equals demand determines the market price and quantity. The Agency assumes constant returns to scale in production so that the percentage change in Btus consumed by manufacturers equals the percentage change in the equilibrium market quantity in each final product and service market.

The Agency assumed that the demand curves for final products and services in all manufacturing sectors are unchanged by the regulation. However, because the demand function quantifies the change in quantity demanded in response to a change in price, the baseline demand conditions are important in determining the regulation's impact. The key demand parameters will be the elasticities of demand with respect to changes in the price of final products. For these markets, a "reasonable" range of elasticity values is assigned based on estimates from similar commodities. Because price changes are anticipated to be small, the point elasticities at the original price and quantity should be applicable throughout the relevant range of prices and quantities examined in this model.

Impact on Commercial Sectors. The proposed regulation will also affect the commercial sector. The commercial sector is represented as a single demander of fuels with a demand curve generated based on the demand elasticity for commercial users. Most of the new RICE in the commercial sector are projected to be installed in the health care industry, but there will be some growth in other commercial sectors as well. It is assumed that the elasticity of demand for health care services is very inelastic with respect to changes in price. Because most of the engines in the commercial sector are projected to be in health care services, all impacts (direct and indirect) in this sector are assumed to be borne by consumers and are shown as changes in consumer surplus in the final results.

4.1.4 Indirectly Affected Markets

In addition to the many markets that are directly affected by the regulation on RICE, some markets feel the regulation's impacts despite having no direct costs resulting from the regulation. Firms in these markets generally face changes in the price of energy that affect their production decisions.

4.1.4.1 Market for Electricity

Although EPA assumed that there are no direct impacts on the production of electricity because engines are not commonly used by utilities to generate power, the market for electricity will still be indirectly affected through changes in fuel prices. Electricity generators are extremely large consumers of coal and natural gas as well as petroleum products to a lesser extent. These fuels are used to generate electricity, so as the prices of fuels rise, there is a decrease in the amount of electricity that producers are willing to supply. This impact feeds back into the fuel markets as utilities reduce their purchases of fuels. In addition to the decrease in supply due to the regulation, an increase in demand is expected as fuel consumers switch from natural gas and petroleum to electricity. Therefore, it is ambiguous whether equilibrium quantity will rise or fall. The price elasticities of supply and demand are the important factors influencing the size of the impacts and whether quantity will increase or decrease.

4.1.4.2 Market for Coal

The coal market is not directly affected by the regulation, but it is included in the market model. Although engines are not commonly used in the production or transportation of coal, the supply of coal will be affected by the price of energy used in coal production, and the demand for coal by utility generators and manufacturers will be affected through changes in the relative price of alternative (noncoal) energy sources such as natural gas and petroleum products. The demand for coal from the industrial, transportation, and residential sectors will increase as consumers switch away from the fuels that face increases in price due to controls. The demand for coal from electric utilities may either increase or decrease depending on whether the equilibrium quantity of electricity rises or falls as a result of the regulation.

4.1.4.3 Final Product and Service Markets

Some final product markets do not include any engines and are therefore not directly affected by the RICE MACT. However, these markets will still be affected indirectly due to the changes in energy prices that they will face following the regulation. There will be a tendency for these users to shift away from natural gas and petroleum products and towards electricity and coal.

4.1.4.4 Impact on Residential Sector

The residential sector does not bear any direct costs associated with the regulation because they do not own RICE. However, they bear indirect costs due to price increases. The residential sector is a significant consumer of electricity, natural gas, and petroleum products used for heating, cooling, and lighting, as well as many other end uses. The change in the quantity of energy demanded by these consumers in response to changes in energy prices is modeled as a single demand curve parameterized by demand elasticities for residential consumers obtained from the literature. Once again, it is expected that in addition to a decrease in the total amount of energy consumed, there will be reallocation across fuels consumed.

4.1.4.5 Impact on Transportation Sector

The transportation sector does not face any direct costs due to the regulation because RICE are not typically used in this sector. The main fuels used in this market are petroleum products. The change in the quantity of energy demanded by these consumers in response to changes in prices is modeled as a single demand curve parameterized by demand elasticities for this sector from the literature. The major impact on this market is an increase in the price of a key input causing a reduction in output. There may also be some fuel switching in this sector towards electricity and coal.

4.2 Operationalizing the Economic Impact Model

Figure 4-4 illustrates the linkages used to operationalize the estimation of economic impacts associated with the compliance costs. Compliance costs placed on existing 4SRB and new RICE shift the supply curve for natural gas and petroleum because RICE are used in the extraction and transportation of these fuels. Adjustments in the natural gas and petroleum energy markets determine the share of the cost increases that producers (natural gas and petroleum companies) and consumers (electricity utilities, product manufacturers, commercial business, and residential households) bear. There are also some relatively small compliance costs on the electricity market from the very few affected engines used in this market.

Increased fuel costs for electricity generators will decrease the supply of electricity. The new equilibrium price and quantity in the electricity market will determine the distribution of impacts between producers (electricity generators) and consumers (product manufacturers, commercial businesses, and residential households). Changes in wholesale electricity generators' demand for input fuels (due to changes in the market quantity of electricity) feed back into the natural gas and petroleum markets as utilities change the allocation of fuels used as inputs.

Manufacturers experience supply curve shifts due to control costs on affected engines they operate and increased prices for natural gas, petroleum, and electricity. The share of these costs borne by producers (manufacturers) and consumers is determined by the new equilibrium price and quantity in the final product markets. Changes in manufacturers' Btu demands due to fuel switching and changes in production levels feed back into the electricity, natural gas, and petroleum markets.

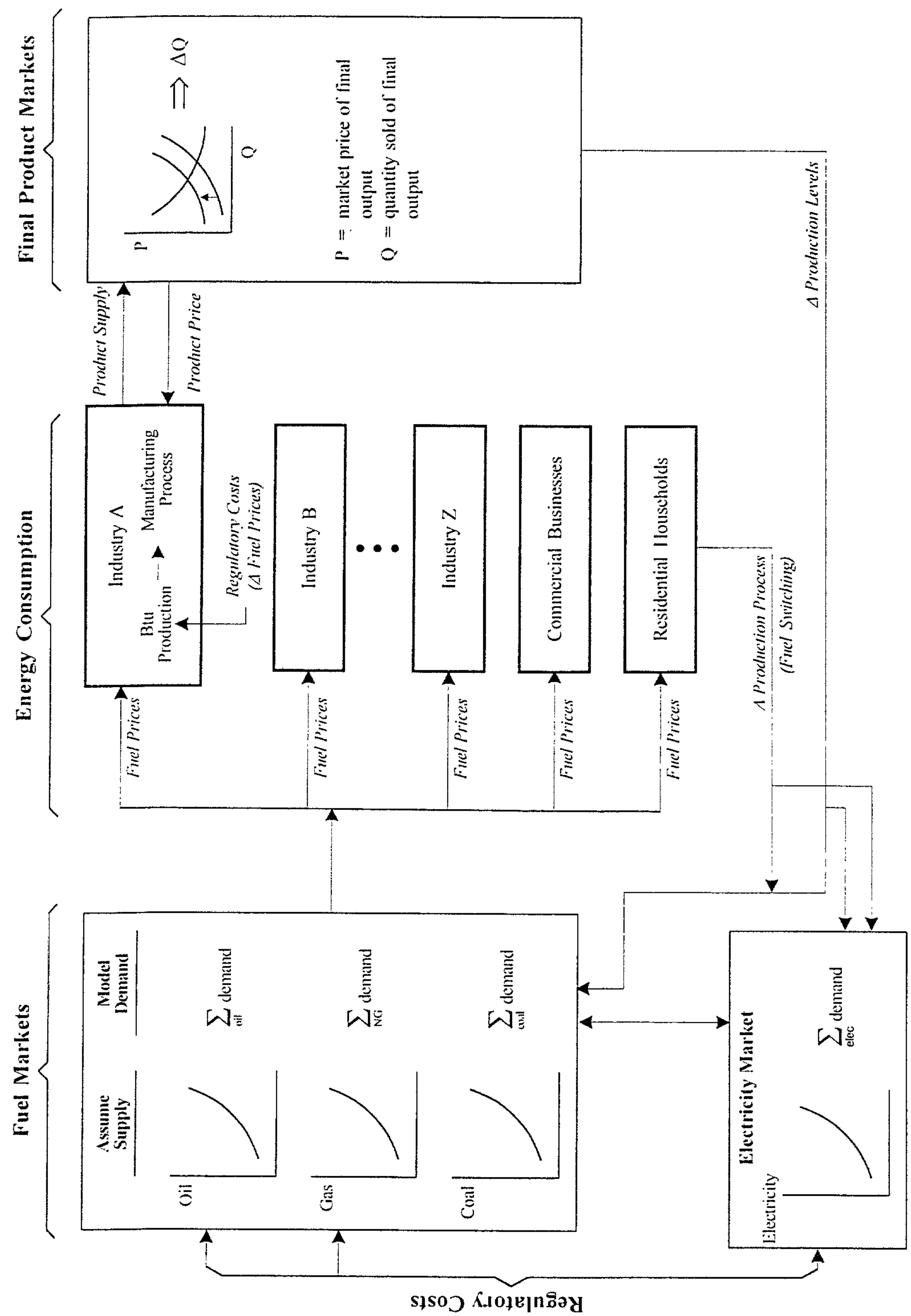


Figure 4-4. Operationalizing the Estimation of Economic Impact

Adjustments in price and quantity in all energy and final product markets occur simultaneously. A computer model was used to numerically simulate market adjustments by iterating over commodity prices until equilibrium is reached (i.e., until the quantity supplied equals the quantity demanded in all markets being modeled). Using the results provided by the model, economic impacts of the regulation (changes in consumer and producer surplus) were estimated for all sectors of the economy being modeled.

4.2.1 Computer Model

The computer model comprises a series of computer spreadsheet modules. The modules integrate the engineering cost inputs and the market-level adjustment parameters to estimate the regulation's impact on the price and quantity in each market being analyzed. At the heart of the model is a market-clearing algorithm that compares the total quantity supplied to the total quantity demanded for each market commodity.

Current prices and production levels are used to calibrate the baseline scenario (without regulation) for the model. Then, the compliance costs associated with the regulation are introduced as a "shock" to the system, and the supply and demand for market commodities are allowed to adjust to account for the increased production costs resulting from the regulation. Using an iterative process, if the supply does not equal demand in all markets, a new set of prices is "called out" and sent back to producers and consumers to "ask" what quantities they would supply and demand based on these new prices. This technique is referred to as an auctioneer approach because new prices are continually called out until an equilibrium set of prices is determined (i.e., where supply equals demand for all markets).

Supply and demand quantities are computed at each price iteration. The market supply for each energy and final product market is obtained by using a mathematical specification of the supply function, and the key parameter is the point elasticity of supply at the baseline condition.

The demand curves for the energy markets are the sum of demand responses across all markets. For example, the demand for natural gas is the sum of the demand for the electricity industry, all 24 manufacturing sectors, the commercial sector, and the residential sector. The demand for electricity is the sum of the demand for the 24 manufacturing sectors, the commercial sector, and the residential sector. The demand for energy in the manufacturing sectors is a derived demand calculated using baseline energy usage and changes associated with fuel switching and changes in production levels.

The demand for final products in the two-digit SIC code manufacturing sectors is obtained by using a mathematical specification of the demand function. Similarly, the energy demand in the commercial and residential sectors is obtained through mathematical specification of the demand functions (see Appendix A).

EPA modeled fuel switching using secondary data developed by the U.S. Department of Energy for the National Energy Modeling System (NEMS). Table 4-2 contains fuel price elasticities of demand for electricity, natural gas, petroleum products, and coal. The diagonal elements in the table represent own-price elasticities. For example, the table indicates that for steam coal, a 1 percent change in the price of coal will lead to a 0.499 percent decrease in the use of coal. The off diagonal elements are cross-price elasticities and indicate fuel switching propensities. For example, for steam coal, the second column indicates that a 1 percent increase in the price of coal will lead to a 0.061 percent increase in the use of natural gas.

4.2.2 Calculating Changes in Social Welfare

The RICE MACT will impact almost every sector of the economy either directly through control costs or indirectly through changes in the price of energy and final products. For example, a share of control costs that originate in the energy markets is passed through the final product markets and borne by both the producers and consumers of final products. To estimate the total change in social welfare without double-counting impacts across the linked partial equilibrium markets being modeled, EPA quantified social welfare changes for the following categories:

- change in producer surplus in the energy markets;
- change in producer surplus in the final product markets;
- change in consumer surplus in the final product markets; and
- change in consumer surplus in the residential, commercial, and transportation energy markets.

Figure 4-5 illustrates the change in producer and consumer surplus in the intermediate energy market and the final product markets. For example, assume a simple world with only one energy market, wholesale electricity, and one final product market, pulp and paper. If the

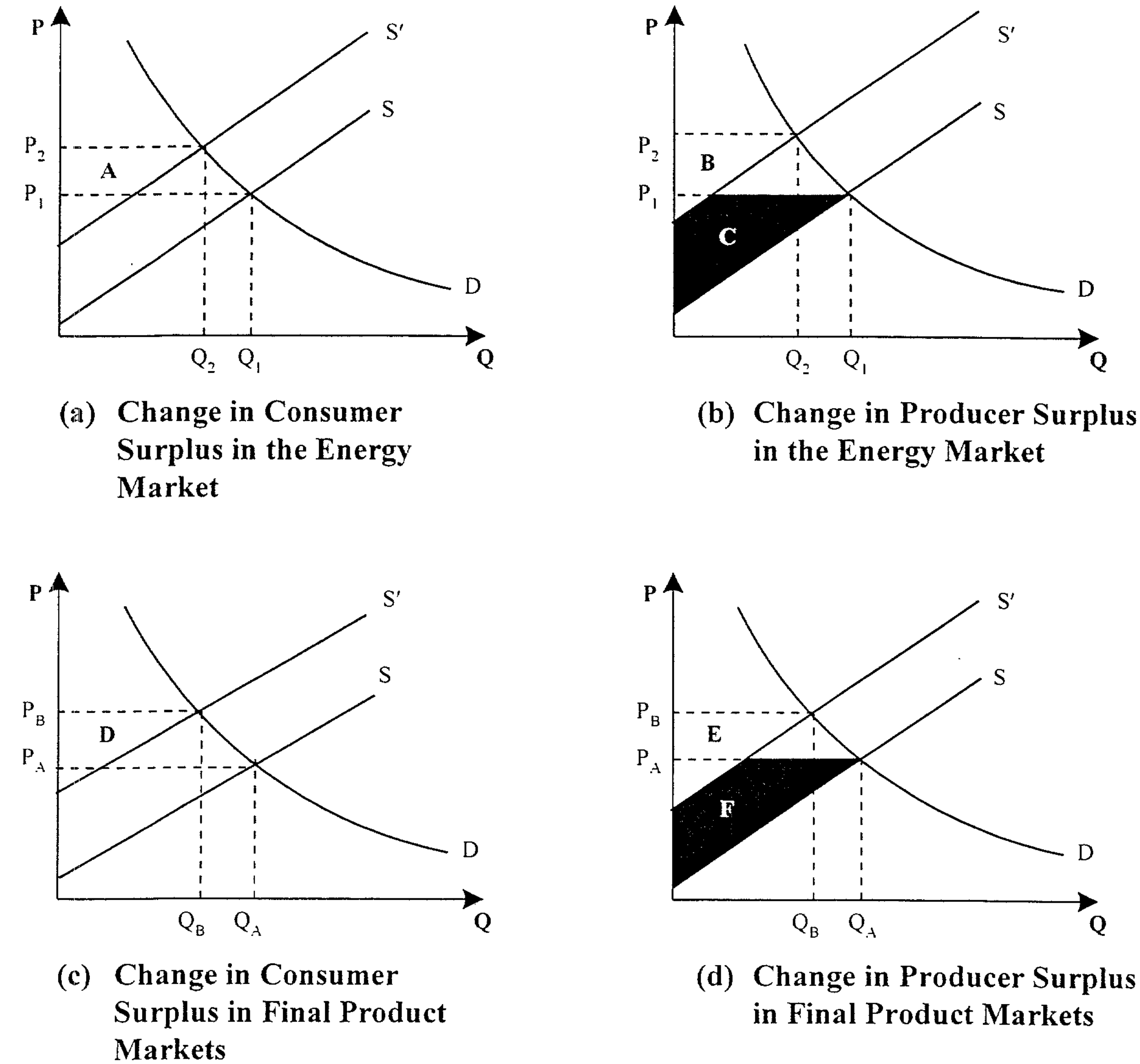
Table 4-2. Fuel Price Elasticities

	Own and Cross Elasticities in 2015				
Inputs	**Electricity**	**Natural Gas**	**Coal**	**Residual**	**Distillate**
Electricity	–0.074	0.092	0.605	0.080	0.017
Natural Gas	0.496	–0.229	1.087	0.346	0.014
Steam Coal	0.021	0.061	–0.499	0.151	0.023
Residual	0.236	0.036	0.650	–0.587	0.012
Distillate	0.247	0.002	0.578	0.044	–0.055

Source: U.S. Department of Energy, Energy Information Administration (EIA). January 1998c. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System.* DOE/EIA-M064(98). Washington, DC: U.S. Department of Energy.

regulation increased the cost of generating wholesale electricity, then part of the cost of the regulation will be borne by the electricity producers as decreased producer surplus, and part of the costs will be passed on to the pulp and paper manufacturers. In Figure 4-5(a), the pulp and paper manufacturers are the consumers of electricity, so the change in consumer surplus is displayed. This change in consumer surplus in the energy market is captured by the final product market (because the consumer is the pulp and paper industry in this case), where it is split between consumer surplus and producer surplus in those markets. Figure 4-5(b) shows the change in producer surplus in the energy market, where B represents an increase in producer surplus and C represents a decrease.

As shown in Figures 4-5(c) and 4-5(d), the cost affects the pulp and paper industry by shifting up the supply curve in the pulp and paper market. These higher electricity prices therefore lead to costs in the pulp and paper industry that are distributed between producers and consumers of paper products in the form of lower producer surplus and lower consumer surplus. Note that the change in consumer surplus in the intermediate energy market must equal the total change in consumer and producer surplus in the final product market. Thus, to avoid double-counting, the change in consumer surplus in the intermediate energy market was not quantified; instead the total change in social welfare was calculated as



(a) Change in Consumer Surplus in the Energy Market

(b) Change in Producer Surplus in the Energy Market

(c) Change in Consumer Surplus in Final Product Markets

(d) Change in Producer Surplus in Final Product Markets

Figure 4-5. Changes in Economic Welfare with Regulation

$$\text{Change in Social Welfare} = \sum \Delta PSE + \sum \Delta PSF + \sum \Delta CSF + \sum \Delta CSR \quad (4.1)$$

where

ΔPSE = change in producer surplus in the energy markets,

ΔPSF = change in producer surplus in the final product markets,

ΔCSF = change in consumer surplus in the final product markets, and

ΔCSR = change in consumer surplus in the commercial, residential, and transportation energy markets.

Appendix A contains the mathematical algorithms used to calculate the change in producer and consumer surplus in the appropriate intermediate and final product markets.

The engineering control costs presented in Section 2.3 are inputs (regulatory "shocks") in the market model approach. The magnitude and distribution of the regulatory costs' impact on the economy depend on the relative size of the impact on individual markets (relative shift of the market supply curves) and the behavioral responses of producers and consumers in each market (measured by the price elasticities of supply and demand).

4.2.3 Supply and Demand Elasticities Used in the Market Model

The market model incorporates behavioral changes based on the price elasticities of supply and demand. The price elasticities used to estimate the economic impacts presented in Section 4.3 are given in Table 4-3. Because most of the direct cost impacts fall on engines involved in the production of natural gas, the price elasticity of supply in the natural gas market is one of the most important factors influencing the size and distribution of the economic impacts associated with the RICE regulation. The supply elasticities in all of the other energy markets also have a significant impact on the results. However, estimates of the elasticity of supply for electric power were unavailable. This is in part because, under traditional regulation, the electric utility industry had a mandate to serve all its customers. In addition, utilities' rates were regulated and were based on allowing them to earn a market rate of return. As a result, the market concept of supply elasticity was not the driving force in utilities' capital investment decisions. However, wholesale market deregulation was initiated by the Energy Policy Act of 1992 and most states have begun to address the issue of retail deregulation. The overall trend is clearly toward deregulation of retail electric markets and the movement is gaining momentum. In future years, the market for electric power will

Table 4-3. Supply and Demand Elasticities

Energy Sectors	Elasticity of Supply	Elasticity of Demand			
		Manufacturing	Commercial[a]	Transportation[a]	Residential[a]
Electricity	0.75	Derived demand	–0.24	–0.24	–0.23
Natural gas	0.41[b]	Derived demand	–0.47	–0.47	–0.26
Petroleum	0.58[c]	Derived demand	–0.28	–0.28	–0.28
Coal	1.0[d]	Derived demand	–0.28	–0.28	–0.28

[a] Energy Information Administration. 2000. "Issues in Midterm Analysis and Forecasting 1999—Table 1." <http://www.eia.doe.gov/oaif/issues/pricetbl1.html>. As obtained on May 8, 2000.

[b] Dahl, Carol A. March 1990. "World Oil Production and Costs in the 1980s." Manuscript. Oxford: Oxford Institute for Energy Studies.

[c] Hogman, William W. 1989. "World Oil Price Projections: A Sensitivity Analysis." Prepared pursuant to the Harvard-Japan World Oil Market Study. Cambridge, MA: Energy Environmental Policy Center, John F. Kennedy School of Government, Harvard University.

[d] Zimmerman, M.B. 1977. "Modeling Depletion in the Mineral Industry: The Case of Coal." *The Bell Journal of Economics* 8(2):41-65.

probably look more like a typical competitive industry because of deregulation. To operationalize the model, a supply elasticity of 0.75 was assumed for the electricity market based on an assumption that the supply of electricity is fairly inelastic in the short run.

In contrast, many studies have been conducted on the elasticity of demand for electricity, and it is generally agreed that, in the short run, the demand for electricity is relatively inelastic. Most residential, commercial, and industrial electricity consumers do not significantly adjust short-run behavior in response to changes in the price of electricity. The elasticity of demand for electricity is primarily driven by long-run decisions regarding equipment efficiency and fuel substitution.

Additional elasticity of demand parameters for the residential, commercial, and transportation sectors were obtained from the Energy Information Administration by fuel type (natural gas, petroleum, coal). The demand elasticities also have a very significant impact on the model results. The elasticities of demand are not provided for manufacturing because the model calculates the derived demand from this sector for each of the energy markets modeled based on the estimated output from these markets. In effect, adjustments in the final product markets due to changes in production levels and fuel switching are used to estimate changes in energy demand, eliminating the need for demand elasticity parameters in the energy markets. For goods produced in the manufacturing final product markets, the elasticity of supply was assumed to be 1.0 and the elasticity of demand was assumed to be –1.0. Appendix B contains the sensitivity analysis for the key supply and demand elasticity assumptions.

4.3 Economic Impact Estimates

This study used a market model to estimate total changes in social welfare and to investigate the distribution of impacts between consumers and producers. In addition, producer impacts are distributed across industries within the energy and manufacturing sectors.

Table 4-4 summarizes the economic impact estimates. The total change in social welfare in 2005 is estimated to be $1,114.2 million. This estimate includes market adjustments in final product markets and fuel switching adjustments in the manufacturing sector in response to changes in relative prices. For comparison, the baseline engineering costs and social costs without fuel switching are also presented in Table 4-4. The economic impact estimate of $1,114.2 million is $0.5 million less than the estimated baseline engineering costs as a result of behavior changes by producers and consumers that reflect lower cost alternatives.

Table 4-4. Summary Table

	Change in Social Welfare (Millions of $1998)
Baseline engineering costs	1,114.7
Social costs with market adjustments	1,114.4
Social costs with market adjustments and fuel switching	1,114.2

Table 4-5 presents the distribution of economic impacts between producers and consumers and shows the distribution of impacts across sectors/markets. The market analysis estimates that consumers will bear a burden of $641.3 million in 2005 (58 percent of the total social cost) because of the increased price of energy, the increased prices of final products, and the smaller quantities of energy and final products generally available. Producer surplus is projected to decrease by $473.0 million in 2005 (42 percent of the total social cost) as a

Table 4-5. Economic Impacts—Changes in Social Welfare ($1998 10^6)

Sectors/Markets		Change in: Producer Surplus	Consumer Surplus	Social Welfare
Energy Markets				
Petroleum		-$9.3		
Natural gas		-$273.1		
Electricity		$31.3		
Coal		$3.0		
Subtotal		-$248.1		
SIC Code	**Description**			
Manufacturing Markets				
1	Crops	-$3.9	-$3.9	-$7.8
2	Livestock	-$1.9	-$1.9	-$3.7
12	Coal Mining	-$0.5	-$0.5	-$0.9
14	Mining and Quarrying	-$48.4	-$48.3	-$96.6
20	Food and Kindred Products	-$17.4	-$17.4	-$34.9
21	Tobacco Products	-$1.3	-$1.3	-$2.6
22	Textile Mill Products	-$2.6	-$2.6	-$5.1
23	Apparel & Other Textile Products	-$0.5	-$0.5	-$1.1
24	Lumber & Wood Products	-$1.2	-$1.2	-$2.5
25	Furniture and Fixtures	-$0.5	-$0.5	-$1.0
26	Paper and Allied Products	-$15.1	-$15.1	-$30.2
27	Printing and Publishing	-$1.0	-$1.0	-$2.0
28	Chemicals and Allied Products	-$61.4	-$61.4	-$122.8
29	Petroleum and Coal Products	-$22.8	-$22.8	-$45.6
30	Rubber and Misc. Plastics	-$5.5	-$5.5	-$11.0
31	Leather & Leather Products	$0.0	$0.0	$0.0
32	Stone. Clay. & Glass	-$10.0	-$10.0	-$20.1
33	Primary Metal Industries	-$17.7	-$17.7	-$35.4
34	Fabricated Metal Products	-$4.4	-$4.4	-$8.9
35	Industrial Machinery & Equip.	-$2.3	-$2.3	-$4.7
36	Electronics	-$1.9	-$1.9	-$3.8
37	Transportation Equip.	-$3.3	-$3.3	-$6.7
38	Analytical Instruments	-$0.7	-$0.7	-$1.3
39	Misc. Mfg.	-$0.4	-$0.4	-$0.8
Commercial Sector[a]		NA	-$260.5	-$260.5
Residential Sector		NA	-$104.9	-$104.9
Transportation Sector		NA	-$51.2	-$51.2
Subtotal		-$224.8	-$641.3	-$866.1
Grand Total		-$473.0	-$641.3	-$1.114.2

[a] This sector includes all commercial SIC codes. The majority of commercial RICE in the Inventory Database are used in hospitals. Commercial prices in the Inventory Database also include various retail and service establishments, as well as government buildings.

result of the direct control costs, higher energy costs, and reductions in output with the majority of the producer surplus losses logically falling on natural gas producers because the rule applies to engines that are primarily used in natural gas production. The costs to natural gas producers are approximately 58 percent of the total producer surplus loss or 24 percent of the total social cost of the regulation. Producer surplus also falls in the petroleum products market and in each of the final product markets. However, there are energy markets in which producer surplus actually rises as a result of the regulation. In particular, both the electricity and coal markets experience increases in producer surplus. Like natural gas producers, the producers of electricity and coal also face higher input costs due to increases in the price of oil and natural gas. However, the increase in input costs is much less for these producers than the increase in costs applied to natural gas and oil producers. As a result, the supply curve shifts less for electricity and coal than for natural gas and petroleum products, and the price does not increase as much. The fact that the prices of electricity and coal increase less than those of natural gas and petroleum cause electricity and coal to become more attractive to energy consumers because they have become relatively less expensive energy sources following the regulation despite their increase in price. This leads to an increase in the demand for electricity and coal as some consumers switch their fuel usage to consume a smaller proportion of natural gas and petroleum products and a larger proportion of electricity and coal due to the changing incentives facing them as relative prices of energy products change. Consumers change their consumption until the energy markets once again reach equilibrium at new levels of price and output. The increase in demand for electricity and coal resulting from fuel switching by energy users outweighs the increase in input costs and leads to increases in producer surplus in these two markets.

The total welfare loss for the manufacturing industries affected by the rule is estimated to total approximately $224.8 million for consumers and $224.8 million for producers in the aggregate. In comparison to the energy expenditures made by these industries (estimated to be $101.2 billion (EIA, 2000)), the cost of this rule to producers as a percentage of their energy expenditures is 0.22 percent. The total value of shipments for the affected manufacturing industries is $3.95 trillion in 1998, so the cost to consumers of these products as a percentage of spending on the outputs from these industries is 0.0006 percent.

The cost to residential consumers is larger than for any individual manufacturing market at $104.9 million, but less than the total consumer surplus losses in the manufacturing industries or commercial markets. The social cost burden to residential consumers of energy is 0.08 percent of their annual residential energy expenditures in 1998 of $131.06 billion

(EIA, 2000). The commercial sector also experiences a large portion of the total social cost with an impact to this sector estimated at $260.5 million. This value is an aggregate across all commercial SIC codes, however. For the commercial sector, energy expenditures in 1998 are estimated to be $96.86 billion (EIA, 2000). Therefore, the regulatory burden associated with the RICE MACT is estimated as 0.27 percent of total energy expenditures by the commercial sector ($260.5 million/$96.86 billion). The cost to transportation consumers is estimated by the economic model to be $51.2 million. This cost represents approximately 0.03 percent of energy expenditures for the transportation sector ($51.2 million/$188.13 billion (EIA, 2000)).

The equilibrium changes in price and quantity in the energy markets are presented in Table 4-6. In both the petroleum and natural gas markets, output decreases and price increases in response to the direct control costs. These control costs increase the cost of producing these products and decrease the supply, resulting in producer surplus losses of $9.3 million and $273.1 million, respectively. The impacts are greater in the natural gas market because that is where the majority of the affected engines operate. Even with the relatively large cost in the natural gas market, natural gas prices are estimated to increase by less than half of 1 percent, while the impacts in the other energy markets are expected to be much smaller as shown in Table 4-6. This increase in the price of natural gas is reasonable given the engineering cost impact on the natural gas market, which is estimated to be 0.6814 percent of the initial price. Market price is expected to increase by less than the increase in engineering costs because the economic model allows producers and consumers to change their behavior in response to price changes. As price increases, consumers reduce the quantity that they are willing to purchase. Therefore, if producers attempted to simply increase the price of their product by the full amount that their costs increased, then there would be a surplus of natural gas because consumers would not be willing to continue purchasing the initial quantity at a higher price. Producers would then respond by lowering prices until a new equilibrium is reached to avoid holding excess inventory. The market for petroleum products faces a similar situation. The engineering costs entering the economic model are estimated to be 0.017 percent of the initial price, and the model results indicate a 0.015 percent increase in the price of petroleum products.

In the electricity market, both price and quantity increase slightly (by 0.014 percent and 0.011 percent, respectively), which implies that, although the supply in this market decreases, there is an increase in demand that is larger than the decrease in supply and which leads to a minimal increase in equilibrium quantity. This is presumably due to consumers

Table 4-6. Change in Price and Quantity

Sectors/Markets		Percentage Change Price	Percentage Change Quantity
Energy Markets			
Petroleum		0.015%	-0.002%
Natural gas		0.418%	-0.109%
Electricity		0.014%	0.011%
Coal		0.011%	0.011%
SIC Code	**Description**		
Manufacturing Markets			
1	Crops	0.003%	-0.003%
2	Livestock	0.002%	-0.002%
12	Coal Mining	0.002%	-0.002%
14	Mining and Quarrying	0.242%	-0.242%
20	Food and Kindred Products	0.003%	-0.003%
21	Tobacco Products	0.003%	-0.003%
22	Textile Mill Products	0.003%	-0.003%
23	Apparel & Other Textile Products	0.001%	-0.001%
24	Lumber & Wood Products	0.001%	-0.001%
25	Furniture and Fixtures	0.001%	-0.001%
26	Paper and Allied Products	0.008%	-0.008%
27	Printing and Publishing	0.000%	0.000%
28	Chemicals and Allied Products	0.014%	-0.014%
29	Petroleum and Coal Products	0.011%	-0.011%
30	Rubber and Misc. Plastics	0.003%	-0.003%
31	Leather & Leather Products	0.000%	0.000%
32	Stone, Clay, & Glass	0.010%	-0.010%
33	Primary Metal Industries	0.009%	-0.009%
34	Fabricated Metal Products	0.002%	-0.002%
35	Industrial Machinery & Equip.	0.001%	-0.001%
36	Electronics	0.000%	0.000%
37	Transportation Equip.	0.001%	-0.001%
38	Analytical Instruments	0.000%	0.000%
39	Misc. Mfg.	0.001%	-0.001%

changing their fuel usage in response to higher prices for natural gas and petroleum. In the petroleum products, natural gas, and electricity markets, the change in price is larger in magnitude than the change in quantity because demand is more inelastic than supply in these markets, meaning that quantity is relatively unresponsive to changes in price. Price and quantity both increase in the coal market also (by 0.011 percent for both price and quantity), again because of a positive demand shift that outweighs any negative supply shift resulting from an increase in the energy input costs for coal production. Demand from utilities and other consumers is increasing due to switching towards coal usage as well as the increase in output of electricity. Because the primary users of coal are electricity producers and much of the electricity produced in the U.S. is produced at coal burning plants, an increase in the equilibrium quantity of electricity will lead to an increase in the derived demand for coal from the utilities.

Table 4-6 also provides the percentage change in price and quantity for the manufacturing final product markets. The regulation increases the price of final products in all markets and decreases the quantity. The final product markets behave similarly to the petroleum and natural gas markets. In each case, the estimated increase in price is less than the engineering costs facing that particular product market. However, the changes are generally very small. Only one market has a change in price or quantity greater than 0.02 percent. That market is mining and quarrying (SIC 14), which has an estimated increase in price of 0.24 percent and an estimated decrease in quantity of 0.24 percent. Note that the change in quantity is always of the same magnitude as the change in price for the final product markets because this analysis assumed that the supply and demand elasticities for each of these markets are equal to 1 and -1, respectively.

Although the impacts on price and quantity in the final product markets are estimated to be small, one possible effect of modeling market impacts at the two-digit SIC code level is that there may potentially be fuel-intensive industries within the larger SIC code definition that are affected more significantly than the average for that SIC code. Thus, the changes in price and quantity should be interpreted as an average for the whole SIC code, not necessarily for each disaggregated industry within that SIC code.

4.4 Conclusions

The decrease in social surplus estimated using the market analysis is $1,114.2 million in the year 2005. The economic impact from the market analysis is $0.5 million less than the estimated baseline engineering costs because the market model accounts for behavioral changes of producers and consumers. Although the rule affects engines that are primarily used in the natural gas industry, the natural gas producers incur only 24 percent of the total social cost of the regulation. The burden is spread across numerous markets because the price of energy increases slightly as a result of the regulation, which increases the cost of production for all markets that use energy as part of their production process.

The market model estimates that the regulation will increase the cost of producing petroleum products and natural gas, leading to decreases in the quantity of these products produced and increases in their prices. Because of fuel switching away from natural gas and petroleum and towards electricity and coal taking place, both the electricity and coal markets have increases in demand that outweigh any reduction in supply caused by an increase in input prices. The market analysis also indicates that the impacts of the regulation will be borne primarily by natural gas producers and consumers in the manufacturing, commercial, and residential sectors. The manufacturing markets that are most affected are the mining and quarrying (SIC 14), food and kindred products (SIC 20), chemicals and allied products (SIC 28), and primary metal industries (SIC 33) markets.

Because of the minimal changes in price and quantity estimated for most of the affected markets, EPA expects that there would be no discernable impact on international trade. Although an increase in the price of U.S. products relative to those of foreign producers is expected to decrease exports and increase imports, the changes in price due to the RICE MACT are generally too small to significantly influence trade patterns. In addition, the market facing the largest increase in price is the natural gas market, but imports of natural gas are essentially limited to Canadian gas, which will also be subject to at least some of the costs of the regulation as it is transported through pipelines in the U.S. There may also be a small decrease in employment, but because the impact of the regulation is spread across so many industries and the decreases in market quantities are so small, it is unlikely that any particular industry will face a significant decrease in employment.

Because of the decrease in the quantity of natural gas and petroleum products projected due to the RICE MACT, as well as the decrease in output in the final product markets, it is expected that fewer new engines will be installed than in the absence of the regulation. Table 4-7 shows the regulation's estimated impact on the number of new engines installed based on a constant number of engines being added per unit of output in each affected market. The manufacturing markets category is the sum of engines used in all 24 manufacturing markets included in this analysis. The category labeled "other" contains all of

Table 4–7. Impacts on the Number of New Engines Installed

New Engines	Baseline	With Regulation
Natural gas market	12,634	12,620
Petroleum products market	1,169	1,169
Manufacturing markets	3,086	3,081
Other	3,426	3,426
Total	**20,306**	**20,287**

the engines in the commercial, residential, and transportation markets. Because the quantity of output was assumed unchanged in these markets, it is assumed that the number of engines demanded in these sectors will also remain constant. Because the percentage changes in price and quantity are so small, the estimated impact on the number of engines is extremely small. According to the economic model, approximately 19 fewer engines (0.09 percent of the projected total) will be installed due to the regulation because of reductions in output in the natural gas and manufacturing markets.

SECTION 5

IMPACTS ON FIRMS OWNING RICE

The regulatory costs imposed on domestic producers to reduce air emissions from internal combustion engines will have a direct impact on owners of the affected facilities. Firms or individuals that own the facilities with internal combustion engines are legal business entities that 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 owners, who must bear the financial consequences of their decisions. Environmental regulations, such as the proposed internal combustion engine standard, affect both large and small entities (businesses or governments), but small entities may have special problems in complying with such regulations.

The Regulatory Flexibility Act (RFA) of 1980 requires that special consideration be given to small entities affected by federal regulation. Specifically, the RFA requires determining whether a regulation will significantly affect a substantial number of small entities or cause a disproportionate burden on small entities in comparison with large companies. In 1996, the Small Business Regulatory Enforcement Fairness Act (SBREFA) was passed, which further amended the RFA by expanding judicial review of agencies' compliance with the RFA and by expanding small entity review of EPA rulemaking.

This analysis assesses the potential impacts of the standard on small entities. To make this assessment, the costs of the regulation are, to the extent possible, mapped to firm-level data (or government-level data) and proportional cost effects are estimated for each identified firm (or government). Then, the focus is placed on small firms and the question of whether there are a substantial number with a large regulatory cost-to-sales impact. The control costs under the MACT floor are used to estimate cost-to-sales ratios (CSRs).

5.1 Identifying Small Businesses

To support the economic impact analysis of the proposed regulation, EPA identified 26,832 engines located at commercial, industrial, and government facilities. The population of engines was developed from the EPA Industrial Combustion Coordinated Rulemaking

(ICCR) Inventory Database version 4.1.[1] The list of engines contained in these databases was developed from information in the AIRS and OTAG databases, state and local permit records, and the combustion source ICR conducted by the Agency. Industry and environmental stakeholders reviewed the units contained in these databases as part of the ICCR FACA process. In addition, stakeholders contributed to the databases by identifying and including omitted units. Information was extracted from the ICCR databases to support the engines NESHAP. This modified database containing information on only engines is referred to as the Inventory Database.

From this initial population of 26,832 engines, 10,118 engines were excluded because the proposed regulation will not cover engines smaller than 500 hp or engines used to supply emergency/backup power. Table 5-1 provides the remaining population of 16,714 engines, broken out by industry SIC code.

Because it is not possible to project specific companies or government organizations that will purchase new engines in the future, the small business screening analysis for the RICE MACT is based on the evaluation of existing owners of engines. It is assumed that the existing size and ownership distribution of engines in the Inventory Database is representative of the future growth in new engines. The remainder of this section presents cost and sales information on small companies and government organizations that own existing engines.

5.2 Screening-Level Analysis

To conduct the small entity analysis, unit model numbers (Ali, 2000) were linked to individual units (engines) at affected facilities so that parent companies' aggregate control costs could be compared to company sales. Of the 16,714 affected units in the Inventory Database, 2,645 units had sufficient information to assign model numbers. Table 5-1 compares the unit counts and percentage of units by industry for the total Inventory Database population and the subset of units used in the small entity analysis.

---

[1]The ICCR Inventory Database contains data for boilers, process heaters, incinerators, landfill gas flares, turbines, and internal combustion engines.

Table 5-1. Unit Counts and Percentages by Industry

Industry (SIC)	Subset Mapped with Control Costs: Number of Units	Subset Mapped with Control Costs: Percentage of Total Units	Inventory Database: Number of Units	Inventory Database: Percentage of Total Units
Agriculture (01-09)	1	0.04	8	0.05
Mining (10-12, 14)	33	1.25	663	3.97
Petroleum & Natural Gas Exploration (13)	1,145	43.29	6,191	37.04
Construction (15-17)	1	0.04	84	0.50
Manufacturing (20-39)	57	2.16	1,547	9.26
Utility Services (40-48)	9	0.34	241	1.44
Electricity & Gas Services (49)	1,306	49.38	6,371	38.12
Wholesale Trade (50-51)	1	0.04	171	1.02
Retail Trade (52-59)	4	0.15	26	0.16
Finance, Real Estate, & Insurance (60-67)	6	0.23	84	0.50
Services (70-89)	50	1.91	331	1.98
Government (90-98)	4	0.15	387	2.32
Not Elsewhere Classified (99)	0		41	0.25
Unknown	28	1.07	670	4.01
Total	2,645		16,714	

As indicated in Table 5-1, the subset of units used in the small entity analysis is fairly representative of the population in the Inventory Database because the percentage of units in each SIC code is similar to the percentage in the Inventory Database for most industries. Petroleum & Natural Gas Exploration (SIC 13) and Electricity & Gas Services (SIC 49) account for the majority of units in both the Inventory Database and subset populations.

5.3 Analysis of Facility-Level and Parent-Level Data

The 2,645 units in the Inventory Database with full information were linked to 834 existing facilities. As shown in Table 5-2, these 834 facilities are owned by 153 parent

Table 5-2. Facility-Level and Parent-Level Data

SIC	Industry Description	Number of Facilities	Number of Parent Companies	Avg. Number of Facilities Per Parent Entity
02	Agricultural Services	1	1	1.0
10	Metal Mining	1	1	1.0
13	Oil & Gas Extraction	311	37	8.4
14	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	27	15	1.8
16	Heavy Construction	1	1	1.0
20	Food & Kindred Products	4	4	1.0
21	Tobacco Products	1	0	
26	Paper & Allied Products	1	1	1.0
28	Chemicals & Allied Products	4	3	1.3
29	Petroleum Refining & Related Industries	7	5	1.4
30	Rubber & Misc. Plastics	2	2	1.0
32	Stone, Clay, Glass, & Concrete Products	1	0	
33	Primary Metals Industries	1	1	1.0
45	Transportation by Air	1	1	1.0
46	Pipelines, Except Natural Gas	4	1	4.0
49	Electric, Gas, & Sanitary Services	436	56	7.8
50	Durable Goods Wholesale Trade	1	0	
55	Automotive Dealers & Gas Stations	1	1	1.0
63	Insurance Carriers	3	3	1.0
65	Real Estate	1	1	1.0
73	Business Services	1	0	
80	Health Services	20	17	1.2
82	Educational Services	1	1	1.0
92	Justice, Public Order, & Safety	1	1	1.0
Unknown		2	0	
Total		834	153	5.5

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

companies. The average number of facilities per company is approximately 5.5; however, as is also illustrated in Table 5-2, several large parent companies in the crude petroleum and natural gas industry and natural gas transmission industry own many facilities with IC engines.

Employment and sales are typically used as measures of business size. Employment, sales, and tax revenue data (when applicable) were collected for 141 of the 153 parent companies.[2] Sales and employment information was unavailable for 12 parent companies. Figure 5-1 shows the distribution of employees by parent company. Employment for parent companies ranges from 5 to 96,650 employees. Fifty-eight of the firms have fewer than 500 employees, and seven companies have more than 25,000 employees.

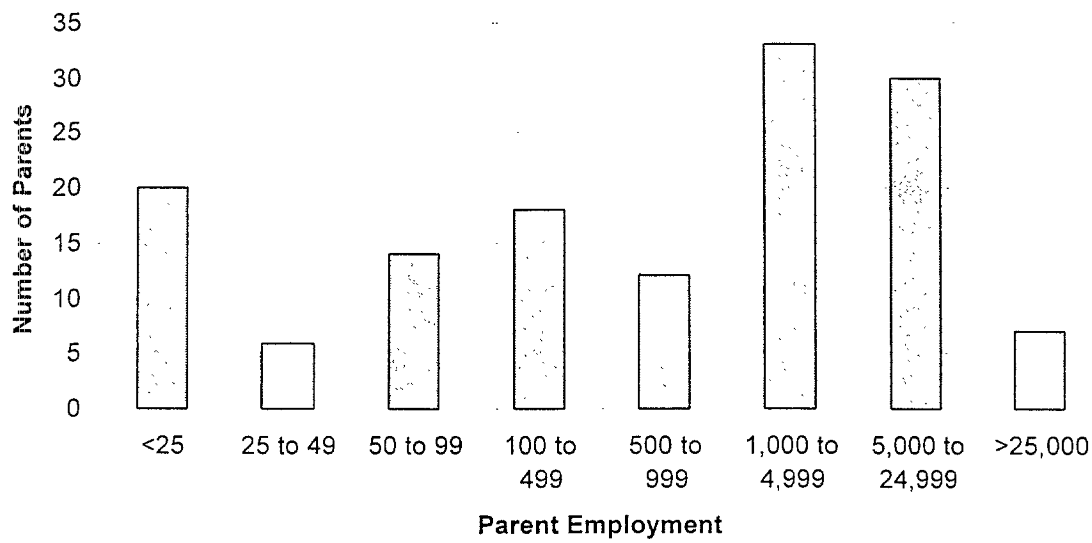


Figure 5-1. Parent Size by Employment Range

Includes 141 parent companies for which data are available.

[2]Total annualized cost is compared to tax revenue to assess the relative impact on local governments.

Sales provide another measure of business size. Figure 5-2 presents the sales distribution for affected parent companies. The median sales figure for affected companies is $300 million, and the average sales figure is $4.7 billion (excluding the federal government). As shown in Figure 5-2, the distribution of firm sales is fairly evenly distributed, but approximately two-thirds of all parent companies have sales greater than $100 million. These figures include all sales associated with the parent company, not just facilities affected by the regulation (i.e., facilities with internal combustion engines).

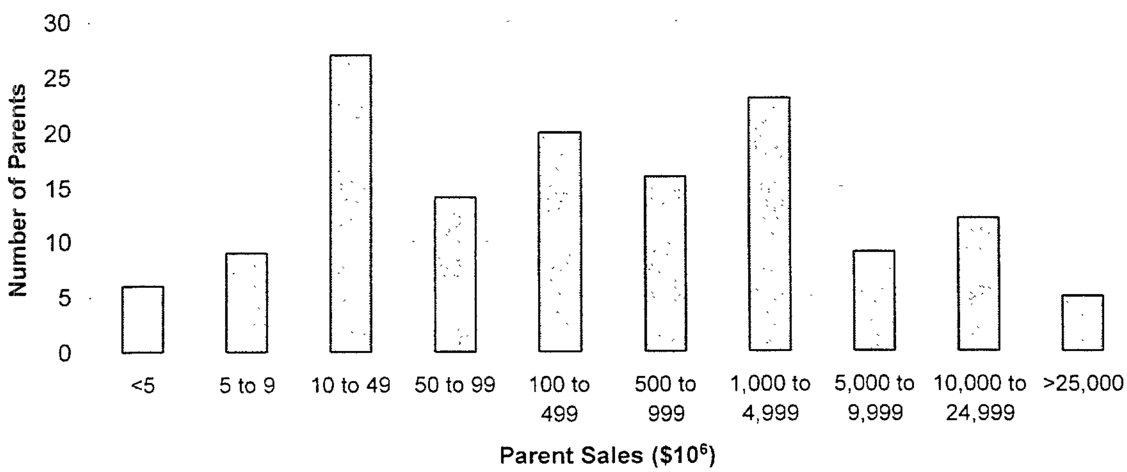


Figure 5-2. Number of Parents by Sales Range

Includes 141 parent companies for which data are available.

Based on Small Business Administration guidelines, 47 entities were identified as small. Small businesses by business type are presented in Table 5-3.[3] The oil and gas extraction industry contains the largest number (14) of the small businesses, followed by nonmetallic minerals mining and quarrying (13), and gas services (6). Also, six

[3]Small business guidelines typically define small businesses based on employment, and the threshold varies from industry to industry. For example, in the paints and allied products industry, a business with fewer than 500 employees is considered a small business; whereas in the industrial gases industry, a business with fewer than 1,000 employees is considered small. However, for a few industries, usually services, sales are used as the criterion. For example, in the veterinary hospital industry, companies with less than $5 million in annual sales are defined as small businesses.

Table 5-3. Small Parent Companies

SIC	Industry Description	Number of Facilities	Number of Parent Companies	Number of Small Parent Companies
02	Livestock & Animal Specialties	1	1	
10	Metal Mining	1	1	1
13	Oil & Gas Extraction	311	37	14
14	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	27	15	13
16	Heavy Construction	1	1	1
20	Food & Kindred Products	4	4	2
21	Tobacco Products	1	0	
26	Paper & Allied Products	1	1	1
28	Chemicals & Allied Products	4	3	1
29	Petroleum Refining & Related Industries	7	5	2
30	Rubber & Misc. Plastics Products	2	2	
32	Stone, Clay, Glass, & Concrete Products	1	0	
33	Primary Metals Industries	1	1	
45	Transportation by Air	1	1	
46	Pipelines, Except Natural Gas	4	1	1
49	Electric, Gas, & Sanitary Services	436	56	11
50	Durable Goods Wholesale Trade	1	0	
55	Automotive Dealers & Gas Stations	1	1	
63	Insurance Carriers	3	3	
65	Real Estate	1	1	
73	Business Services	1	0	
80	Health Services	20	17	
82	Educational Services	1	1	
92	Justice, Public Order, & Safety	1	1	
Unknown		2	0	
Total		834	153	47

Source: Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

cities are classified as small governments because they have fewer than 50,000 residents, based on guidelines established by EO 12875. The remaining small businesses are distributed across seven different two-digit SIC code groupings.

5.4 Small Business Impacts

Although there are a total of 47 small entities identified in the Inventory Database, only 13 of them own 4SRB engines. As mentioned in previous sections, the only existing engines affected by the rule are 4SRB units, while all other types of engines will only have requirements on new engines rather than existing units. These small entities own a total of 39 4SRB units at 20 facilities. The impacts on the affected entities in the Inventory Database are summarized in Table 5-4. One small firm has compliance costs that are slightly above 3 percent of firm revenues. Three other small firms owning 4SRB engines have impacts between 1 and 3 percent of revenues. In addition, there is one small government in the Inventory Database affected by this rule. The costs to this city are less than $6 per capita annually, less than 0.02 percent of median household income.

Table 5-4. Summary Statistics for SBREFA Screening Analysis: Existing Affected Small Entities

Total Number of Small Entities		**13**[a]
Average Annual Compliance Cost ($$10^6$/yr)[b]		**$155,571**
Small Entities with Sales/Revenue Data	Number	Share
Compliance Costs < 1% of sales	8	66.6%
Compliance Costs between 1 and 3% of sales	3	25.0%
Compliance Costs > 3% of sales	1	8.3%
Total	12	100.0%
Compliance Cost-to-Sales Ratios Descriptive Statistics		
Average		0.92%
Median		0.63%
Minimum		3.57%
Maximum		0.09%

[a] One of these is a small city for which no sales were available.
[b] Assumes no market responses (i.e., price and output adjustments) by regulated entities.

Based on this subset of the existing engines population, the regulation will affect about 2 percent (1/47) of small entities owning RICE greater than 500 hp at a CSR greater than 3 percent, while approximately 6 percent (3/47) of small entities owning RICE greater than 500 hp will have compliance costs between 1 and 3 percent of sales. The total existing population of engines with greater than 500 hp that are not backup units is estimated to be 22,018 (Ali, 2000). Assuming the same breakdown of large and small company ownership of engines in the total population of existing engines as in the subset with parent company information identified, the Agency expects that approximately eight small entities in the total existing population of RICE owners would have CSRs above 3 percent, and about 25 small entities in the existing population of RICE owners would have CSRs between 1 and 3 percent.

In addition, because many small entities owning RICE will not be affected because of the exclusion of engines with less than 500 hp, the percentage of all small companies owning RICE that are affected by this regulation is even smaller. Based on the proportion of engines in the Inventory Database that are greater than 500 hp and are not backup units (16,714/26,832, or 62.3 percent) and assuming that small companies own the same proportion of small engines (less than 500 hp) as they do of engines greater than 500 hp, the Agency estimates that 632 small companies own RICE. Of all small companies owning RICE, only 1.3 percent (8/632) are expected to have CSRs above 3 percent, while 4.0 percent (25/632) are expected to have CSRs between 1 and 3 percent.

5.5 Assessment of SBREFA Screening

As outlined above, this regulation will affect only a very small percentage of small entities owning RICE. To determine whether the impacts on existing small entities are significant, typical profit margins in the affected industries were considered. The engines included in the database are owned and operated in more than 25 different industries, but the majority of the small businesses affected by the proposed regulation are in the oil and gas extraction; mining and quarrying; and electric, gas, and sanitary services sectors (see Table 5-3). As shown in Table 5-5, the average profit margin for these sectors is approximately 5 percent. Table 5-5 also shows the profit margins for the other industry sectors with affected small entities. All profit margins of industry sectors with affected small businesses are above 2 percent. Based on this median profit margin data, it seems reasonable to review the number of small firms with CSRs above 3 percent in screening for significant impacts.

Table 5-5. Profit Margins for Industry Sectors with Affected Small Businesses

SIC	Industry Description	Median Profit Margin
10	Metal Mining	5.1%
13	Oil & Gas Extraction	4.6%
14	Mining & Quarrying of Nonmetallic Minerals, Except Fuels	2.1%
16	Heavy Construction	3.5%
20	Food & Kindred Products	3.6%
26	Paper & Allied Products	3.3%
28	Chemicals & Allied Products	2.7%
46	Pipelines, Except Natural Gas	26.8%
49	Electric, Gas, & Sanitary Services	7.5%

Source: Dun & Bradstreet. 1997. Industry Norms & Key Business Ratios. Desktop Edition 1996-97. Murray Hill, NJ: Dun & Bradstreet, Inc.

This analysis shows that none of the small entities in the Inventory Database have impacts greater than 5 percent, only one small firm has an impact greater than 3 percent, and four small firms have impacts between 1 and 3 percent. Based on the low number of affected small firms, the low number of firms with CSRs between 3 and 5 percent, and the fact that industry profit margins average 5 percent, this analysis concludes that this proposed regulation will not have a significant impact on a substantial number of existing small entities.

For new sources, it can be reasonably assumed that the investment decision to purchase a new engine may be slightly altered as a result of the regulation. For the entire population of affected engines projected to exist in 2005, the economic model predicts 19 fewer engines (0.09 percent of the projected total in the absence of the regulation) will be purchased because of market responses to the regulation. Specifically, the slight declines in output in industries that use RICE leads to a small decrease in the number of engines needed to produce that output. It is not feasible, however, to determine future investment decisions at the small entities in the affected industries, so EPA cannot link these 19 engines to any one firm (small or large). Overall, it is very unlikely that a substantial number of small firms who may consider purchasing a new engine will be significantly affected because the decision to purchase new engines is not altered to a large extent. In addition, the rule is likely to increase profits at the many small firms owning RICE that are not affected by the rule by increasing their revenues due to the estimated increase in prices in the energy markets and final product markets.

Although this proposed rule will not have a significant economic impact on a substantial number of small entities, EPA nonetheless has tried to reduce the impact of this rule on small entities. In this proposed rule, the Agency is applying the minimum level of control (i.e., the MACT floor) and the minimum level of monitoring, recordkeeping, and reporting to affected sources allowed by the CAA. In addition, as mentioned earlier in this report, new RICE units with capacities under 500 hp and those that operate as emergency/temporary units are not covered by this proposed rule. This provision should reduce the level of small entity impacts. EPA continues to be interested in the potential impacts of the proposed rule on small entities and welcomes comments on issues related to such impacts.

SECTION 6

ASSUMPTIONS AND LIMITATIONS OF THE ECONOMIC MODEL

In developing the economic model of effects of the RICE NESHAP, several assumptions were necessary to make the model operational. These assumptions are in addition to those described in Section 4.2 for the values of supply and demand elasticities. In this section, the major operational assumptions are listed and explained. Possible impacts and limitations of the model resulting from each assumption are then described.

Assumption: The domestic markets for energy are perfectly competitive.

Explanation: Assuming that the markets for energy are perfectly competitive implies that individual producers are not capable of unilaterally affecting the prices they receive for their products. Under perfect competition, firms that raise their price above the competitive price are unable to sell at that higher price because they are a small share of the market and consumers can easily buy from one of a multitude of other firms that are selling at the competitive price level. Given the relatively homogeneous nature of individual energy products (petroleum, coal, natural gas, electricity), the assumption of perfect competition at the national level seems to be appropriate.

Possible Impact: If energy markets were in fact imperfectly competitive, implying that individual producers can exercise market power and thus affect the prices they receive for their products, then the economic model would understate possible increases in the price of energy due to the regulation as well as the social costs of the regulation. Under imperfect competition, energy producers would be able to pass along more of the costs of the regulation to consumers; thus, consumer surplus losses would be greater, and producer surplus losses would be smaller in the energy markets.

Assumption: The domestic markets for industrial products are all perfectly competitive.

Explanation: Assuming that these markets are perfectly competitive implies that the producers of these products are unable to unilaterally affect the prices they receive for their products. Because the industries used in this analysis are aggregated across a large number of individual producers, it is a reasonable assumption that the individual producers have a very small share of industry sales and cannot individually influence the price of output from that industry.

Possible Impact: If these product markets were in fact imperfectly competitive, implying that individual producers can exercise market power and thus affect the prices they receive for their products, then the economic model would understate possible increases in the price of final products due to the regulation as well as the social costs of the regulation. Under imperfect competition, producers would be able to pass along more of the costs of the regulation to consumers; thus, consumer surplus losses would be greater, and producer surplus losses would be smaller in the final product markets.

Assumption: The baseline year of the analysis, 2005, provides representative information about the impacts on affected industries after new engines subject to the regulation have been installed.

Explanation: The engineering costs of the regulation are estimated for all engines projected to exist in 2005 in terms of 1998 dollars. For the economic model to be consistent, all costs and prices must be denominated in the same year. However, to examine future impacts, the number of engines projected to exist in 2005 is used in conjunction with costs and prices in 1998 dollars. Because most of the impact of the regulation is borne by new engines, it is more informative to use a future year that includes some of these new engines rather than the current year. In the current year, no new engines would be subject to the proposed rule. Choosing a baseline year 5 years into the future allows an examination of intermediate-run costs resulting from the regulation.

Possible Impact: If the projections for growth in the number of engines of each type (4SRB, 2SLB, 4SLB, CI) turn out to be incorrect, then the actual costs of the regulation will differ from the estimated values. Also, it is assumed that the relationships between many variables stay the same in 2005 as they are in 1998, the year that most of the data are from. For example, it is assumed that fuel costs remain the same proportion of production costs in 2005 as in 1998. If these relationships change over time, then the actual cost of the regulation in 2005 will differ from the estimated values. Also, because the number of engines subject to the regulation is projected to increase over time, the farther into the future the analysis looks, the higher the costs will be given the current projections. However, extrapolating far into the future may not give an accurate picture of the number of engines that will be used because many factors could change the growth rate of RICE.

Assumption: Fuel costs are a constant proportion of production costs.

Explanation: It is assumed that the percentage of production costs spent on fuels remains constant as the price of fuel changes. Because the price changes obtained in the model are so small, it is not unreasonable to assume that producers will not change the mix of inputs that they use in the production process as a result of the price increase.

Possible Impact: Theoretically, producers could switch their production process to one that requires less fuel by substituting more labor, capital, etc., for fuel. If producers respond to the increase in fuel prices by significantly altering their input mix and using less fuel, then the price in the energy markets will increase less than the estimated value due to the decrease in demand, and prices in the final product markets will also increase less than expected. In this case, producers will face higher welfare losses and consumers smaller welfare losses than in the current model.

Assumption: The amount of fuel required to produce a unit of output in the final product markets remains constant as output changes.

Explanation: The importance of this assumption is that when output in the final product markets changes as a result of a change in energy prices, it is assumed that the amount of fuel used changes in the same proportion as output, although the distribution of fuel usage among fuel types may change due to fuel switching. This change in the demand for fuels feeds into the energy markets and affects the equilibrium price and quantity in the energy markets.

Possible Impact: Fuel usage may not actually change in exactly this way. If fuel usage decreases more than proportionately, then the demand for fuels will decrease more, and there will be more downward pressure on energy prices than the model results suggest. If fuel usage decreases less than proportionately, then the demand for fuels will decrease less, and the price will be higher than the model result.

Assumption: All pipelines are affected by the regulation.

Explanation: It is assumed that new engines will be distributed across all existing pipelines and any new pipelines so that the cost of distribution rises for all natural gas rather than only affecting some producers and leaving others unaffected.

Possible Impact: If only some natural gas producers are affected and others are unaffected, then the unaffected firms may see their profits rise if the market price increases due to decreases in output from affected suppliers because the unaffected firms experience no shift in their cost curves as a result of the regulation. The relative proportion of affected and unaffected producers would then be important in determining the overall change in equilibrium price and quantity. If the regulation affected only a very small percentage of the market, then market price and quantity may not change appreciably.

Assumption: The demand for products and services in the affected commercial sectors is very inelastic.

Explanation: All affected engines that are not associated with the energy or manufacturing markets are grouped into the "commercial" sector. The majority of the engines in the commercial sector are associated with health care services, with most located at hospitals. It is assumed that the demand for health care services in highly inelastic with respect to price. Thus, all impacts in the commercial sector are assumed to be borne by consumers and are shown as changes in consumer surplus in the final results tables in Section 4.3.

Possible Impact: Assuming a perfectly inelastic demand in the commercial market enables producers to pass along all costs to consumers in the form of higher prices. Relaxing this assumption would lead to a decrease in producer surplus in the commercial market, a smaller decrease in consumer surplus in the commercial market, and a slight decrease in the overall welfare losses associated with the regulation because the quantity produced would decrease as consumers substituted away from commercial goods and services.

REFERENCES

Ali, Tanya, Alpha-Gamma Technologies, Inc. Memorandum to Roy Sims, EPA/OAQPS/ESD Combustion Group. June 6, 2000. "National Impacts Associated with Reciprocating Internal Combustion Engines."

American Gas Association. 1999. "Gas Facts 1998. <http://www.aga.org/StatsStudies/GasFacts/2131.html>.

Berger, Bill D., and Kenneth E. Anderson. 1978. *Modern Petroleum: A Basic Primer of the Industry*. Tulsa, OK: The Petroleum Publishing Co.

Conces, Elaine. 2000. "Hoover's Online—Energy Industry Snapshot." As obtained on April 18, 2000. <http://www.hoovers.com/industry/snapshot/0,2204,16,00.html>.

Dun & Bradstreet. 1997. *Industry Norms & Key Business Ratios*. Desktop Edition 1996-97. Murray Hill, NJ: Dun & Bradstreet, Inc.

Energy Information Administration. 1999a. *Natural Gas 1998: Issues and Trends*. Washington, DC: U.S. Department of Energy.

Energy Information Administration. 1999b. *Natural Gas Annual 1998*. Washington, DC: U.S. Department of Energy.

Energy Information Administration. 1999c. *Petroleum Supply Annual 1998, Volume I*. Washington DC: U.S. Department of Energy.

Energy Information Administration. 2000. As obtained on June 1, 2000. <http://www.eia.doe.gov/emeu/cabs/use.html>.

Gas Research Institute (GRI). 2000. "Engine Design, Operation, and Control in the Natural Gas Industry." As obtained on May 9, 2000. <http://www.gri.org/pub/oldcontent/tech/e+s/engines/des_op.htm>.

Heil, Scott F., Ed. 1998. *Ward's Business Directory of U.S. Private and Public Companies 1998, Volume 5*. Detroit, MI: Gale Research Inc.

Hoover's Incorporated. 2000. Hoover's Company Profiles. Austin, TX: Hoover's Incorporated. <http://www.hoovers.com/>.

Industrial Combustion Coordinated Rulemaking (ICCR). 1998. Data/Information Submitted to the Coordinating Committee at the Final Meeting of the Industrial Combustion Coordinated Rulemaking Federal Advisory Committee. EPA Docket Numbers A-94-63, II-K-4b2 through -4b5. Research Triangle Park, North Carolina. September 16-17.

Lillis, Kevin. 1998. "Crude Petroleum and Natural Gas." *The U.S. Industry and Trade Outlook '98*. New York: DRI/McGraw-Hill, Standard & Poor's, and U.S. Department of Commerce/International Trade Administration.

Natural Gas Information and Educational Resources. As obtained on July 20, 2000. <www.naturalgas.org/PRODUCT.HTM>.

Natural Gas Supply Association (NGSA) et al. 2000a. "Transportation of Natural Gas." As obtained on March 22, 2000a. <http://www.naturalgas.org/TRANS.htm>.

Natural Gas Supply Association (NGSA) et al. 2000b. "Storage of Natural Gas." As obtained on March 22, 2000b. <http://www.naturalgas.org/STOR2.htm>.

Natural Gas Supply Association (NGSA) et al. 2000c. "Natural Gas Production." As obtained on March 22, 2000c. <http://www.naturalgas.org/PRODUCT.HTM>.

Small Business Administration (SBA). 1999. Size Standards by SIC Industry. <http://www.sba.gov/regulations/sicodes/siccodes.htm>.

Tussing, Arlon R., and Bob Tippee. 1995. *The Natural Gas Industry: Evolution, Structure, and Economics.* 2nd Edition. Tulsa, OK: PennWell Publishing Company.

U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Mineral Industries, Industry Series: Crude Petroleum and Natural Gas.* MIC92-I-13A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Mineral Industries, Industry Series: Natural Gas Liquids.* MIC92-I-13B. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1995c. *1992 Census of Mineral Industries, Industry Series: Oil and Gas Field Services*. MIC92-I-13C. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Economic Census, Mining, Industry Series: Crude Petroleum and Natural Gas Extraction*. EC97N-2111A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Economic Census, Mining, Industry Series: Natural Gas Liquid Extraction*. EC97N-2111b. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1999c. *1997 Economic Census, Mining, Industry Series: Drilling Oil and Gas Wells*. EC97N-2131A. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 1999d. *1997 Economic Census, Mining, Industry Series: Support Activities for Oil and Gas Operations*. EC97N-2131B. Washington, DC: U.S. Department of Commerce.

U.S. Department of Commerce, Bureau of the Census. 2000. *1997 Economic Census, Transportation and Warehousing: Geographic Area Series*. EC97T48A-US. Washington, DC: Government Printing Office.

U.S. Department of Energy, Energy Information Administration. 1999. "Petroleum: An Energy Profile." <http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/petroleum_profile_1999/profile99v8.pdf.>

U.S. Department of Energy, Energy Information Administration (EIA). "Supplement Tables to the AEO 2000." <http://www.eia.doe.gov/oiaf/aeo/supplement/index.html>. As obtained on June 20, 2000.

U.S. Department of Transportation, Office of Pipeline Safety (OPS). "Annual Mileage Totals Transmission—Distribution." As obtained on March 22, 2000. <http://ops.dot.gov/gtannual.htm>.

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1993. "Supplement F to Compilation of Air Pollutant Emission Factors." Volume 1: Stationary Point and Area Sources. Research Triangle Park, NC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 1996. *National Emission Standards for Hazardous Air Pollutants for Source Categories: Oil and Natural Gas Production and Natural Gas Transmission and Storage - Background Information for Proposed Standards.* Research Triangle Park, NC: Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency. 1999a. *Economic Analysis Resource Document.* Research Triangle Park, NC: Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency. 1999b. *EPA Office of Compliance Sector Notebook Project: Profile of the Oil and Gas Extraction Industry.* Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 2000a. "Draft Preamble." *National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines.* Research Triangle Park, NC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 2000b. *Economic Analysis of the Stationary Combustion Turbines MACT Standard.* Research Triangle Park, NC: U.S. Environmental Protection Agency.

Whelan, Michael. 1998. "Improving Compressor Station Performance: Getting at the Heart of the Matter." <http://www.gri.org/pub/content/sep/19990923/145119/wtcompressor12.html>.

APPENDIX A

ECONOMIC MODEL OF MARKETS AFFECTED BY THE RICE MACT

Implementation of the proposed MACT standards will affect the costs of production in U.S. energy markets, thus changing the amount of energy that producers are willing to supply and leading to a change in price. Because energy is used as an input in the production of most goods and services, changes in the price of energy will affect almost all of the markets in the U.S. to some extent. Specifically, the cost of the regulation may cause individual facilities to decrease their current level of production or even to close. These choices affect, and in turn are affected by, the market price for each product. As the individual facilities in a market decrease their current level of production, the market supply will decrease as well.

The Agency developed an economic model of markets affected by the proposed rule to estimate its economic impact (see Section 4 for details on the conceptual approach). In addition to the impact on the energy markets, many final product markets where RICE are used as part of the production process will also be affected. The EIA employs standard concepts in microeconomics to model the regulation's impacts on production costs, supply, equilibrium price and quantity, and economic welfare. This appendix presents the structural equations used in the computer model to estimate these impacts and discusses the method used for welfare calculations.

A.1 Energy Markets Model

The operational model includes four energy markets: coal, electricity, natural gas, and petroleum. The following sections describe supply and demand equations the Agency developed to characterize these markets. The data source for the price and quantity data used to calibrate these functions is the Department of Energy's Supplemental Tables to the Annual Energy Outlook 2000 (DOE, EIA, 2000).

A.1.1 Supply Side Modeling

The Agency modeled the market supply of energy markets (Q_{Si}) using a single representative supplier with an upward-sloping supply curve. The generalized Leontief function specification is

$$Q_{Si} = \gamma_i + \frac{\beta_i}{2}\left[\frac{1}{p_i}\right]^{\frac{1}{2}} , \tag{A.1}$$

where p is the market price, γ and β are model parameters, and i indexes the energy market (i.e., electricity, natural gas, petroleum products, and coal). The theoretical restrictions on the model parameters that ensure upward-sloping supply curves are $\gamma_j > 0$ and $\beta < 0$. Note the curvature of the supply function is determined by the β parameter, which is computed using the following equation:

$$\beta_i = \xi_i 4 Q_{Si}\left[\frac{1}{p_i}\right]^{-\frac{1}{2}} , \tag{A.2}$$

where ξ is an assumed market supply elasticity obtained from the literature (actual values are presented in Section 4.3).

Regulatory-Induced "Shock": The annual control costs estimated by the engineering analysis were divided by the production level (Q_{Si}) to develop a per-unit "cost-shifter," c_i. This shifter is incorporated into the supply equation as a net price change (i.e., $p_i - c_i$):

$$Q_{Si} = \gamma_i + \frac{\beta_i}{2}\left[\frac{1}{p_i - c_i}\right]^{\frac{1}{2}} . \tag{A.3}$$

A.1.2 Demand Side Modeling

Market demand in the energy markets (Q_{Di}) is expressed as the sum of the commercial, residential, transportation, and industrial sectors:

$$Q_{Di} = \sum_{j=1}^{n} q_{Dij} , \tag{A.4}$$

where i indexes the energy market and j indexes the consuming sector. The Agency modeled the commercial, residential, and transportation sectors as single representative demanders using a simple Cobb Douglas specification:

$$q_{Dij} = A_{ij} p_i^{\eta_{ij}} , \tag{A.5}$$

where p is the market price, η is an assumed demand elasticity (actual values are presented in Section 4.3), and A is a demand parameter. In contrast, the industrial sector demand is modeled as a derived demand resulting from the production/consumption choices in 24 agricultural and manufacturing industries. Changes in energy demand for these industries respond to changes in industry output and fuel switching that occurs in response to changes in relative energy prices projected in the energy markets. For each industry group, industrial energy demand is expressed as follows:

$$q_{Dijx} = \left[(1 + \%\Delta Q_{Dx}) \cdot (q_{Dijx})\right] \cdot \left[\frac{\alpha_{ijxwithreg}}{\alpha_{ijxbaseline}}\right] , \tag{A.6}$$

where q_D is demand for energy, Q_D is output in the final product market, α is the fuel share of industry value of shipments, i indexes the energy market, j indexes the industrial sector, and x indexes the final product market.

A.2 Estimating Economic Impacts for Final Product Markets

Given data limitations associated with the scope of potentially affected final product markets, EPA used an alternative approach to estimate economic impacts of the rule for these markets.

A.2.1 Changes in Price and Quantities

The Agency used the following approach to estimate the percentage change in price and quantities in each final product market.

Compute Percentage Change in Market Price (Direct Effect). First, compute the share of annual compliance costs of value of shipments for each industry segment:

$$\%\Delta p_{jdirect} = \left[\frac{C_j}{VOS_j}\right]. \tag{A.7}$$

Compute Percentage Change in Market Price (Indirect Effect). Next, compute the change in production costs resulting from changes in the market price of fuels (determined by the model described above):

$$\%\Delta p_{jindirect} = \sum_{i=1}^{n} \alpha_i \Delta p_i , \tag{A.8}$$

where α is the fuel share of value of shipments, i indexes the fuel market, and j indexes the final product market. The fuel share is allowed to vary using a fuel switching rule using cross-price elasticities of demand between energy sources, as described in Section 4.

Compute Percentage Change in Market Price (Total). The direct and indirect effects were then summed to compute an estimated price change for the market.

Compute Percentage Change in Market Quantity. Using the percentage change in the final product price calculated above and assumptions regarding the demand elasticity for the final product, the relative change in quantity was computed. For example, in a market where the demand elasticity is assumed to be -1 (i.e., unitary), a 1 percent increase in price results in a 1 percent decrease in quantity. This quantity was then fed back into the energy markets and this process was continued until equilibrium was reached.

A.3 Economic Welfare Impacts

The economic welfare implications of the market price and output changes associated with the regulation can be examined using two different strategies, each giving a somewhat different insight but the same implications: changes in the net benefits of consumers and producers based on the price changes and changes in the total benefits and costs of these products based on the quantity changes. This analysis focuses on the first measure—the changes in the net benefits of consumers and producers affected by the RICE MACT based on price changes. This is relatively straightforward in the energy markets. However, because the final product markets are defined at the two-digit SIC code level, there is no easily defined price or quantity due to the wide variety of products that fall under each SIC code. However, the model is able to predict percentage changes in the price and quantity of an average product for each final product market. Therefore, methods of calculating consumer and producer surplus are defined that are based on these percentage changes in price and quantity and total industry sales rather than on the price and quantity directly. In the energy markets, consumer and producer surplus were calculated using standard methods based on the price and quantity before and after regulation because price and quantity are well defined in these markets.

A.3.1 Change in Economic Welfare: Consumer Surplus

In the model of the final product markets, neither the demand nor supply curve is linear. However, because a parallel shift in the curves was assumed, the area between the curves is the same as for a parallel shift in linear curves. In the typical case where prices and quantities for a particular industry are well defined and regulation is assumed to cause a parallel shift in the supply curve, the change in consumer surplus can be calculated by applying the following formula:

$$\Delta CS = -[(\Delta P)\ Q_1 - 0.5(\Delta Q)\ (\Delta P)], \qquad (A.9)$$

where Q_1 denotes the initial quantity. However, because of the high level of aggregation in our final product markets, there is not a single price and quantity that can be defined for an entire two-digit SIC code. Therefore, changes in consumer surplus were calculated using percentage changes in average price and quantity and total revenue by SIC code. This formula was derived in the following manner from Eq. (A.9):

$$\Delta CS = -[(\Delta P)\ Q_1 - 0.5\ (\Delta Q)\ (\Delta P)]\ (P_1\ Q_1)/(P_1\ Q_1)$$

$$\Delta CS = -[\%\Delta P - 0.5\ (\%\Delta P)\ (\%\Delta Q)]\ (P_1\ Q_1). \qquad (A.10)$$

A.3.2 Change in Economic Welfare: Producer Surplus

The change in producer surplus in the case of a parallel shift in the supply curve can be calculated by applying the following formula:

$$\Delta PS = -[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\ [(CC/Q_1 - \Delta P)\ (\Delta Q)]\ , \qquad (A.11)$$

where CC/Q_1 equals the per-unit "cost-shifter" of the regulation. However, as for the consumer surplus calculation above, there is not a single price and quantity that can be defined. Thus, we are interested in a measure that relies only on percentage changes in price and quantity, total revenue, and compliance costs. To convert this measure into one requiring only percentage changes and total revenue, the following steps are necessary:

$$\Delta PS = -[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\,[((CC/Q_1) - \Delta P)(\Delta Q)](P_1\,Q_1)/(P_1\,Q_1)$$

$$\Delta PS = -[(\%\text{ cost shift} - \%\Delta P)(1 - \%\Delta Q) + 0.5\,(\%\text{ cost shift} - \%\Delta P)(\%\Delta Q)][P_1\,Q_1]$$

$$\Delta PS = -[\%\text{ cost shift} - \%\Delta P][1 - 0.5(\%\Delta Q)][TR], \qquad (A.12)$$

where TR refers to total revenue. This modified formula no longer requires price and quantity directly[1] and can be applied to the final product markets where this information is not available.

[1]Only the product of price and quantity is required for this formula. Multiplying price and quantity in an industry yields total industry revenue. The value used for total industry revenue is derived from industry-level value of shipments data so that price and quantity do not have to be individually defined.

APPENDIX A

ECONOMIC MODEL OF MARKETS AFFECTED BY THE RICE MACT

Implementation of the proposed MACT standards will affect the costs of production in U.S. energy markets, thus changing the amount of energy that producers are willing to supply and leading to a change in price. Because energy is used as an input in the production of most goods and services, changes in the price of energy will affect almost all of the markets in the U.S. to some extent. Specifically, the cost of the regulation may cause individual facilities to decrease their current level of production or even to close. These choices affect, and in turn are affected by, the market price for each product. As the individual facilities in a market decrease their current level of production, the market supply will decrease as well.

The Agency developed an economic model of markets affected by the proposed rule to estimate its economic impact (see Section 4 for details on the conceptual approach). In addition to the impact on the energy markets, many final product markets where RICE are used as part of the production process will also be affected. The EIA employs standard concepts in microeconomics to model the regulation's impacts on production costs, supply, equilibrium price and quantity, and economic welfare. This appendix presents the structural equations used in the computer model to estimate these impacts and discusses the method used for welfare calculations.

A.1 Energy Markets Model

The operational model includes four energy markets: coal, electricity, natural gas, and petroleum. The following sections describe supply and demand equations the Agency developed to characterize these markets. The data source for the price and quantity data used to calibrate these functions is the Department of Energy's Supplemental Tables to the Annual Energy Outlook 2000 (DOE, EIA, 2000).

A.1.1 Supply Side Modeling

The Agency modeled the market supply of energy markets (Q_{Si}) using a single representative supplier with an upward-sloping supply curve. The generalized Leontief function specification is

$$Q_{Si} = \gamma_i + \frac{\beta_i}{2}\left[\frac{1}{p_i}\right]^{\frac{1}{2}} , \tag{A.1}$$

where p is the market price, γ and β are model parameters, and i indexes the energy market (i.e., electricity, natural gas, petroleum products, and coal). The theoretical restrictions on the model parameters that ensure upward-sloping supply curves are $\gamma_j > 0$ and $\beta < 0$. Note the curvature of the supply function is determined by the β parameter, which is computed using the following equation:

$$\beta_i = \xi_i 4 Q_{Si}\left[\frac{1}{p_i}\right]^{-\frac{1}{2}} , \tag{A.2}$$

where ξ is an assumed market supply elasticity obtained from the literature (actual values are presented in Section 4.3).

Regulatory-Induced "Shock": The annual control costs estimated by the engineering analysis were divided by the production level (Q_{Si}) to develop a per-unit "cost-shifter," c_i. This shifter is incorporated into the supply equation as a net price change (i.e., $p_i - c_i$):

$$Q_{Si} = \gamma_i + \frac{\beta_i}{2}\left[\frac{1}{p_i - c_i}\right]^{\frac{1}{2}} . \tag{A.3}$$

A.1.2 Demand Side Modeling

Market demand in the energy markets (Q_{Di}) is expressed as the sum of the commercial, residential, transportation, and industrial sectors:

$$Q_{Di} = \sum_{j=1}^{n} q_{Dij} , \tag{A.4}$$

where i indexes the energy market and j indexes the consuming sector. The Agency modeled the commercial, residential, and transportation sectors as single representative demanders using a simple Cobb Douglas specification:

$$q_{Dij} = A_{ij} p_i^{\eta_{ij}} , \qquad (A.5)$$

where p is the market price, η is an assumed demand elasticity (actual values are presented in Section 4.3), and A is a demand parameter. In contrast, the industrial sector demand is modeled as a derived demand resulting from the production/consumption choices in 24 agricultural and manufacturing industries. Changes in energy demand for these industries respond to changes in industry output and fuel switching that occurs in response to changes in relative energy prices projected in the energy markets. For each industry group, industrial energy demand is expressed as follows:

$$q_{Dijx} = \left[(1 + \%\Delta Q_{Dx}) \cdot (q_{Dijx})\right] \cdot \left[\frac{\alpha_{ijxwithreg}}{\alpha_{ijxbaseline}}\right] , \qquad (A.6)$$

where q_D is demand for energy, Q_D is output in the final product market, α is the fuel share of industry value of shipments, i indexes the energy market, j indexes the industrial sector, and x indexes the final product market.

A.2 Estimating Economic Impacts for Final Product Markets

Given data limitations associated with the scope of potentially affected final product markets, EPA used an alternative approach to estimate economic impacts of the rule for these markets.

A.2.1 Changes in Price and Quantities

The Agency used the following approach to estimate the percentage change in price and quantities in each final product market.

Compute Percentage Change in Market Price (Direct Effect). First, compute the share of annual compliance costs of value of shipments for each industry segment:

$$\%\Delta p_{jdirect} = \left[\frac{C_j}{VOS_j}\right] . \qquad (A.7)$$

Compute Percentage Change in Market Price (Indirect Effect). Next, compute the change in production costs resulting from changes in the market price of fuels (determined by the model described above):

$$\%\Delta p_{jindirect} = \sum_{i=1}^{n} \alpha_i \Delta p_i , \qquad (A.8)$$

where α is the fuel share of value of shipments, i indexes the fuel market, and j indexes the final product market. The fuel share is allowed to vary using a fuel switching rule using cross-price elasticities of demand between energy sources, as described in Section 4.

Compute Percentage Change in Market Price (Total). The direct and indirect effects were then summed to compute an estimated price change for the market.

Compute Percentage Change in Market Quantity. Using the percentage change in the final product price calculated above and assumptions regarding the demand elasticity for the final product, the relative change in quantity was computed. For example, in a market where the demand elasticity is assumed to be -1 (i.e., unitary), a 1 percent increase in price results in a 1 percent decrease in quantity. This quantity was then fed back into the energy markets and this process was continued until equilibrium was reached.

A.3 Economic Welfare Impacts

The economic welfare implications of the market price and output changes associated with the regulation can be examined using two different strategies, each giving a somewhat different insight but the same implications: changes in the net benefits of consumers and producers based on the price changes and changes in the total benefits and costs of these products based on the quantity changes. This analysis focuses on the first measure—the changes in the net benefits of consumers and producers affected by the RICE MACT based on price changes. This is relatively straightforward in the energy markets. However, because the final product markets are defined at the two-digit SIC code level, there is no easily defined price or quantity due to the wide variety of products that fall under each SIC code. However, the model is able to predict percentage changes in the price and quantity of an average product for each final product market. Therefore, methods of calculating consumer and producer surplus are defined that are based on these percentage changes in price and quantity and total industry sales rather than on the price and quantity directly. In the energy markets, consumer and producer surplus were calculated using standard methods based on the price and quantity before and after regulation because price and quantity are well defined in these markets.

A.3.1 Change in Economic Welfare: Consumer Surplus

In the model of the final product markets, neither the demand nor supply curve is linear. However, because a parallel shift in the curves was assumed, the area between the curves is the same as for a parallel shift in linear curves. In the typical case where prices and quantities for a particular industry are well defined and regulation is assumed to cause a parallel shift in the supply curve, the change in consumer surplus can be calculated by applying the following formula:

$$\Delta CS = -[(\Delta P)\, Q_1 - 0.5(\Delta Q)\, (\Delta P)], \tag{A.9}$$

where Q_1 denotes the initial quantity. However, because of the high level of aggregation in our final product markets, there is not a single price and quantity that can be defined for an entire two-digit SIC code. Therefore, changes in consumer surplus were calculated using percentage changes in average price and quantity and total revenue by SIC code. This formula was derived in the following manner from Eq. (A.9):

$$\Delta CS = -[(\Delta P)\, Q_1 - 0.5\, (\Delta Q)\, (\Delta P)]\, (P_1\, Q_1)/(P_1\, Q_1)$$

$$\Delta CS = -[\%\Delta P - 0.5\ (\%\Delta P)\, (\%\Delta Q)]\, (P_1\, Q_1). \tag{A.10}$$

A.3.2 Change in Economic Welfare: Producer Surplus

The change in producer surplus in the case of a parallel shift in the supply curve can be calculated by applying the following formula:

$$\Delta PS = -[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\, [(CC/Q_1 - \Delta P)\, (\Delta Q)]\,, \tag{A.11}$$

where CC/Q_1 equals the per-unit "cost-shifter" of the regulation. However, as for the consumer surplus calculation above, there is not a single price and quantity that can be defined. Thus, we are interested in a measure that relies only on percentage changes in price and quantity, total revenue, and compliance costs. To convert this measure into one requiring only percentage changes and total revenue, the following steps are necessary:

$$\Delta PS = -[((CC/Q_1) - \Delta P)(Q_1 - \Delta Q)] + 0.5\,[((CC/Q_1) - \Delta P)(\Delta Q)](P_1\,Q_1)/(P_1\,Q_1)$$

$$\Delta PS = -[(\%\text{ cost shift} - \%\Delta P)(1 - \%\Delta Q) + 0.5\,(\%\text{ cost shift} - \%\Delta P)(\%\Delta Q)][P_1\,Q_1]$$

$$\Delta PS = -[\%\text{ cost shift} - \%\Delta P][1 - 0.5(\%\Delta Q)][TR], \tag{A.12}$$

where TR refers to total revenue. This modified formula no longer requires price and quantity directly[1] and can be applied to the final product markets where this information is not available.

[1]Only the product of price and quantity is required for this formula. Multiplying price and quantity in an industry yields total industry revenue. The value used for total industry revenue is derived from industry-level value of shipments data so that price and quantity do not have to be individually defined.

APPENDIX B

ECONOMIC MODEL SENSITIVITY ANALYSIS

Estimates of the economic impacts of the MACT standard are sensitive to the parameters used in the model. Therefore, a sensitivity analysis was conducted to determine the effects on the model results of changing several of the key parameters. Sensitivity analyses were developed for the elasticity of supply in the electricity markets, the demand and supply elasticities in the manufacturing final product markets, the own- and cross-price elasticities used to model fuel switching, and the distribution of affected engines in SIC 13 between the natural gas and petroleum industries. In general, estimates of the change in social welfare are robust. The distribution of welfare losses across producers and consumers responds moderately to changes in the selected parameters.

B.1 Elasticity of Supply for Electricity

The price elasticity of supply in the electricity markets represents the behavioral responses from existing sources to changes in the price of electricity. However, there is no consensus on estimates of the price elasticity of supply for electricity, as discussed in Section 4 of the report. Because of deregulation, the market price for electricity has become the determining factor in decisions to retire older units or to make higher cost units available to the market, so the price elasticity of supply is becoming more important to utilities' decisionmaking. To examine how the assumed value of the elasticity of supply for electricity affects the model's outcomes, welfare impacts were estimated for supply elasticities both higher and lower than the assumed value of 0.75. Table B-1 shows the economic impact estimates as the elasticity of supply in the electricity markets is varied between 0.5 and 1.0. As the table indicates, there is no discernable change in the values reported as the elasticity of supply changes from 0.5 to 1.0.

B.2 Final Product Market Elasticities

The final product markets were modeled at the two-digit SIC code level to operationalize the economic model. Because of the high level of aggregation, elasticities of supply and demand estimates are not available in the literature. Therefore, the elasticity of

Table B-1. Sensitivity Analysis: Elasticity of Supply in the Electricity Markets ($\$10^6$)

	ES = 0.5	ES = 0.75	ES = 1.0
Change in producer surplus	-473.0	-473.0	-473.0
Change in consumer surplus	-641.3	-641.3	-641.3
Change in social welfare	-1,114.2	-1,114.2	-1,114.2

supply was assumed to equal 1.0 and the elasticity of demand was assumed to equal -1.0. The elasticities of supply and demand in the final product markets primarily determine the distribution of economic impacts between producers and consumers. To examine the change in distribution of welfare impacts as the elasticities are changed, two alternative assumptions about the elasticities in the final product markets were used. In the first alternative, supply is assumed to be 25 percent more inelastic than in the model, while the demand elasticity estimate remains the same. In the second alternative, the supply elasticity is the same as used in the model, but demand is assumed to be 25 percent more inelastic. Table B-2 shows how the economic impact estimates vary as the supply and demand elasticities in the final product markets vary. As expected, when supply becomes more inelastic (the case where $E_s = 0.75$), producers bear a larger share of the costs relative to the model results and when demand becomes more inelastic (the case where $E_d = -0.75$), it is the consumers who bear a larger share of the cost burden.

Table B-2. Sensitivity Analysis: Supply and Demand Elasticities in the Final Product Markets ($\$10^6$)

	$E_S = 0.75$ $E_D = -1.0$	$E_S = 1.0$ $E_D = -1.0$	$E_S = 1.0$ $E_D = -0.75$
Change in producer surplus	-501.4	-473.0	-436.8
Change in consumer surplus	-612.9	-641.3	-677.4
Change in social welfare	-1,114.2	-1,114.2	-1,114.2

B.3 Own and Cross-Price Elasticities for Fuels

Own- and cross-price elasticities of demand from NEMS were used to capture fuel switching in the manufacturing sectors in the economic model. However, the NEMS projection reflects aggregate behavioral responses in the year 2015. Because this is a longer window of analysis compared to the baseline year 2005, this analysis may overestimate firms' ability to switch fuels in the short run. Table B-3 shows how the economic impact estimates vary as the own- and cross-price elasticities used in the EIA are reduced by 75 percent and 50 percent. Changing the elasticities used to model fuel switching has only a very small effect on the estimates of welfare changes.

Table B-3. Sensitivity Analysis: Own- and Cross-Price Elasticities Used to Model Fuel Switching ($\$10^6$)

	Fuel Price Elasticities Presented in Table 4-2	Reduced by 75 Percent	Reduced by 50 Percent
Change in producer surplus	-473.0	-471.5	-476.7
Change in consumer surplus	-641.3	-642.8	-637.6
Change in social welfare	-1,114.2	-1,114.4	-1,114.3

B.4 Share of SIC 13 Associated with Natural Gas and Petroleum Products

Direct costs associated with the regulation are linked to the energy markets in which engines are operating. Because no information was available on each unit's application, SIC codes were used to link engines to specific energy markets. However, for SIC 13 it was not possible to distinguish between engines involved in the extraction and production of natural gas and engines involved in the extraction and processing of petroleum products. In addition, because petroleum and natural gas are frequently joint products, some engines may be involved in both markets.

Based on information from industry, it was determined that the majority of the engines classified under SIC 13 were involved in natural gas extraction and transportation. The economic impact estimates presented in Section 4 use an 80/20 percent distribution of control costs between the natural gas and petroleum markets. Table B-4 shows how the economic impact estimates vary as the 80/20 percent distribution of control costs between the natural gas and petroleum markets varies. Once again, there is only a slight difference in the distribution of costs between producers and consumers under this sensitivity analysis.

Table B-4. Sensitivity Analysis: Distribution of Affected Units in SIC 13 Between the Natural Gas and Petroleum Industries ($$10^6$)

	Natural Gas = 70% Petroleum = 30%	Natural Gas = 80% Petroleum = 20%	Natural Gas = 90% Petroleum = 10%
Change in producer surplus	-469.4	-473.0	-476.5
Change in consumer surplus	-644.8	-641.3	-637.7
Change in social welfare	-1,114.3	-1,114.2	-1,114.2