Economic Analysis of Air Pollution Regulations: Boilers and Process Heaters

Final Report

Prepared for

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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) or the Act for industrial, commercial, and institutional (ICI) boilers and process heaters. These combustion devices are used in the production processes of numerous industries in the U.S. The proposed hazardous air pollutants (HAPs) are generated by the combustion of fossil fuels and biomass in boilers and process heaters. The primary HAPs emitted by ICI boilers and process heaters include arsenic, beryllium, cadmium, lead, hydrochloric acid, mercury, and other HAPs. In addition, ICI boilers and process heaters also emit non-HAP pollutants such as sulfur dioxide and particulate matter. To inform this rulemaking, the Innovative Strategies and Economics Group (ISEG) of EPA's Office of Air Quality Planning and Standards (OAQPS) has developed an economic impact analysis (EIA) to estimate the potential social costs of the regulation. This report presents the results of this analysis in which a market model was 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

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

Agency's *OAQPS Economic Analysis Resource Document* provides detailed instructions and expectations for economic analyses that support rulemaking (EPA, 1999).

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 ICI boilers and process heaters 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.

The proposed MACT floor will affect approximately 5,600 existing and new units. EPA developed annual compliance costs for model units in each of 83 different model unit types. EPA then linked the annualized compliance costs from the model units to the estimated existing population of boilers and process heaters to obtain national impact estimates. In addition, the Agency projected entrance of new boilers and process heaters through the year 2005, and linked the annualized compliance costs to these projected new units.

The economic impacts of national compliance costs, including both existing and new units, on affected markets was then estimated using a computerized market model. EPA used changes in prices and quantities in energy markets and final product markets to estimate the firm-, industry-, market-, and societal-level impacts associated with the regulation.

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[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.

1.3 Organization of the Report

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

- Section 2 provides background information on ICI boiler and process heater technologies.
- Section 3 profiles existing ICI boilers and process heaters by capacity, fuel type, and industry and presents projections of the future population of units in 2005. National compliance cost estimates are also presented in this section.
- Section 4 profiles the industries with the largest number of affected facilities. Included are profiles of the lumber and wood products (SIC 24), paper and allied products (SIC 26), and electrical services (SIC 149) industries.
- Section 5 describes the methodology for assessing the economic impacts of the proposed National Emission Standard for Hazardous Air Pollutants (NESHAP).
- Section 6 presents the results of the economic analysis, including market, industry, and social cost impacts.
- Section 7 provides the Agency’s analysis of the regulation’s impact on small entities.

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

BOILER AND PROCESS HEATER TECHNOLOGIES

The three categories of combustion devices affected under the proposed regulations are industrial, commercial, and institutional (ICI) boilers and process heaters. Although their primary function is to transfer heat generated from fuel combustion to materials used in the production process, the applications for boilers and process heaters are somewhat different. As a result, the primary industries using boilers may not be the same as those using process heaters. It is important to note that throughout this report the terms "boilers and process heaters," and "units" are synonymous with "ICI boilers and process heaters." Utility boilers primarily engaged in generating electricity are not covered by the NESHAP under analysis and are therefore excluded from this analysis.

Boilers are combustion devices used to produce steam or heat water. Steam is produced in boilers by heating water until it vaporizes. The steam is then channeled to applications within a facility or group of facilities via pipes. Steam is an important power and heating source for the U.S. economy. It is used in the preparation or manufacturing of many key products, such as paper, petroleum products, furniture, and chemicals. Steam is also used to heat buildings and to generate the majority of the electricity consumed in this country. There are literally thousands of boilers currently being used in the United States throughout a wide variety of industries.

Process heaters are primarily used as heat transfer units in which heat from fuel combustion is transferred to process fluids, although they may also be used to transfer heat to other nonfluid materials or to heat transfer materials for use in a process unit (not including generation of steam). Process heaters are generally used in heat transfer applications where boilers are inadequate. Often these are uses in which heat must be transferred at temperatures in excess of 90° to 204°C (200° to 400°F). Process heaters are used in the petroleum refining and petrochemical industries, with minor applications in the asphalt concrete, gypsum, iron and steel, and wood and forest products industries.

Since one of the main uses of boilers is to generate steam, some of the characteristics of steam are discussed in this section. This section also provides an overview of the various types of boiler and process heater characteristics and designs.

2.1 Characteristics of Steam

Steam, an odorless, invisible gas of vaporized water, may be interspersed with water droplets, which gives it a cloudy appearance. It is produced naturally when underground water is heated by volcanic processes and mechanically using boilers and other heating processes. When water is heated at atmospheric pressure, it remains in liquid form until its temperature exceeds 212°F, the boiling point of water. Additional heat does not raise the water's temperature but rather vaporizes the water, converting it into steam. However, if water is heated under pressure, such as in a boiler, the boiling point is higher than 212°F and more heat is required to generate steam. Once all the water has been vaporized into steam, the addition of heat causes the temperature and volume to increase. Steam's heating and work capabilities increase as it is produced under greater pressure coupled with higher temperatures. As steam escapes from the boiler, it can be directed through pipes to drive mechanical processes or to provide heat.

The steam used in most utility, industrial, and commercial applications is referred to as "clean steam." Clean steam encompasses steam purities ranging from pure, solid-free steam used in critical processes to filtered steam for less demanding applications. The various types of clean steam differ in steam purity and steam quality. Steam purity is a quantitative measure of contamination of steam caused by dissolved particles in the vapor or by tiny droplets of water that may remain in the steam. Steam quality is a measure of how much liquid water is mixed in with the dry steam (Fleming, 1992). Firms select the levels of steam quality and steam purity for their applications based on the sensitivity of their equipment to impurities, water droplet size, and condensation as well as the requirements for their production process. Using clean steam minimizes the risk of product contamination and prolongs equipment life. Although there are infinite possible levels of water purity and quality, the term "clean steam" generally refers to three basic types of steam:

- filtered steam—produced by filtering plant steam using high-efficiency filters. Filtered steam is generally of high steam quality because most large water droplets and other contaminants will be filtered out.

- clean steam—steam that is frequently produced from deionized and distilled water. Deionized and distilled water is free of dissolved solids and ions, which may corrode pipework.

- pure steam—similar to clean steam except that it is always produced from deionized and distilled water.

Steam applications can be categorized by the amount of pressure required: hot water, low pressure, and high pressure. Low pressure is 0 to 15 pounds per square inch (psi) and high pressure steam is above 15 psi (*Plant Engineering*, 1991). Hot water systems, which generate little steam, are primarily used for comfort applications, such as hot water for a building. Low pressure applications include process heat and space heating. High pressure steam applications are more frequently used in industrial and utility applications. Some high pressure applications require that the steam be superheated, a process which ensures that the steam is free of water droplets, to avoid damaging sensitive equipment.

Electric cogenerators, such as large factories and processing facilities, use steam to drive turbines to generate electricity. A conventional steam electric power plant burns fossil fuels (coal, gas, or oil) in a boiler, releasing heat that boils water and converts it into high-pressure steam (see Figure 2-1). The steam enters a turbine where it expands and pushes against blades to turn the generator shaft and create electric current. In this way, the thermal energy of steam becomes mechanical energy, which is converted into electricity. Steam used to drive turbines generates most of the electric power in the United States (TXU, 2000).

Industrial operations use steam to perform work such as powering complex machinery operations, in the same way that electric utilities use steam to rotate turbines. Textile mills, pulp and paper mills, and other manufacturing outfits are examples of facilities that use steam to run machinery. Steam also provides heat and pressure for manufacturing processes. Industrial establishments use steam to provide heat for drying or to heat and separate materials. For example, the paper industry uses steam to heat rollers that dry paper during the final stages of the production process. Petroleum refineries and chemical producers use steam to heat petroleum, raw materials, and other inputs to separate inputs into their constituent components or to facilitate chemical interactions. In addition to these applications, steam is employed in many other industrial processes, including textile production, wood working, furniture making, metal working, food preparation, and the manufacture of chemicals. Substitutes for using steam as process heat include

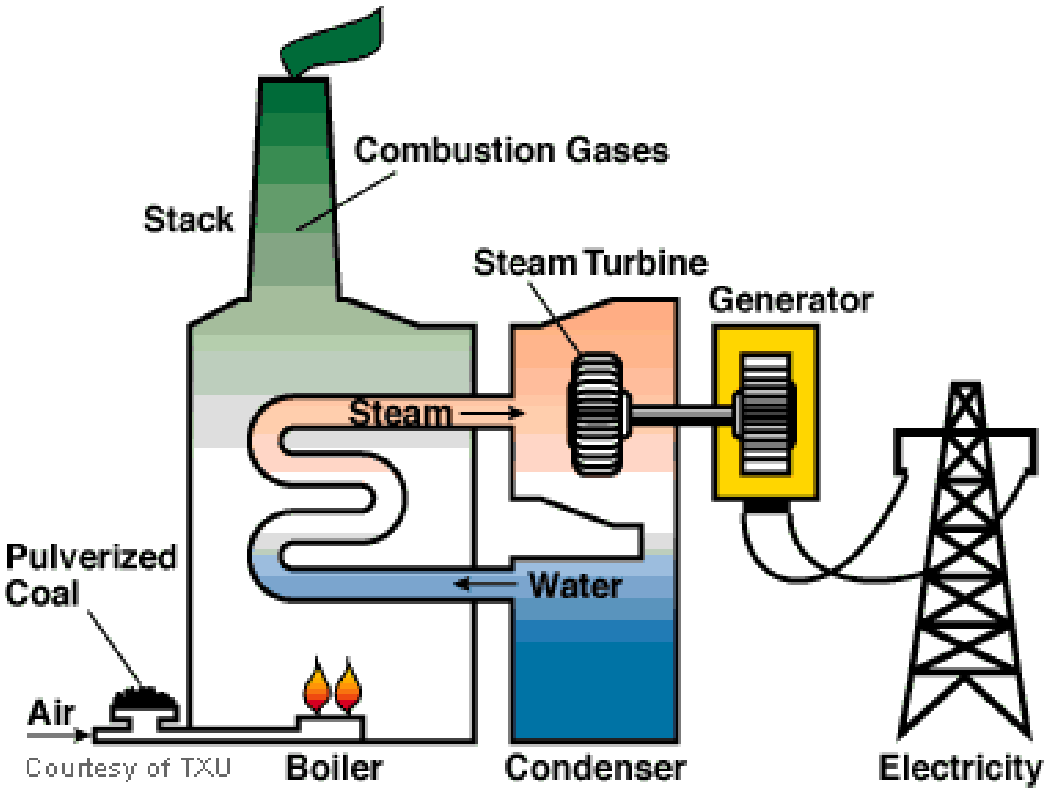


Figure 2-1. Generating Electricity: Steam Turbines

Source: Texas Utilities (TXU). 2000. "Generating Electricity: Steam Turbines." As obtained in September 2000. <http://www.txu.com/knowledge/energy_lib/generating01.html>.

electrical heating equipment, infrared, and other radiant drying techniques. Electricity may be used to power machinery, as well. However, switching from steam-powered to electricity-powered machinery would require significant equipment retrofits or replacement.

Other steam applications include heating, sanitation, food processing and preparation, and cleaning. In addition to using boilers to heat water, factories, hospitals, government buildings, schools and other large buildings use boiler-generated steam to provide space heating. Substitutes for boilers in heating air and water include electrical water and space heaters; furnaces; and other heating, ventilation, and air conditioning equipment.

2.2 Fossil-Fuel Boiler Characterization

Section 2.2 discusses the different classes of fossil-fuel boilers, the most common heat transfer configurations, and the major design types. The discussion indicates the type(s) of fuel that each design can use to operate.

2.2.1 Industrial, Commercial, and Institutional Boilers

Industrial, commercial, and institutional boilers are primarily used for process heating, electrical or mechanical power generation, and/or space heating. Industrial boilers are used in all major industrial sectors but primarily by the paper products, chemical, food, and petroleum industries. It is estimated that the heat input capacity for these boilers is typically between 10 and 250 MMBtu/hr; however, larger industrial boilers do exist and are similar to utility boilers (EPA, 1997b). Commercial/institutional boilers are generally smaller than the industrial units, with heat input capacities generally below 10 MMBtu/hr. These units normally supply the steam and hot water for space heating in a wide range of locations, including wholesale and retail trade, office buildings, hotels, restaurants, hospitals, schools, museums, government buildings, and airports. Five hundred ninety-three of the 3,615 units potentially affected by the floor alternative for the proposed regulation are commercial/institutional units.

A boiler system includes the boiler itself, associated piping and valves, operation and safety controls, water treatment system, and peripheral equipment such as pollution control devices, economizers, or superheaters (*Plant Engineering*, 1991). Most boilers are made of steel, cast iron, or copper. The primary fuels used by boilers are coal, oil, and natural gas, but some use electricity, waste gases, or biomass.

Boilers may either be erected onsite (field-erected boilers) or assembled at a factory (packaged boilers). Packaged boilers are typically lower in initial cost and more simple to install. However, field-erected boilers may have lower operating costs, less maintenance, and greater flexibility because the furnace or convection pattern chosen to meet required steam pressure, capacity, and fuel specifications is tailored to the boiler’s potential use (*Plant Engineering*, 1991). Applications requiring more than 100,000 pounds of steam per hour are usually equipped with a field-erected boiler.

2.2.2 Heat Transfer Configurations

The heat transfer configuration of a boiler refers to the method by which heat is transferred to the water. The four primary boiler configurations are watertube, firetube, cast iron, and tubeless. Most industrial users tend to rely on either watertube or firetube configurations.

In a watertube boiler, combustion heat is transferred to water flowing through tubes lining the furnace walls and boiler passes. The furnace watertubes absorb primarily radiative heat, while the watertubes in the boiler passes gain heat by convective heat transfer. These units have a wide range of heat input capacities (ICI units range from 0.4 to 1,500 MMBtu/hr) and can be either field erected or packaged.[1] Watertube boilers with heat input capacities greater than 200 MMBtu/hr are typically field erected.

Because firetube, cast iron, and tubeless heat transfer configurations typically have heat input capacities below 10 MMBtu/hr, they will not generally be covered by the proposed NESHAP. Therefore, this profile focuses on those boiler types that use watertube heat transfer configurations.

2.2.3 Major Design Types

This section summarizes the five major design types for fossil fuel industrial boilers that will be covered by the proposed NESHAP. It also discusses, where possible, the fuels used, capacity, and assembly method of each of these types of boilers.

2.2.3.1 Stoker-Fired Boilers (Coal)

These units use underfeed air to combust the coal char on a stationary grate, combined with one or more levels of overfire air introduced above the grate. There are three types of stoker units:

- spreader stokers,
- underfeed stokers, and
- overfeed stokers.

Stokers generally burn all types of coal, with the exception of overfeed stokers, which do not burn coking bituminous coals. Stokers can also burn other types of solid fuel, such as wood, wood waste, and bagasse. Spreader stokers are the most common of these boiler types and have heat input capacities that typically range from 5 to 550 MMBtu/hr. However, some of these boilers have capacities as high as 1,500 MMBtu/hr. Smaller stoker units (i.e., those with heat input capacities less than 100 MMBtu/hr) are generally packaged, while larger units are usually field erected.

2.2.3.2 Pulverized Coal Boilers (Coal)

Combustion in pulverized coal-fired units takes place almost entirely while the coal is suspended, unlike in stoker units in which the coal burns on a grate. Finely ground coal is typically mixed with primary combustion air and fed to the burner or burners, where it is ignited and mixed with secondary combustion air. Depending on the location of the burners and the direction of coal injection into the furnace, pulverized coal-fired boilers can be classified into three different firing types:

- single and opposed wall,
- tangential, and
- cyclone.

Of these types, wall and tangential configurations are the most common. These firing methods are described further in Sections 2.2.3.4 and 2.2.3.5.

2.2.3.3 Fluidized Bed Combustion (FBC) Boilers (Coal)

FBC is an integrated technology for reducing sulfur dioxide (SO_2) and NO_x emissions during the combustion of coal. In a typical FBC boiler, crushed coal and inert material (sand, silica, alumina, or ash) and/or a sorbent (limestone) are maintained in a highly turbulent suspended state by the upward flow of primary air from the windbox located directly below the combustion floor. This fluidized state provides a large amount of surface contact between the air and solid particles, which promotes uniform and efficient combustion at lower furnace temperatures than conventional coal-fired boilers. Once the hot gases leave the combustion chamber, they pass through the convective sections of the boiler, which are similar or identical to components used in conventional boilers.

For the FBCs currently in use in all sectors, coal is the primary fuel source, followed in descending order by biomass, coal waste, and municipal waste. The heat input capacities of all ICI FBC units generally range from 1.4 to 1,075 MMBtu/hr.

2.2.3.4 Tangentially Fired Boilers (Coal, Oil, Natural Gas)

The tangentially fired boiler is based on the concept of a single flame zone within the furnace. The fuel-air mixture projects from the four corners of the furnace along a line tangential to an imaginary cylinder located along the furnace centerline. As fuel and air are fed to the burners and the fuel is combusted, a rotating "fireball" is formed. Primarily because of their tangential firing pattern, which leads to larger flame volumes and flame interaction, uncontrolled tangentially fired boilers generally emit relatively lower NO_x than other uncontrolled boiler designs.

Utilities primarily use this type of boiler. Coal is the most common fuel used by these units. Tangentially fired boilers operated by utilities are typically larger than 400 MW, while industrial ones almost always have heat input capacities over 100 MMBtu/hr. In general, most units with heat input capacities over 100 MMBtu/hr are field erected.

2.2.3.5 Wall-fired Boilers (Coal, Oil, Natural Gas)

Wall-fired boilers are characterized by multiple individual burners located on a single wall or on opposing walls of the furnace. In contrast to tangentially fired boilers, each of the burners in a wall-fired boiler has a relatively distinct flame zone, and the burners in wall-fired boilers do not tilt. Superheated steam temperatures are instead controlled by excess air levels, heat input, flue gas recirculation, and/or steam attemperation (water spray). Depending on the design and location of the burners, wall-fired boilers are referred to as single wall or opposed wall.

Wall-fired boilers are used to burn coal, oil, or natural gas, and some designs feature multifuel capability. Almost all industrial wall-fired boilers have heat input capacities greater than 100 MMBtu/hr. Opposed-wall boilers in particular are usually much larger than 250 MMBtu/hr heat input capacity and are much more common in utility rather than in industrial operations. Because of their size, most wall-fired units are field erected. Field-erected watertube boilers strictly designed for oil firing are more compact than coal-fired boilers with the same heat input, because of the more rapid combustion characteristics of fuel oil. Field-erected watertube boilers fired by natural gas are even more compact because of the rapid combustion rate of the gaseous fuel, the low flame luminosity, and the ash-free content of natural gas.

2.3 Process Heater Characterization

Process heaters are heat transfer units in which heat from fuel combustion is transferred to materials used in a production process. The process fluid stream is heated primarily for one of two reasons: to raise the temperature for additional processing or to make chemical reactions occur. This section describes the different classes of process heaters and major design types.

2.3.1 Classes of Process Heaters

The universe of process heaters is divided into two categories:

- indirect-fired process heater—any process heater in which the combustion gases do not mix with or exhaust to the atmosphere from the same stack(s) or vent(s) with any gases emanating from the process or material being processed.

- direct-fired process heater—any process heater in which the combustion gases mix with and exhaust to the atmosphere from the same stack(s) or vent(s) with gases originating from the process or material being processed.

Indirect-fired units are used in situations where direct flame contact with the material being processed is undesirable because of problems with contamination and ignition of the process material. Direct-fired units are used where such problems are not an important factor. Emissions of indirect-fired units consist solely of the products of combustion (including those of incomplete combustion). On the other hand, direct-fired units will generate emissions consisting not only of the products of combustion, but also the process material(s). This means that the emissions from indirect-fired process heaters will be generic to the fuel in use and are common across industries while emissions from direct-fired process heaters are unique to a given process and may vary widely depending on the process material. Only indirect-fired process heaters are considered under this proposed regulation. Many direct-fired process heaters are being considered under separate MACT-development projects.

In addition to the distinction between direct- and indirect-fired heaters, process heaters may also be considered either heated feed or reaction feed. Heated feed process heaters are used to heat a process fluid stream before additional processing. These types of process heaters are used as preheaters for various operations in the petroleum refining industry such as distillation, catalytic cracking, hydroprocessing, and hydroconversion. In addition, heated feed process heaters are used widely in the chemical manufacturing industry as fired reactors (e.g., steam-hydrocarbon reformers and olefins pyrolysis furnaces), feed preheaters for nonfired reactors, reboilers for distillation operations, and heaters for heating transfer oils. Reaction feed process heaters are used to provide enough heat to cause chemical reactions to occur inside the tubes being heated. Many chemical reactions do not occur at room temperature and require the application of heat to the reactants to cause the reaction to take place. Applications include steam-hydrocarbon reformers used in ammonia and methanol manufacturing, pyrolysis furnaces used in ethylene manufacturing, and thermal cracking units used in refining operations.

2.3.2 Major Design Types

Process heaters may be designed and constructed in a number of ways, but most process heaters include burner(s), combustion chamber(s), and tubes that contain process fluids. Sections 2.3.2.1 through 2.3.2.4 describe combustion chambers setups, combustion air supply, tube configurations, and burners, respectively.

2.3.2.1 Combustion Chamber Set-Ups

Process heaters contain a radiant heat transfer area in the combustion chamber. This area heats the process fluid stream in the tubes by flame radiation. Equipment found in this area includes the burner(s) and the combustion chamber(s). Most heat transfer to the process fluid stream occurs here, but these tubes do not necessarily constitute a majority of the tubes in which the process fluid flows.

Most process heaters also use a convective heat transfer section to recover residual heat from the hot combustion gases by convective heat transfer to the process fluid stream. This section is located after the radiant heat transfer section and also contains tubes filled with process fluid. The first few rows of tubes in this section are called shield tubes and are subject to some radiant heat transfer. Typically, the process fluid flows through the convective section prior to entering the radiant section to preheat the process fluid stream. The temperature of the flue gas upon entering the convective section usually ranges from 800°C to 1,000°C (1,500°F to 2,000°F). Preheating in the convective section improves the efficiency of the process heater, particularly if the tube design includes fins or other extended surface areas. An extended tube surface area can improve efficiency by 10 percent. Extended tubes can reduce flue gas temperatures from 800°C to 1,000°C to (1,500°F to 2,000°F) to 120°C to 260°C (250°F to 500°F).

2.3.2.2 Combustion Air Supply

Air for combustion is supplied to the burners via either natural draft (ND) or mechanical draft (MD) systems. Natural draft heaters use ductwork systems to route air, usually at ambient conditions, to the burners. MD heaters use fans in the ductwork system to supply air, usually preheated, to the burners. The combustion air supply must have sufficient pressure to overcome the burner system pressure drops caused by ducting, burner registers, and dampers. The pressure inside the firebox is generally a slightly negative draft of approximately 49.8 to 125 Pascals (Pa) at the radiant-to-convective section transition point. The negative draft is achieved in ND systems via the stack effect and in MD systems via fans or blowers.

ND combustion air supply uses the stack effect to induce the flow of combustion air in the heater. The stack effect, or thermal buoyancy, is caused by the density difference between the hot flue gas in the stack and the significantly cooler ambient air surrounding the stack. Approximately 90 percent of all gas-fired heaters and 76 percent of all oil-fired heaters use ND combustion air supply (EPA, 1993).

There are three types of MD combustion air supply: forced draft, induced draft, and balanced draft. The draft types are named according to the position, relative to the combustion chamber, of the fans used to create the pressure difference in the process heater. All three types of MD heaters rely on the fans to supply combustion air and remove flue gas. In forced draft combustion air supply systems, the fan is located upstream from the combustion chamber, supplying combustion air to the burners. The air pressure supplied to the burners in a forced draft heater is typically in the range of 0.747 to 2.49 kilopascals (kPa). Though combustion air is supplied to the burners under positive pressure, the remainder of the process heater operates under negative pressure caused by the stack effect. In induced draft combustion air systems, the fan is located downstream of the combustion chamber, creating negative pressure inside the combustion chamber.

This negative pressure draws, or induces, combustion air into the burner registers. Balanced draft combustion air systems use fans placed both upstream and downstream (forced and induced draft) of the combustion chamber.

There are advantages and disadvantages for both ND and MD combustion air supply. One advantage to natural draft heaters is that they do not require the fans and equipment associated with MD combustion air supply. However, control over combustion air flow is not as precise in ND heaters as in MD heaters. MD heaters, unlike ND heaters, provide the option of using alternate sources of combustion oxygen, such as gas turbine exhaust. They also allow the use of combustion air preheat. Combustion air preheat has limited application in ND heaters due to the pressure drops associated with combustion air preheaters.

Combustion air preheaters are often used to increase the efficiency of MD process heaters. The maximum thermal efficiency obtainable with current air preheat equipment is 92 percent. Preheaters allow heat to be transferred to the combustion air from flue gas, steam, condensate, hydrocarbon, or other hot streams. The preheater increases the efficiency of the process heater because some of the thermal energy is reclaimed that would have been exhausted from the hot streams via cooling towers. If the thermal energy is from a hot stream other than the flue gas, the entire plant's efficiency is increased. The benefit of higher thermal efficiency is that less fuel is required to operate the heater.

2.3.2.3 Tube Configurations

The orientation of the tubes through which a process fluid stream flows is also taken into consideration when designing a process heater. The tubes in the convective section are oriented horizontally in most process heaters to allow cross-flow convection. However, the tubes in the radiant area may be oriented either horizontally or vertically. The orientation is chosen on a case-by-case basis according to the design specifications of the individual process heater. For example, the arbor, or wicket, type of heater is a specialty design to minimize the pressure drop across the tubes.

2.3.2.4 Burners

Many different types of burners are used in process heaters. Burner selection depends on several factors including process heat flux requirements, fuel type, and draft type. The burner chosen must provide a radiant heat distribution that is consistent with the configuration of the tubes carrying process fluid. Also, the number and location of the burner(s) depend on the process heater application.

Many burner flame shapes are possible, but the most common types are flat and conical. Flat flames are generally used in applications that require high temperatures such as ethylene pyrolysis furnaces, although some ethylene furnaces use conical flames to achieve uniform heat distribution. Long conical flames are used in cases where a uniform heat distribution is needed in the radiant section.

Fuel compatibility is also important in burner selection. Burners may be designed for combustion of oil, gas, or a gas/oil mixture. Gas-fired burners are simpler in operation and design than oil-fired burners and are classified as either premix or raw gas burners. In premix burners, 50 to 60 percent of the air necessary for combustion is mixed with the gas prior to combustion at the burner tip. This air is induced into the gas stream as the gas expands through orifices in the burner. The remainder of the air necessary for combustion is provided at the burner tip. Raw gas burners receive fuel gas without any premixed combustion air. Mixing occurs in the combustion zone at the burner tip.

Oil-fired burners are classified according to the method of fuel atomization used. Atomization is needed to increase the mixing of fuel and combustion air. Three types of fuel atomization commonly used are mechanical, air, and steam. Steam is the most widely used method because it is the most economical, provides the best flame control, and can handle the largest turndown ratios. Typical steam requirements are 0.07 to 0.16 kilogram (kg) steam/kg of oil.

Combination burners can burn 100 percent oil, 100 percent gas, or any combination of oil and gas. A burner with this capability generally has a single oil nozzle in the center of a group of gas nozzles. The air needed for combustion can be controlled separately in this type of burner. Another option is to base load the burners with one fuel and to add the other fuel to meet increases in load demand. Combination burners add flexibility to the process heater, especially when the composition of the fuel is variable.

The location and number of burners needed for a process heater are also determined on an individual basis. Burners can be located on the ceiling, walls, or floor of the combustion chamber. Floor- and wall-fired units are the most common burner types found in process heaters because they are both efficient and flexible. In particular, floor-mounted burners integrate well with the use of combustion air preheat, liquid fuels, and alternate sources of combustion oxygen such as turbine exhaust.

The number of burners in a heater can range from 1 to over 100. In the refinery industry, the average number of burners is estimated at 24 in ND heaters with an average design heat release of 69.4 million Btu per hour (MMBtu/hr). The average number of burners is estimated at 20 in MD heaters with ambient combustion air and an average design heat release of 103.6 MMBtu/hr. The average number of burners is estimated at 14 in MD heaters with combustion air preheat and an average design heat release of 135.4 MMBtu/hr. In general, the smaller the number of burners, the simpler the heater will be. However, multiple burners provide a more uniform temperature distribution.

SECTION 3

PROFILE OF AFFECTED UNITS AND FACILITIES, AND COMPLIANCE COSTS

The floor-level MACT for the proposed regulation will affect existing and new ICI boilers and process heaters that have input capacity greater than 10 million Btus and are fueled by fossil and nonfossil fuel solids and liquids. In addition, two above-the-floor alternatives were investigated, Options 1A and 1B. Option 1A broadens the scope of affected units to include those fueled by residual fuel oil and units of covered fuel types with input capacities less than 10 million Btus. Option 1B further expands the affected population to include all distillate fuel oil and natural gas-fueled units. Although descriptive statistics on the Option 1B population are included in this section, this alternative was not analyzed for this EIA. More information on these options can be found in the preamble to the proposed rule.

The economic impact estimates presented in Section 6 and the small entity screening analysis presented in Section 7 are based on the estimated stock of existing units and the projection of new units through the year 2005. They are also based on the compliance costs associated with the applying a regulatory alternative to these units. This chapter begins with a review of the industry distribution and technical characteristics of existing boilers and process heaters contained in the Agency's Inventory Database. It also presents projected growth estimates for boilers and process heaters through the year 2005, a description of how costs are estimated, and the national engineering cost estimates and cost-effectiveness (cost/ton) estimates by pollutant controlled.

3.1 Profile of Existing Boiler and Process Heaters Units

This section profiles existing boilers and process heaters, collectively referred to as "units," with respect to business applications, industry of parent company, and fuel use. The unit population database in combination with the model units that helped in preparing that database were used to determine which types of boilers, fuel, and control devices were in the existing unit population so that corresponding emission factors could be developed for all combinations. The development of the population database and the model units are discussed in the memoranda, "Development of the Population Database for the Industrial, Commercial, and Institutional Boiler and Process Heater National Emission Standard for

Hazardous Air Pollutants (NESHAP)" and "Development of the Model Units for the Industrial, Commercial, and Institutional Boiler and Process Heater National Emission Standard for Hazardous Air Pollutants (NESHAP)." The units contained in the Inventory Database are based on information from the Aerometric Information Retrieval System (AIRS) and Ozone Transport Assessment Group (OTAG) databases, state and local permit records, and the combustion source Information Collection Request (ICR) conducted by the Agency in 1997. The list of units contained in the Inventory Database was reviewed and updated by industry and environmental stakeholders as part of the Industrial Combustion Coordinated Rulemaking (ICCR), chartered under the Federal Advisory Committee Act (FACA).

The entire Inventory Database contains more than 58,000 ICI boilers and process heaters; however, only about 4,000 are estimated to be affected by the floor alternative. Of these existing units, a little over half had sufficient information on operating parameters to be included in the floor-level EIA. The number of potentially affected units included in the profile for the floor alternative was 2,186. The number of units included in the profile was 3,580 for Option 1A and 22,117 for Option 1B.

3.1.1 Distribution of Existing Boilers and Facilities by Industry

Tables 3-1 through 3-3 present the number of existing boilers and process heaters and the number of facilities owning units by two-digit SIC code and three-digit NAICS code that may be affected by the floor or above-the-floor alternatives. For the floor alternative, the industries with the largest number of potentially affected units are the furniture, paper, lumber, and electrical services industries. These four industries alone account for nearly 60 percent of affected units. Almost all the process heaters are in the lumber industry. (Section 4 presents industry profiles for the lumber and wood products, electrical services, and paper industries, among others.) The remaining units are primarily distributed across the manufacturing sector and service industries. The distribution of units affected by the Option 1A alternative is similar to that for the floor alternative, although both the number of units and the number of facilities is greater for the Option 1A alternative. For Option 1B, the industries with the greatest number of units shifts to oil and gas exploration, chemical and transportation equipment manufacturing, and petroleum refining.

Table 3-1. Units and Facilities Affected by the Floor Alternative by Industry[a]

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
01	111	Agriculture—Crops	3	0	3	3
02	112	Agriculture—Livestock	0	0	0	0
07	115	Agricultural Services	0	0	0	0
10	212	Metal Mining	9	0	9	4
12	212	Coal Mining	2	0	2	1
13	211	Oil and Gas Extraction	0	0	0	0
14	212	Mining/Quarrying—Nonmetallic Minerals	8	0	8	4
17	235	Construction—Special Trade Contractors	0	0	0	0
20	311	Food and Kindred Products	138	0	138	60
21	312	Tobacco Products	11	0	11	7
22	313	Textile Mill Products	135	0	135	71
23	315	Apparel and Other Products from Fabrics	2	0	2	2
24	321	Lumber and Wood Products	335	25	360	262
25	337	Furniture and Fixtures	234	0	234	154
26	322	Paper and Allied Products	321	0	321	194
27	511	Printing, Publishing, and Related Industries	0	0	0	0
28	325	Chemicals and Allied Products	171	3	174	70
29	324	Petroleum Refining and Related Industries	11	0	11	8
30	326	Rubber and Miscellaneous Plastics Products	17	0	17	13
31	316	Leather and Leather Products	1	0	1	1
32	327	Stone, Clay, Glass, and Concrete Products	9	0	9	7
33	331	Primary Metal Industries	41	0	41	16
34	332	Fabricated Metal Products	16	0	16	10
35	333	Industrial Machinery and Computer Equipment	23	0	23	12
36	335	Electronic and Electrical Equipment	5	0	5	5
37	336	Transportation Equipment	102	0	102	41
38	334	Scientific, Optical, and Photographic Equip.	8	0	8	4
39	339	Miscellaneous Manufacturing Industries	2	0	2	2
40	482	Railroad Transportation	4	0	4	1
42	484	Motor Freight and Warehousing	5	0	5	1
46	486	Pipelines, Except Natural Gas	0	0	0	0

(continued)

Table 3-1. Units and Facilities Affected by the Floor Alternative by Industry[a] (continued)

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
49	221	Electric, Gas, and Sanitary Services	318	0	318	160
50	421	Wholesale Trade—Durable Goods	3	0	3	2
51	422	Wholesale Trade—Nondurable Goods	2	0	2	1
55	441	Automotive Dealers and Gasoline Service Stations	0	0	0	0
58	722	Eating and Drinking Places	0	0	0	0
60	522	Depository Institutions	0	0	0	0
59	445–454	Miscellaneous Retail	0	0	0	0
70	721	Hotels and Other Lodging Places	1	0	1	1
72	812	Personal Services	0	0	0	0
76	811	Miscellaneous Repair Services	2	0	2	1
80	621	Health Services	37	0	37	18
81	541	Legal Services	0	0	0	0
82	611	Educational Services	105	0	105	45
83	624	Social Services	2	0	2	1
86	813	Membership Organizations	0	0	0	0
87	541	Engineering, Accounting, Research, Management and Related Services	2	0	2	2
89	711/514	Services, N.E.C.	2	0	2	1
91	921	Executive, Legislative, and General Administration	1	0	1	1
92	922	Justice, Public Order, and Safety	29	0	29	9
94	923	Administration of Human Resources	1	0	1	1
96	926	Administration of Economic Programs	4	0	4	3
97	928	National Security and International Affairs	29	0	29	11
NA		SIC Information Not Available	7	0	7	4
			2,158	28	2,186	1,214

[a] Based on the Inventory Database.

Table 3-2. Units and Facilities Affected by the Option 1A Alternative by Industry[a]

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
01	111	Agriculture—Crops	6	0	6	6
02	112	Agriculture—Livestock	0	0	0	0
07	115	Agricultural Services	0	0	0	0
10	212	Metal Mining	10	1	11	5
12	212	Coal Mining	2	0	2	1
13	211	Oil and Gas Extraction	8	10	18	4
14	212	Mining/Quarrying—Nonmetallic Minerals	10	0	10	5
17	235	Construction—Special Trade Contractors	2	0	2	1
20	311	Food and Kindred Products	163	0	163	72
21	312	Tobacco Products	22	0	22	11
22	313	Textile Mill Products	247	3	250	134
23	315	Apparel and Other Products from Fabrics	4	0	4	4
24	321	Lumber and Wood Products	434	28	462	337
25	337	Furniture and Fixtures	310	0	310	209
26	322	Paper and Allied Products	503	0	503	272
27	511	Printing, Publishing, and Related Industries	8	0	8	6
28	325	Chemicals and Allied Products	332	101	433	163
29	324	Petroleum Refining and Related Industries	54	108	162	50
30	326	Rubber and Miscellaneous Plastics Products	56	0	56	37
31	316	Leather and Leather Products	22	0	22	12
32	327	Stone, Clay, Glass, and Concrete Products	40	2	42	25
33	331	Primary Metal Industries	83	2	85	33
34	332	Fabricated Metal Products	44	0	44	28
35	333	Industrial Machinery and Computer Equipment	46	0	46	25
36	335	Electronic and Electrical Equipment	45	0	45	29
37	336	Transportation Equipment	158	0	158	61
38	334	Scientific, Optical, and Photographic Equip.	33	0	33	16
39	339	Miscellaneous Manufacturing Industries	14	0	14	10
40	482	Railroad Transportation	4	0	4	1
42	484	Motor Freight and Warehousing	5	2	7	3
46	486	Pipelines, Except Natural Gas	3	3	6	5

(continued)

Table 3-2. Units and Facilities Affected by the Option 1A Alternative by Industry[a] (continued)

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
49	221	Electric, Gas, and Sanitary Services	371	1	372	185
50	421	Wholesale Trade—Durable Goods	3	0	3	2
51	422	Wholesale Trade—Nondurable Goods	2	0	2	1
55	441	Automotive Dealers and Gasoline Service Stations	0	1	1	1
58	722	Eating and Drinking Places	0	0	0	0
60	522	Depository Institutions	0	0	0	0
59	445–454	Miscellaneous Retail	1	0	1	1
70	721	Hotels and Other Lodging Places	1	0	1	1
72	812	Personal Services	0	0	0	0
76	811	Miscellaneous Repair Services	2	0	2	1
80	621	Health Services	40	0	40	19
81	541	Legal Services	0	0	0	0
82	611	Educational Services	114	0	114	50
83	624	Social Services	3	0	3	2
86	813	Membership Organizations	0	0	0	0
87	541	Engineering, Accounting, Research, Management and Related Services	6	0	6	5
89	711/514	Services, N.E.C.	2	0	2	1
91	921	Executive, Legislative, and General Administration	2	0	2	2
92	922	Justice, Public Order, and Safety	33	0	33	10
94	923	Administration of Human Resources	1	0	1	1
96	926	Administration of Economic Programs	4	0	4	3
97	928	National Security and International Affairs	41	0	41	13
NA		SIC Information Not Available	24	0	24	18
			3,318	262	3,580	1,881

[a] Based on the Inventory Database.

Table 3-3. Units and Facilities Affected by the Option 1B Alternative by Industry[a]

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
01	111	Agriculture—Crops	7	0	7	6
02	112	Agriculture—Livestock	6	0	6	1
07	115	Agricultural Services	3	0	3	1
10	212	Metal Mining	55	6	61	20
12	212	Coal Mining	20	6	26	5
13	211	Oil and Gas Extraction	497	657	1,154	371
14	212	Mining/Quarrying—Nonmetallic Minerals	48	1	49	19
17	235	Construction—Special Trade Contractors	2	0	2	1
20	311	Food and Kindred Products	441	3	444	145
21	312	Tobacco Products	69	0	69	30
22	313	Textile Mill Products	755	6	761	347
23	315	Apparel and Other Products from Fabrics	4	0	4	4
24	321	Lumber and Wood Products	561	40	601	412
25	337	Furniture and Fixtures	499	10	509	297
26	322	Paper and Allied Products	981	0	981	493
27	511	Printing, Publishing, and Related Industries	333	3	336	134
28	325	Chemicals and Allied Products	2,265	415	2,680	913
29	324	Petroleum Refining and Related Industries	322	729	1,051	184
30	326	Rubber and Miscellaneous Plastics Products	508	36	544	268
31	316	Leather and Leather Products	91	2	93	44
32	327	Stone, Clay, Glass, and Concrete Products	423	13	436	184
33	331	Primary Metal Industries	754	197	951	314
34	332	Fabricated Metal Products	771	102	873	388
35	333	Industrial Machinery and Computer Equipment	402	19	421	191
36	335	Electronic and Electrical Equipment	430	13	443	203
37	336	Transportation Equipment	803	207	1,010	291
38	334	Scientific, Optical, and Photographic Equip.	180	2	182	71
39	339	Miscellaneous Manufacturing Industries	123	36	159	65
40	482	Railroad Transportation	4	0	4	1
42	484	Motor Freight and Warehousing	5	2	7	3
46	486	Pipelines, Except Natural Gas	8	3	11	7

(continued)

Table 3-3. Units and Facilities Affected by the Option 1B Alternative by Industry[a] (continued)

SIC Code	NAICS Code	Description	Boilers	Heaters	Total Units	Facilities
49	221	Electric, Gas, and Sanitary Services	1,227	140	1,367	615
50	421	Wholesale Trade—Durable Goods	4	0	4	2
51	422	Wholesale Trade—Nondurable Goods	2	0	2	1
55	441	Automotive Dealers and Gasoline Service Stations	0	2	2	2
58	722	Eating and Drinking Places	0	3	3	1
60	522	Depository Institutions	3	0	3	1
59	445–454	Miscellaneous Retail	1	0	1	1
70	721	Hotels and Other Lodging Places	3	0	3	2
72	812	Personal Services	2	0	2	1
76	811	Miscellaneous Repair Services	58	0	58	28
80	621	Health Services	27	0	27	25
81	541	Legal Services	2	0	2	0
82	611	Educational Services	144	0	144	57
83	624	Social Services	4	0	4	2
86	813	Membership Organizations	1	0	1	1
87	541	Engineering, Accounting, Research, Management and Related Services	6	0	6	5
89	711/514	Services, N.E.C.	2	0	2	1
91	921	Executive, Legislative, and General Administration	7	0	7	5
92	922	Justice, Public Order, and Safety	36	0	36	10
94	923	Administration of Human Resources	2	0	2	2
96	926	Administration of Economic Programs	11	0	11	5
97	928	National Security and International Affairs	51	3	54	15
NA		SIC Information Not Available	6,163	335	6,498	2,378
			19,126	2,991	22,117	8,573

[a] Based on the Inventory Database.

3.1.2 Technical Characteristics of Existing Boilers

Figure 3-1 characterizes the population of 2,186 (3,580; 22,117) units identified in the Inventory Database by capacity range, fuel type, and level of preexisting control for each alternative. Throughout most of this section, the values in the text are for the floor alternative. Those for the above-the-floor alternatives follow in parentheses, first for Option 1A then for Option 1B.

3.1.2.1 Floor Alternative

- Capacity Range: Unit input capacities in the population are expressed in four ranges: 0–10, 10–100, 100–250, and >250 MMBtu/hr. Fifty-two percent of the units affected for this alternative have capacities between 10 and 100 MMBtu/hr. The two largest capacity ranges each contain approximately one quarter of the population. Only 1 percent of units have input capacities less than 10 MMBtu/hr.
- Fuel Type: About half of these units consume coal as their primary fuel (1,074 units). After coal, the next most common fuel type is wood (479 units).
- Control Level: Eighty-three percent of units have some type of control device already installed; 289 do not. Typical control devices include fabric filters, wet scrubbers, and electrostatic precipitators.

3.1.2.2 Option 1A Alternative

- Capacity Range: About half of the 3,580 units affected by this alternative have input capacities between 10 and 100 MMBtu/hr. Twenty percent have capacities between 100 and 250, 16 percent have capacities greater than 250, and 13 percent have capacities less than 10 MMBtu/hr.
- Fuel Type: Coal and residual fuel oil are the primary fuel types each accounting for slightly less than one-third of the units. The remaining third primarily consists of units that consume wood or some other type of biomass fuel.
- Control Level: Forty-one percent have no existing pollution control equipment installed. Typical control devices include fabric filters, wet scrubbers, and electrostatic precipitators.

3.1.2.3 Option 1B Alternative

- Capacity Range: More than half of the 22,117 units affected by the Option 1B alternative have input capacities less than 10 MMBtu/hr. Thirty-six percent have input capacities between 10 and 100 MMBtu/hr. The remaining 12 percent have input capacities in excess of 100 MMBtu/hr.

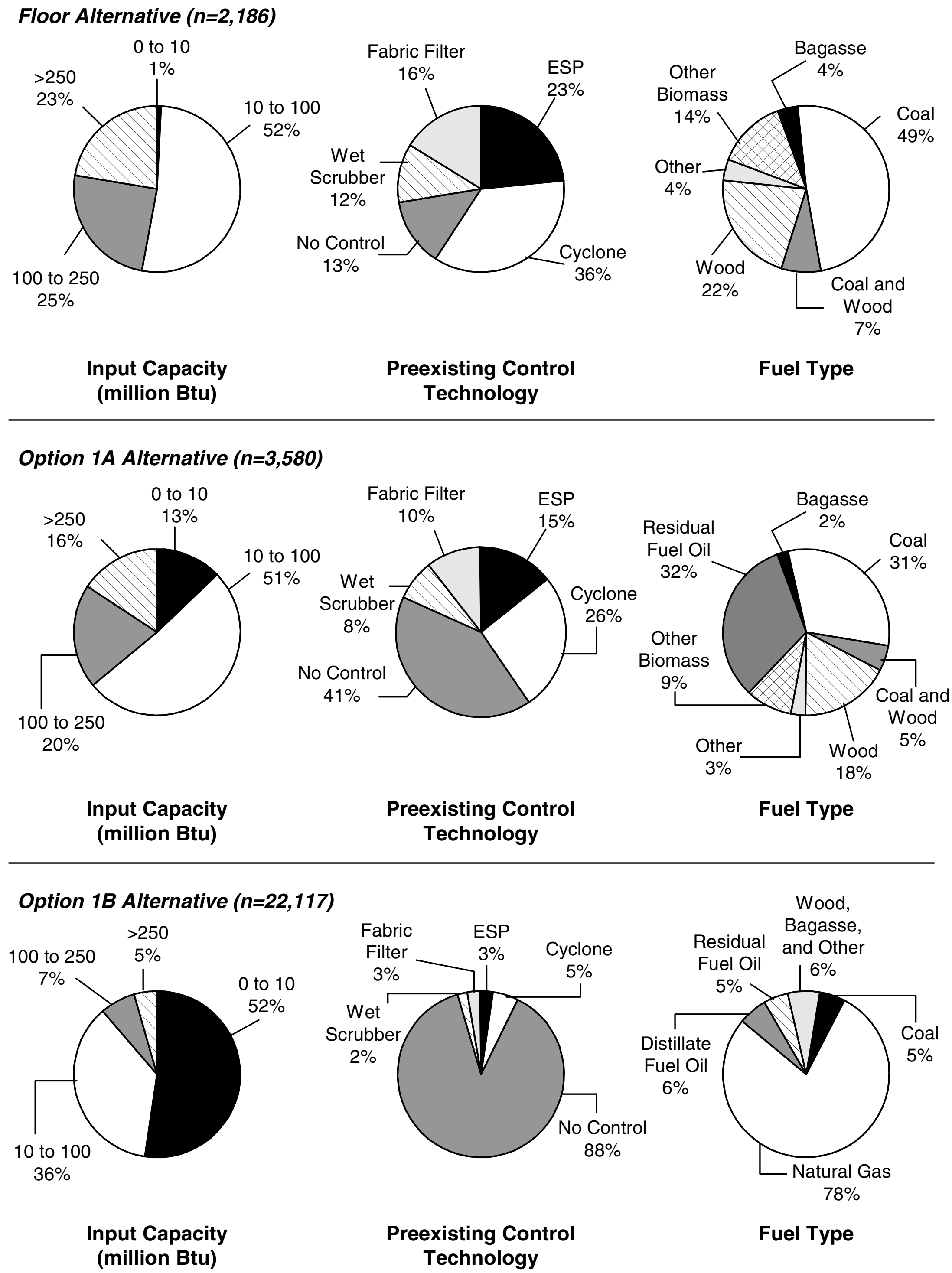


Figure 3-1. Characteristics of Units Affected by Alternatives

- Fuel Type: This alternative includes those units affected under Option 1A, as well as a large number of natural gas units that were not affected under Option 1A. The vast majority of the 78 percent of the total number of potentially affected units are fueled by natural gas.

- Control Level: Eighty-eight percent of the affected units have no preexisting control equipment.

3.2 Methodology for Estimating Cost Impacts

The predominant type of control measure that is considered in the analysis of emission reductions needed for sources to achieve the MACT floor, which is the proposed alternative, as well as other alternatives, are add-on control technologies. Add-on control techniques are those technologies that are applied to the vent gas stream of the boiler or process heater to reduce emissions. The boiler and process heaters population database includes information on all control techniques that are applied to industrial, commercial, institutional boilers and process heaters. Generally, they can be grouped into PM control or acid gas control. The most common technologies, and the ones analyzed for the impacts analysis, include fabric filters, ESP's, packed scrubbers, venturi scrubbers, and spray dryers. In addition, when add-on technologies are used, the cost of ductwork and associated equipment also needed to be considered.

Components of capital cost include:

- purchased equipment cost of the primary device and auxiliary equipment,

- instrumentation,

- sales tax and freight, and

- installation costs. Installation costs include foundations and support, handling and erection, electrical, piping, insulation, and painting, engineering, construction and field expenses, contractor fees, start-up, performance tests, and contingencies.

Components of annual cost include:

- raw materials,

- utilities (electricity, fuel, steam, air, water),

- waste treatment and disposal,

- labor (operating, supervisory, maintenance),

- maintenance materials,
- replacement parts,
- overhead,
- property taxes,
- insurance,
- administration charges, and
- capital recovery costs.

For this analysis, costs were estimated in 1999 dollars. Capital recovery was calculated assuming 7 percent interest rate over the life of the equipment. The use of this interest rate is based on Office of Management and Budget (OMB) guidance (Circular A-94, October 29, 1992).

The algorithms used to estimate these costs were obtained from previous EPA studies. These cost algorithms are included as appendices to the cost methodology memorandum in the public docket. Inputs for the algorithms used in the impacts analysis are also presented in this memorandum.

Fabric Filter

The algorithms used to estimate capital and annual costs of fabric filters were obtained from EPA's EPA Air Pollution Control Cost Manual. Algorithms were provided for 4 types of fabric filters: shaker, reversed air, pulse-jet modular, and pulse-jet common. The cost algorithms for estimating capital costs reduced to basic equations for each are provided in Appendix A-1 of the cost methodology memorandum (henceforth called the "cost memo"). Capital costs are based on the gross cloth area of the fabric filter, which is a function of the gas inlet flow rate. Algorithms for calculating annual costs are provided in Appendix A-2 of the cost memo. Annual costs include dust disposal, electricity, maintenance, labor, bag replacement, maintenance labor, compressed air, overhead, administrative, property taxes, and insurance. Capital recovery is annualized over 20 years at 7 percent interest. Appendix A-3 of the cost memo presents the values for the inputs used in this analysis and the reasons for their use.

Electrostatic Precipitator

The algorithms used to estimate capital and annual costs of ESPs were obtained from EPA's Air Pollution Control Cost Manual. Capital costs are based on the total collection plate area, which is calculated from the gas inlet flow rate and the required removal efficiency. The cost algorithms for estimating capital costs of ESPs reduced to basic equations are provided in Appendix B-1 of the cost memo. Algorithms for calculating annual costs are provided in Appendix B-2 of the cost memo. Annual costs include dust disposal, electricity, maintenance, labor, maintenance labor, overhead, administrative, property taxes, and insurance. Capital recovery is annualized at 7 percent interest. Appendix B-3 of the cost memo presents the values for the inputs used in this analysis and the reasons for their use.

Venturi Scrubber

The algorithms used to estimate capital and annual costs of venturi scrubbers were obtained from EPA cost algorithms on EPA's website(http://www.epa.gov/ttn/catc/products.html#cccinfo.) Capital costs include not only the cost of the venturi scrubber but also a pump to provide motive force for the solvent. Capital costs are based on the gas flow rate and saturation temperature of the gas-solvent. The cost algorithms for estimating capital costs of each piece of equipment were reduced to basic equations in Appendix C-1 of the cost memo. The cost algorithms for estimating annual costs were reduced to basic equations in Appendix C-2 of the same memorandum. Annual costs include wastewater disposal, solvent, electricity, maintenance, labor, maintenance labor overhead, administrative, property taxes, and insurance. Capital recovery is an annualized cost estimated using a 7 percent interest rate. Appendix C-3 of the cost memo presents the values for the inputs used in this analysis and the reasons for their use.

Packed Bed Scrubber

The algorithms used to estimate capital and annual costs of packed bed scrubbers were obtained from EPA's Air Pollution Control Cost Manual. The capital costs are comprised of the scrubber tower, packing, pumps, and fans. Capital costs are based primarily on gas flow rate and removal efficiency. The cost algorithms for estimating capital costs of packed scrubber equipment reduced to their basic equations for each are provided in Appendix D-1 of the cost memo. The cost algorithms for estimating annual costs of packed scrubbers are provided in Appendix D-2 of the cost memo. Annual costs include caustic, wastewater disposal, water, electricity, maintenance, labor, overhead, administrative, property taxes, and insurance. Capital recovery is an annualized cost estimated using a 7 percent interest rate. Appendix D-3 of the cost memo presents the values for the inputs used in this analysis and the reasons for their use.

Spray Dryer

The algorithms used to estimate capital and annual costs of spray dryers were obtained from previous EPA studies. Capital costs include the cost of the spray dryer and pumps. Capital costs are based on the gas flow rate. The cost algorithms for estimating capital costs of spray dryer equipment reduced to basic equations are provided in Appendix E-1 of the cost memo. The cost algorithms for estimating annual costs for spray dryers are provided in Appendix E-2 of the cost memo. Annual costs include lime, water, electricity, maintenance, labor, maintenance labor, overhead, administrative, property taxes, and insurance. Capital recovery is an annualized cost estimated using a 7 percent interest rate. Appendix E-3 of the cost memo presents the values for the inputs used in this analysis and the reasons for their use.

Ductwork

The algorithms used to estimate capital and annual costs of ductwork were obtained from EPA's Air Pollution Control Cost Manual. Capital costs include 500 feet of ductwork, elbows, and fans. The 500 feet of ductwork was based on engineering judgement and previous experience on the distance between emission points and control devices in chemical facilities and the availability of space for retrofitting controls. Costs are based on ductwork diameter, which is calculated from the gas flow rate. The cost algorithms for estimating capital costs and annual costs reduced to basic equations are provided in Appendix F-1 of the cost memo. Annual costs include electricity, maintenance, maintenance labor, overhead, administrative, property taxes, and insurance. Capital recovery is an annualized cost estimated using a 7 percent interest rate. Required inputs to the ductwork algorithms are provided in the input tables provided in Appendices A-3, B-3, C-3, D-3, and E-3 of the cost memo.

Good Combustion Practices

Few sources in the population database specifically reported using good combustion practices. Boilers and process heaters within each subcategory might use any of a wide variety of different work practices, depending on the characteristics of the individual unit.

Consequently, any uniform requirements or set of work practices that would meaningfully reflect the use of good combustion practices, or that could be meaningfully implemented across any subcategory of boilers and process heaters could not be identified.

Additionally, few of the GCP's have been documented to reduce organic HAP emissions, and they could not be considered in the MACT analysis. One GCP that may effect organic HAP emissions is maintaining CO emission levels. CO is generally an indicator of incomplete combustion because CO will burn to carbon dioxide if adequate oxygen is available. Controlling CO emissions is a mechanism for ensuring combustion efficiency, and therefore may be viewed as a kind of GCP.

Capital and annual costs for CO monitoring is presented in Appendix G of the cost memo. The costing information was obtained from a previous EPA study. Capital costs are comprised of the initial cost of the equipment. Annual costs include operating and maintenance costs, annual and quarterly checks, recordkeeping and reporting, taxes, insurance, and administrative costs. Annualized costs such as capital recovery costs are calculated assuming an equipment life of 20 years and an interest rate of 7 percent.

Testing and Monitoring Costs

The proposed rule includes emission limits for HCl, PM, metallic HAP, and mercury. Additionally, as mentioned in Section 1 of this EIA and the preamble, the rule allows sources to meet requirements by monitoring fuel content instead of emissions. Consequently, testing and monitoring costs of meeting the standards were incorporated into the cost estimates. Capital costs for testing include initial stack tests for PM, HCl, and metals for fossil fuels, and materials and fuel analysis for biomass. Capital cost components include operation and maintenance costs and capital recovery assuming the initial capital investment is annualized over a 5 year period at 7 percent interest. Monitoring costs are included for opacity monitoring, HCl monitoring, and scrubber parametric monitoring.[1] Monitoring costs include the capital cost of monitoring equipment, and the annual costs of capital recovery assuming the initial capital investment is annualized over a 20 year period at 7 percent interest. Annual monitoring costs also include operation and maintenance as well as other additional costs.

[1]The monitoring costs reported for existing units are not the cost of continuous emission monitors (CEM), but the costs associated with monitoring the process parameters of the control device. Installation of these process monitors are integral to the control device and would be installed with or without the monitoring requirements of the MACT. Therefore, even though we present these monitoring costs separately, they are included in the overall reported control costs and should not be considered as an additional cost for emission monitoring.

The testing and monitoring costs are shown in Table 3-4. Appendix G of the cost memo includes further details on these costs. Information used to estimate testing and monitoring costs were obtained from previous EPA studies.

Costs to Control Non-Air Effects Related to Rule Implementation

The EPA estimated the additional water usage that would result from the MACT floor level of control to be 110 million gallons per year for existing sources and 0.6 million gallons per year for new sources. In addition to the increased water usage, an additional 3.7 million gallons per year of wastewater would be produced for existing sources and 0.6 million gallons per year for new sources. The EPA estimated the additional solid waste that would result from the MACT floor level of control to be 102,000 tons per year for existing sources and 1 ton per year for new sources. The costs ($900,000) of handling the additional solid waste generated from applying MACT floor technology are accounted for in the control cost estimates for ESP and fabric filter applications. The costs ($20,000) of treating wastewater from venturi and packed bed scrubber are also accounted for in the control cost estimates.

Cost Effectiveness

To provide additional information on the magnitude of the cost estimates, Table 3-5 shows the cost-effectiveness (cost/ton reduced estimates) for the HAP and non-HAP pollutants whose emissions are reduced by this proposed rule.

Cost Uncertainties

The primary limitation to the cost estimates developed for the proposed rule is that costs were calculated for model units rather than each individual boiler or process heater. Consequently, the costs do not characterize any "real" unit. This was done for practical reasons. Because there are over 60,000 units in the U.S., it would not be possible to gather unit-specific information for each unit necessary for estimating costs, such as flue gas temperatures and flow rates. Additionally, emission information was only available for less than 1 percent of the units. In order to estimate costs and emission reductions of the proposed rule, model units were developed to represent the population of boilers and process heaters in the U.S. While sufficient information was not available for characterizing each unit, sufficient emissions and process information were available to develop model units. Each unit in the U.S. was then assigned to a model based on their size and fuel burned. It also should be noted that the costing methodology is the cost algorithms for the control

Table 3-4. Testing and Monitoring Costs for Units Covered by the Proposed Rule

Material or Fuel	No. of Industrial Boilers	No. of Process Heaters	Total Capital Investment of Testing and Monitoring ($)	Total Annual Costs of Testing ($)	Total Annual Costs of Monitoring ($)	Annual Capital Recovery - Testing and Monitoring (1999$)	Total Annual Costs of Testing and Monitoring (1999$)
Regular Use Units							
Coal	2,328	0	151,169,238	63,608,655	59,828,340	8,265,169	123,436,995
Coal/Wood/NFF[a] Liquid/NFF Solid	169	0	8,847,579	2,444,456	1,302,784	280,698	3,747,240
Gas	30,473	13,481	0	0	0	0	0
Gas/Wood/Other Biomass/Liquid FF	201	0	9,831,749	2,909,994	2,327,840	447,120	5,237,834
Distillate Liquid FF	2,921	353	0	0	0	0	0
NFF Liquid/NFF Solid/Gas	115	11	7,452,131	3,074,918	2,930,348	404,077	6,005,266
Wood	663	42	26,446,200	5,268,614	6,392,240	1,411,706	11,660,854
Wood/Other Biomass/NFF Liquid/NFF Solid	147	0	8,180,852	3,003,146	2,001,492	299,112	5,004,638
Residual Liquid FF	2,036	674	0	0	0	0	0
Bagasse/Other	132	0	5,821,106	490,000	2,891,728	412,546	3,381,728
Total for Regular Use Units	39,185	14,561	217,748,855	80,799,783	77,674,772	11,520,428	158,114,555

(continued)

Table 3-4. Testing and Monitoring Costs for Units Covered by the Proposed Rule (continued)

Material or Fuel	No. of Industrial Boilers	No. of Process Heaters	Total Capital Investment of Testing and Monitoring ($)	Total Annual Costs of Testing ($)	Total Annual Costs of Monitoring ($)	Annual Capital Recovery - Testing and Monitoring (1999$)	Total Annual Costs of Testing and Monitoring (1999$)
Limited Use Units							
Coal	198	0	6,427,715	1,584,000	1,716,416	457,169	3,330,416
Coal/Wood/NFF Liquid/NFF Solid	4	0	119,600	32,000	29,772	8,268	61,772
Gas	2,314	624	0	0	0	0	0
Gas/Wood/Other Biomass/Liquid FF	8	0	290,366	64,000	105,020	21,366	169,020
Distillate Liquid FF	672	31	0	0	0	0	0
NFF Liquid/NFF Solid/Gas	4	1	156,800	40,000	39,696	11,024	79,696
Wood	28	0	1,074,549	224,000	331,200	80,279	555,200
Wood/Other Biomass/NFF Liquid/NFF Solid	6	0	194,000	48,000	49,620	13,780	97,620
Residual Liquid FF	533	31	0	0	0	0	0
Total for Limited Use Units	3,767	687	8,263,030	1,992,000	2,271,724	591,886	4,263,724
Grand Total	42,952	15,248	226,011,885	82,791,783	79,946,496	12,112,314	162,738,279

[a] NFF = costs for units that are not fossil fueled; FF = units that are fossil fueled.

Table 3-5. Cost Effectiveness (C/E) of Industrial Boiler and Process Heater MACT on Existing Units and Subcategories

	Total Annualized Costs	Large Solid Fuel Subcategory	Large Solid Fuel Subcategory—Coal Only	Large Solid Fuel Subcategory—Wood Only	Limited Use Solid Fuel Subcategory
Control Costs ($)	833,273,781[b]	810,422,230	669,353,690	141,068,540	22,851,551
PM Emissions Reduction (Tons/Year)	565,900	563,060	359,920	203,140	2,840
C/E ($/ton PM)	1,472[a]	1,439	1,860	694	8,046
Metals Emissions Reduction (Tons/Year)	1,093	1,087	591	496	6
C/E ($/ton metals)	762,373[a]	745,558[a]	1,132,578[a]	284,412[a]	3,808,592[a]
HCl Emissions Reduction (Tons/Year)	46,515	46,515	45,136	1,379	—
C/E ($/ton HCl)	17,914[a]	17,422[a]	14,830[a]	102,298[a]	—
HAP Emissions Reduction (Tons/Year)	47,608	47,602	45,727	1,875	6
C/E ($/ton HAP)	**17,502**	**17,025**	**14,638**	**75,236**	**3,808,500**

[a] The cost-effectiveness value is based on the total annualized cost of the rule and not on the cost for controlling the specific pollutant, and, thus, overstates the cost/ton for the specific HAP or other pollutant.

[b] Costs are in 1999 dollars. Emission reductions are calculated for 2005.

devices provide a cost range of +/- 30 percent. This aspect of the costing methodology reflects the degree of variability typically found in study-level cost estimates. This is also the degree of variability found in the cost methodology employed in the EPA Air Pollution Control Cost Manual, which is an important reference for the cost estimates supplied in the RIA. Cost information available to owners and operators of boilers and process heaters will be more specific and accurate. Consequently, the cost estimates may overestimate or underestimate costs.

3.3 Projection of New Boilers and Process Heaters

Energy Information Administration fuel consumption forecasts were used in conjunction with existing model boiler population data to project the number and type of new boilers to be installed by 2005. EPA used the following steps to calculate new boiler population estimates:

1. *Calculate the percentage change in industrial fuel consumption*. Energy Information Administration data were used to obtain industrial and commercial fuel use projections. The percentage change in consumption (1998 to 2005) in the industrial and commercial sectors was calculated for the following fuel categories using 1998 as the base year (the same year that the model boiler algorithms are based on): steam coal (2.6%), natural gas (6.3%), residual fuel oil (-7.4%), distillate fuel oil (12.0%), and biomass (11.5%). It should be noted that 1998 was a year of below average energy prices, and that current and potential future energy prices are higher than the historical average. If real fuel prices increase faster than the EIA's projections, then conservation measures may lead to fewer projected boilers and process heaters. This trend would lead to an overestimate (upward bias) of the impact estimates presented in this report.

2. *Estimate the number of new boilers by model number-fuel type*. To predict the number of new boilers in operation by 2005, EPA applied the percentage difference for each fuel category to the 1998 fuel consumption of boilers represented by the boiler models to calculate total energy consumed by boilers in 2005 for each model number. The number of new boilers per model was calculated by dividing the model fuel forecasts by the annual fuel consumption of one unit and then subtracting the number of units present in 1998, as follows:

$$\text{Number of New Units} = \left(\frac{\text{Total energy consumed (2005) [MMBtu/yr]}}{\text{Avg capacity [MMBtu/hr]} \times 8{,}760 \text{ [hr/yr]}} \right) - \text{Number of Units} \quad (1998)$$

Following these steps, EPA projects that 1,458 boilers and 374 process heaters to be installed between 1998 and 2005 will be affected by the new source MACT floor and the Option 1A alternative. The only new ICI boilers and process heaters that will be unaffected are those natural gas and distillate fuel units that have input capacities less than 10 MMBtu/hr. These projections were developed by model unit type, not by industry. To assess the distribution of the boilers and process heaters estimated to be operating in 2005 across industries, EPA attached unit-level weights by model number to each unit in the Inventory Database. These weights 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 units by industry.

Table 3-6 presents the projected number of new boilers and process heaters for the MACT floor and Option1A above-the-floor alternatives. Industries with the estimated greatest concentrations of new units include chemicals and allied products (295), petroleum refining (198), electric services (134), and paper and allied products (96). New source estimates by industry were not developed for the Option 1B above-the-floor alternative.

3.4 National Engineering Population, Cost Estimates, and Cost-Effectiveness Estimates

The Agency estimates that in 2005 5,562 units (existing units and new units) may be affected by the floor alternative and 9,163 units may be affected by the Option 1A above-the-floor alternative. These populations were used to estimate national engineering costs. The population estimates were determined by unit configuration, not by industry. Thus, the distribution of units by industry shown in Tables 3-6 and 3-7 was determined by weighting existing units by the estimates by unit configuration and tallying weighted units by SIC code. The average cost of control by unit configuration was multiplied by the weighted number of units to determine industry-level control cost estimates.

Table 3-8 presents industry-level population and cost estimates for boilers and process heaters for both the floor and above-the-floor alternatives. The distribution of weighted units across industries mirrors that of the analysis population even though it was determined by weighting units by configuration, not industry-level growth estimates. The floor cost of control for the estimated 5,562 boilers and process heaters is $863.0 million, with an average per-unit additional control cost of $155,157. The Option 1A cost of control for the 9,163 potentially affected units is $1,995.8 million, with an average per-unit cost of $217,811.

Table 3-6. New Unit Projections by Industry, MACT Floor and Option 1A Alternatives

SIC Code	NAICS Code	Description	Floor Alternative New Units	Floor Alternative Cost	Option 1A Alternative New Units	Option 1A Alternative Cost
01	111	Agriculture—Crops	—	—	—	—
02	112	Agriculture—Livestock	—	—	—	—
07	115	Agricultural Services	—	—	—	—
10	212	Metal Mining	6	$47,040	6	$47,040
12	212	Coal Mining	1	$7,840	1	$7,840
13	211	Oil and Gas Extraction	89	$697,760	89	$697,760
14	212	Mining/Quarrying—Nonmetallic Minerals	6	$87,740	6	$87,740
17	235	Construction—Special Trade Contractors	—	—	—	—
20	311	Food and Kindred Products	63	$801,836	63	$11,170,931
21	312	Tobacco Products	7	$54,880	7	$54,880
22	313	Textile Mill Products	73	$1,329,391	73	$1,463,682
23	315	Apparel and Other Products from Fabrics	—	—	—	—
24	321	Lumber and Wood Products	61	$1,748,655	61	$10,621,232
25	337	Furniture and Fixtures	47	$1,354,701	47	$4,306,979
26	322	Paper and Allied Products	96	$1,526,704	96	$15,984,332
27	511	Printing, Publishing, and Related Industries	19	$148,960	19	$148,960
28	325	Chemicals and Allied Products	295	$3,793,738	295	$3,883,243
29	324	Petroleum Refining and Related Industries	198	$1,552,320	198	$1,552,320
30	326	Rubber and Miscellaneous Plastics Products	44	$385,660	44	$385,660
31	316	Leather and Leather Products	5	$39,200	5	$39,200
32	327	Stone, Clay, Glass, and Concrete Products	37	$549,975	37	$549,975
33	331	Primary Metal Industries	80	$2,873,492	80	$2,873,492
34	332	Fabricated Metal Products	53	$496,920	53	$496,920
35	333	Industrial Machinery and Computer Equipment	35	$396,500	35	$396,500
36	335	Electronic and Electrical Equipment	40	$313,600	40	$313,600
37	336	Transportation Equipment	80	$1,133,423	80	$1,357,219
38	334	Scientific, Optical, and Photographic Equipment	11	$86,240	11	$86,240
39	339	Miscellaneous Manufacturing Industries	9	$162,323	9	$254,722
40	482	Railroad Transportation	—	—	—	—
42	484	Motor Freight and Warehousing	1	$48,540	1	$48,540

(continued)

Table 3-6. New Unit Projections by Industry, MACT Floor and Option 1A Alternatives (continued)

SIC Code	NAICS Code	Description	Floor Alternative New Units	Floor Alternative Cost	Option 1A Alternative New Units	Option 1A Alternative Cost
46	486	Pipelines, Except Natural Gas	1	$7,840	1	$7,840
49	221	Electric, Gas, and Sanitary Services	134	$2,094,546	134	$10,490,757
50	421	Wholesale Trade—Durable Goods	—	—	—	—
51	422	Wholesale Trade—Nondurable Goods	—	—	—	—
55	441	Automotive Dealers and Gasoline Service Stations	—	—	—	—
58	722	Eating and Drinking Places	—	—	—	—
59	445–454	Miscellaneous Retail	—	—	—	—
60	522	Depository Institutions	—	—	—	—
70	721	Hotels and Other Lodging Places	—	—	—	—
72	812	Personal Services	1	$7,840	1	$7,840
76	811	Miscellaneous Repair Services	—	—	—	—
80	621	Health Services	6	$209,840	6	$209,840
81	541	Legal Services	—	—	—	—
82	611	Educational Services	19	$815,855	19	$815,855
83	624	Social Services	—	—	—	—
86	813	Membership Organizations	—	—	—	—
87	541	Engineering, Accounting, Research, Management and Related Services	2	$388,350	2	$388,350
89	711/514	Services, N.E.C.	—	—	—	—
91	921	Executive, Legislative, and General Administration	—	—	—	—
92	922	Justice, Public Order, and Safety	4	$153,460	4	$153,460
94	923	Administration of Human Resources	—	—	—	—
96	926	Administration of Economic Programs	—	—	—	—
97	928	National Security and International Affairs	2	$97,080	2	$97,080
NA		SIC Information Not Available	307	$2,497,327	307	$2,586,832
State		Parent is a State Government	—	—	—	—
			1,832	$25,909,574	1,832	$71,586,861

Table 3-7. Unit Cost and Population Estimates for the Floor Alternative by Industry, 2005

SIC Code	NAICS Code	Description	Total Units: Floor Units	Total Units: Percent	Total Cost: Floor Costs (by Unit)	Total Cost: Percent
01	111	Agriculture—Crops	5	0.08%	$628,943	0.07%
02	112	Agriculture—Livestock	—	0.00%	—	0.00%
07	115	Agricultural Services	—	0.00%	—	0.00%
10	212	Metal Mining	27	0.48%	$6,651,678	0.77%
12	212	Coal Mining	6	0.10%	$683,026	0.08%
13	211	Oil and Gas Extraction	89	1.60%	$697,760	0.08%
14	212	Mining/Quarrying—Nonmetallic Minerals	25	0.46%	$8,253,479	0.96%
17	235	Construction—Special Trade Contractors	—	0.00%	—	0.00%
20	311	Food and Kindred Products	312	5.60%	$37,774,020	4.38%
21	312	Tobacco Products	28	0.51%	$6,014,216	0.70%
22	313	Textile Mill Products	360	6.47%	$74,152,804	8.59%
23	315	Apparel and Other Products from Fabrics	4	0.08%	$679,510	0.08%
24	321	Lumber and Wood Products	483	8.68%	$48,896,055	5.67%
25	337	Furniture and Fixtures	311	5.59%	$29,632,880	3.43%
26	322	Paper and Allied Products	565	10.15%	$123,008,263	14.25%
27	511	Printing, Publishing, and Related Industries	19	0.34%	$148,960	0.02%
28	325	Chemicals and Allied Products	644	11.58%	$116,236,183	13.47%
29	324	Petroleum Refining and Related Industries	217	3.91%	$4,620,563	0.54%
30	326	Rubber and Miscellaneous Plastics Products	73	1.32%	$6,356,835	0.74%
31	316	Leather and Leather Products	7	0.13%	$607,530	0.07%
32	327	Stone, Clay, Glass, and Concrete Products	57	1.02%	$6,253,678	0.72%
33	331	Primary Metal Industries	159	2.85%	$27,110,619	3.14%
34	332	Fabricated Metal Products	87	1.56%	$10,042,680	1.16%
35	333	Industrial Machinery and Computer Equipment	84	1.51%	$11,208,392	1.30%
36	335	Electronic and Electrical Equipment	52	0.93%	$3,744,828	0.43%
37	336	Transportation Equipment	300	5.39%	$55,440,341	6.42%
38	334	Scientific, Optical, and Photographic Equipment	26	0.46%	$3,511,206	0.41%
39	339	Miscellaneous Manufacturing Industries	12	0.22%	$826,346	0.10%
40	482	Railroad Transportation	9	0.16%	$1,251,062	0.14%
42	484	Motor Freight and Warehousing	12	0.22%	$2,128,148	0.25%

(continued)

Table 3-7. Unit Cost and Population Estimates for the Floor Alternative by Industry, 2005 (continued)

			Total Units		Total Cost	
SIC Code	NAICS Code	Description	Floor Units	Percent	Floor Costs (by Unit)	Percent
46	486	Pipelines, Except Natural Gas	1	0.02%	$7,840	0.00%
49	221	Electric, Gas, and Sanitary Services	718	12.91%	$150,341,645	17.42%
50	421	Wholesale Trade—Durable Goods	6	0.12%	$2,154,760	0.25%
51	422	Wholesale Trade—Nondurable Goods	4	0.07%	$1,673,511	0.19%
55	441	Automotive Dealers and Gasoline Service Stations	—	0.00%	—	0.00%
58	722	Eating and Drinking Places	—	0.00%	—	0.00%
59	445–454	Miscellaneous Retail	—	0.00%	—	0.00%
60	522	Depository Institutions	—	0.00%	—	0.00%
70	721	Hotels and Other Lodging Places	2	0.04%	$567,811	0.07%
72	812	Personal Services	1	0.02%	$7,840	0.00%
76	811	Miscellaneous Repair Services	4	0.08%	$625,531	0.07%
80	621	Health Services	86	1.55%	$15,172,212	1.76%
81	541	Legal Services	—	0.00%	—	0.00%
82	611	Educational Services	251	4.52%	$60,490,956	7.01%
83	624	Social Services	5	0.08%	$820,191	0.10%
86	813	Membership Organizations	—	0.00%	—	0.00%
87	541	Engineering, Accounting, Research, Management and Related Services	38	0.68%	$2,240,544	0.26%
89	711/514	Services, N.E.C.	2	0.04%	$918,360	0.11%
91	921	Executive, Legislative, and General Administration	2	0.04%	$312,765	0.04%
92	922	Justice, Public Order, and Safety	69	1.23%	$13,707,649	1.59%
94	923	Administration of Human Resources	2	0.04%	$314,316	0.04%
96	926	Administration of Economic Programs	8	0.15%	$2,300,308	0.27%
97	928	National Security and International Affairs	64	1.16%	$18,018,010	2.09%
NA		SIC Information Not Available	326	5.86%	$6,747,652	0.78%
State		Parent is a state government	—	0.00%	—	0.00%
			5,562		$862,981,906	

Table 3-8. Unit Cost and Population Estimates for the Option 1A Above-the-Floor Alternative by Industry, 2005

SIC Code	NAICS Code	Description	Total Units: Option 1A Units	Total Units: Percent	Total Cost: Option 1A Costs (by Unit)	Total Cost: Percent
01	111	Agriculture—Crops	11	0.12%	$1,633,841	0.08%
02	112	Agriculture—Livestock	—	0.00%	—	0.00%
07	115	Agricultural Services	—	0.00%	—	0.00%
10	212	Metal Mining	34	0.37%	$8,952,098	0.45%
12	212	Coal Mining	6	0.06%	$683,026	0.03%
13	211	Oil and Gas Extraction	137	1.50%	$6,070,001	0.30%
14	212	Mining/Quarrying—Nonmetallic Minerals	31	0.34%	$17,958,177	0.90%
17	235	Construction—Special Trade Contractors	2	0.03%	$230,525	0.01%
20	311	Food and Kindred Products	376	4.10%	$122,487,346	6.14%
21	312	Tobacco Products	56	0.61%	$13,685,614	0.69%
22	313	Textile Mill Products	673	7.34%	$147,094,726	7.37%
23	315	Apparel and Other Products from Fabrics	10	0.11%	$1,213,586	0.06%
24	321	Lumber and Wood Products	620	6.77%	$89,961,854	4.51%
25	337	Furniture and Fixtures	421	4.60%	$50,045,573	2.51%
26	322	Paper and Allied Products	1,050	11.46%	$323,736,302	16.22%
27	511	Printing, Publishing, and Related Industries	37	0.40%	$1,824,933	0.09%
28	325	Chemicals and Allied Products	1,359	14.83%	$293,027,205	14.68%
29	324	Petroleum Refining and Related Industries	677	7.38%	$73,172,001	3.67%
30	326	Rubber and Miscellaneous Plastics Products	178	1.94%	$18,100,195	0.91%
31	316	Leather and Leather Products	66	0.72%	$6,924,480	0.35%
32	327	Stone, Clay, Glass, and Concrete Products	154	1.68%	$17,509,996	0.88%
33	331	Primary Metal Industries	271	2.95%	$65,174,064	3.27%
34	332	Fabricated Metal Products	165	1.80%	$22,066,661	1.11%
35	333	Industrial Machinery and Computer Equipment	151	1.65%	$26,418,385	1.32%
36	335	Electronic and Electrical Equipment	167	1.82%	$18,770,867	0.94%
37	336	Transportation Equipment	453	4.95%	$107,402,909	5.38%
38	334	Scientific, Optical, and Photographic Equipment	104	1.13%	$13,638,983	0.68%
39	339	Miscellaneous Manufacturing Industries	37	0.41%	$4,222,427	0.21%
40	482	Railroad Transportation	9	0.10%	$2,240,871	0.11%
42	484	Motor Freight and Warehousing	19	0.21%	$3,475,610	0.17%

(continued)

Table 3-8. Unit Cost and Population Estimates for the Option 1A Above-the-Floor Alternative by Industry, 2005 (continued)

			Total Units		Total Cost	
SIC Code	NAICS Code	Description	Option 1A Units	Percent	Option 1A Costs (by Unit)	Percent
46	486	Pipelines, Except Natural Gas	19	0.21%	$1,959,589	0.10%
49	221	Electric, Gas, and Sanitary Services	865	9.44%	$331,479,389	16.61%
50	421	Wholesale Trade—Durable Goods	6	0.07%	$2,675,296	0.13%
51	422	Wholesale Trade—Nondurable Goods	4	0.04%	$2,693,380	0.13%
55	441	Automotive Dealers and Gasoline Service Stations	2	0.02%	$195,421	0.01%
58	722	Eating and Drinking Places	—	0.00%	—	0.00%
59	445–454	Miscellaneous Retail	3	0.03%	$259,585	0.01%
60	522	Depository Institutions	—	0.00%	—	0.00%
70	721	Hotels and Other Lodging Places	2	0.02%	$849,114	0.04%
72	812	Personal Services	1	0.01%	$7,840	0.00%
76	811	Miscellaneous Repair Services	4	0.05%	$1,120,435	0.06%
80	621	Health Services	93	1.01%	$22,545,605	1.13%
81	541	Legal Services	—	0.00%	—	0.00%
82	611	Educational Services	273	2.98%	$91,770,778	4.60%
83	624	Social Services	8	0.08%	$1,448,405	0.07%
86	813	Membership Organizations	—	0.00%	—	0.00%
87	541	Engineering, Accounting, Research, Management and Related Services	49	0.54%	$5,016,627	0.25%
89	711/514	Services, N.E.C.	2	0.02%	$1,211,582	0.06%
91	921	Executive, Legislative, and General Administration	5	0.06%	$845,423	0.04%
92	922	Justice, Public Order, and Safety	77	0.85%	$21,308,885	1.07%
94	923	Administration of Human Resources	2	0.02%	$314,316	0.02%
96	926	Administration of Economic Programs	8	0.09%	$4,200,975	0.21%
97	928	National Security and International Affairs	96	1.05%	$36,080,306	1.81%
NA		SIC Information Not Available	368	4.01%	$12,099,975	0.61%
State		Parent is a state government	—	0.00%	—	0.00%
			9,163		$1,995,805,181	

The Agency estimates that Option 1B will potentially affect 62,215 boilers and process heaters. The Option 1B cost of control for the 62,215 potentially affected units is $2,944.8 million. Option 1B costs are not presented by industry because approximately one-third of the units did not have SIC code (and, hence, no NAICS code) information.

SECTION 4

PROFILES OF AFFECTED INDUSTRIES

This section contains profiles of the major industries affected by the proposed MACT for boilers and process heaters. Included are profiles of the following industries:

- Textile Mill Products (SIC 22/NAICS 313)
- Lumber and Wood Products (SIC 24/NAICS 321)
- Furniture and Related Product Manufacturing (SIC 25/NAICS 337)
- Paper and Allied Products (SIC 26/NAICS 322)
- Medicinal Chemicals and Botanical Products and Pharmaceutical Preparations (SICs 2833, 2834/NAICS 32451)
- Industrial Organic Chemicals (SIC 2869/NAICS 3251)
- Electric Services (SIC 4911/NAICS 22111)

4.1 Textile Mill Products (SIC 22/NAICS 313)

The textile industry is one of the few industries found throughout the world, from the most industrialized countries to the poorest. This industry includes firms producing the following products: broadwoven fabric; weft, lace, and warp knit fabrics; carpets and rugs; spun yarn products; and man-made fibers. The United States has typically run a trade deficit in the textiles sector in recent years, importing about $1.3 billion more than was exported in 1995. Although trade has become an increasingly important part of this industry, trade in this segment is relatively small compared with trade in the downstream apparel segment. In 1996, the total value of shipments for the textile industry was $80,242 million.

4.2 Lumber and Wood Products (SIC 24/NAICS 321)

The lumber and wood products industry comprises a large number of establishments engaged in logging; operating sawmills and planing mills; and manufacturing structural wood panels, wooden containers, and other wood products. Table 4-1 lists the lumber and wood products markets that are likely to be affected by the proposed regulation on boilers. Most products are produced for the domestic market, but exports increasingly account for a larger proportion of sales (Haltmaier, 1998). The largest consumers of lumber and wood products are the remodeling and construction industries.

Table 4-1. Lumber and Wood Products Markets Likely to Be Affected by the Regulation

SIC	NAICS	Description
2421	321113	Sawmills and Planing Mills, General
2434	33711	Wood Kitchen Cabinets
2449	32192	Wood Containers, N.E.C.
2491	32114	Wood Preserving
2493	321219	Reconstituted Wood Products
2499	321999	Wood Products, N.E.C.

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.

In 1996, the lumber and wood products industry's total value of shipments was $85,724.0 million. As seen in Table 4-2, shipment values increased steadily through the late 1980s before declining slightly through the early 1990s as new construction starts and furniture purchases declined (Haltmaier, 1998). Shipment values recovered, however, as the economy expanded in the mid-1990s.

4.2.1 Supply Side of the Industry

This section describes the lumber industry's production processes, output, costs of production, and capacity utilization.

Table 4-2. Value of Shipments for the Lumber and Wood Products Industry (SIC 24/NAICS 321), 1987–1996

Year	Value of Shipments (1992 $$10^6$)
1987	85,383.4
1988	85,381.2
1989	85,656.8
1990	86,203.0
1991	81,666.0
1992	81,564.8
1993	74,379.6
1994	79,602.0
1995	87,574.6
1996	85,724.0

Sources: U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures [Multiple Years]*. Washington, DC: Government Printing Office.

4.2.1.1 Production Processes

Sawn lumber. Sawn lumber is softwood or hardwood trimmed at a sawmill for future uses in construction, flooring, furniture, or other markets. Softwoods, such as Douglas fir and spruce, are used for framing in residential or light-commercial construction. Hardwoods, such as maple and oak, are used in flooring, furniture, crating, and other applications.

Lumber is prepared at mills using a four-step process. First, logs are debarked and trimmed into cants, or partially finished lumber. The cants are then cut to specific lengths. Logs are generally kept wet during storage to prevent cracking and to keep them supple. However, after being cut, the boards undergo a drying process, either in open air or in a kiln, to reduce the moisture content. The drying process may take several months and varies according to the plant's climate and the process used. Finally, the lumber may be treated with a surface protectant to prevent sap stains and prepare it for export (EPA, 1995a).

Reconstituted wood products. Reconstituted wood products, such as particleboard, medium density fiberboard, hardboard, and oriented strandboard, are made from raw wood that is combined with resins and other additives and processed into boards. The size of the wood particles used varies from sawdust to strands of wood. Once combined, the ingredients are formed into a mat and then, at high temperatures, pressed into a board. A final finishing process prepares the boards for delivery.

Wood preserving. Wood is treated with preservative to protect it from mechanical, physical, and chemical influences (EPA, 1995a). Treatment agents are either water-based inorganics, such as copper arsenate (78 percent), or oil-borne organics, such as creosote (21 percent) (EPA, 1995a). Wood preservatives are usually applied using a pressure treatment process or a dipping tank. Producers achieve the best results when the lumber's moisture content is reduced to a point where the preservative can be easily soaked into the wood. Treated wood is then placed in a kiln or stacked in a low-humidity climate to dry.

4.2.1.2 Types of Output

The lumber and wood products industry produces essential inputs into the construction, remodeling, and furniture sectors. Lumber and reconstituted wood products are produced in an array of sizes and can be treated to enhance their value and shelf-life. These products are intermediate goods; they are purchased by other industries and incorporated into higher value-added products. In addition to sawmills, the lumber and wood products industry includes kitchen cabinets, wood containers, and other wooden products used for fabricating finished goods for immediate consumption.

4.2.1.3 Major By-Products and Co-Products

Shavings, sawdust, and wood chips are the principal co-products of sawn lumber. Paper mills and makers of reconstituted wood products frequently purchase this material as an input. By-products are limited to emissions from the drying process and from use of preservatives.

Very little solid waste is generated by reconstituted wood products manufacturing. Because the production process incorporates all parts of the sawn log, little is left over as waste. However, air emissions from dryers are a source of emissions.

Wood preserving results in two types of by-products: air emissions and process debris. As preservatives dry, either in a kiln or outside, they emit various chemicals into the air. At plants with dipping processes, wood chips, stones, and other debris build up in the dipping tank. The debris is routinely collected and disposed of.

4.2.1.4 Costs of Production

The costs of production for the wood products industry fluctuate with the demand for the industry's products. Most notably, the costs of production steadily declined during the early 1990s as recession stifled furniture purchases and new housing starts (see Table 4-3). Overall, employment in the lumber and wood products industry increased approximately 6 percent from 1987 to 1996. During this same period, payroll costs decreased 12 percent, indicating a decrease in average annual income per employee. New capital investment and costs of materials generally moved in tandem over the 10-year period, increasing from 1987 to 1990 and 1994 to 1996 and decreasing from 1991 to 1993.

4.2.1.5 Capacity Utilization

Full production capacity is broadly defined as the maximum level of production an establishment can obtain under normal operating conditions. The capacity utilization ratio is the ratio of the actual production level to the full production level. Table 4-4 presents the historical trends in capacity utilization for the lumber and wood products industry. The varying capacity utilization ratios reflect adjusting production levels and new production facilities going on- or off-line. The capacity utilization ratio for the industry in 1996 was 78; the average over the last 6 years was 79 percent.

4.2.2 Demand Side of the Industry

This section describes the demand side of the market, including product characteristics, the uses and consumers of the final products, organization of the industry, and markets and trends.

4.2.3 Product Characteristics

Lumber and wood products are valued both for their physical attributes and their relative low cost. Wood is available in varying degrees of durability, shades, and sizes and can be easily shaped. Lumber and wood products have long been the principal raw materials for the residential and light commercial construction industries, the remodeling industry, and the furniture industry.

Table 4-3. Inputs for the Lumber and Wood Products Industry (SIC 24/NAICS 321), 1987–1996

Year	Labor		Materials (1992 $$10^6$)	New Capital Investment (1992 $$10^6$)
	Quantity (10^3)	Payroll (1992 $$10^6$)		
1987	698.4	15,555.5	50,509.2	2,234.3
1988	702.4	15,800.0	51,341.0	2,099.4
1989	684.2	15,381.3	51,742.2	2,329.9
1990	677.7	15,612.9	53,369.0	2,315.3
1991	623.6	14,675.8	50,416.3	2,006.5
1992	655.8	13,881.8	48,570.0	1,760.1
1993	685.4	11,798.9	45,300.3	1,538.1
1994	718.5	12,212.5	48,535.6	1,956.8
1995	740.2	13,915.4	53,732.9	2,553.1
1996	738.7	13,933.7	52,450.1	2,659.9

Sources: U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures [Multiple Years]*. Washington, DC: Government Printing Office.

Table 4-4. Capacity Utilization Ratios for Lumber and Wood Products Industry, 1991–1996

1991	1992	1993	1994	1995	1996
78	80	81	80	77	78

Note: All values are percentages.
Source: U.S. Department of Commerce, Bureau of the Census. 1998. *Survey of Plant Capacity: 1996.* Washington, DC: Government Printing Office.

Wood is readily available because over one-third of the United States is forested. The ready supply of wood reduces its costs.

4.2.4 Uses and Consumers of Outputs

Lumber and wood products are used in a wide range of applications, including residential and noresidential construction; repair/remodeling and home improvement projects; manufactured housing; millwork and wood products; pulp, paper, and paperboard mills; toys and sporting goods; kitchen cabinets; crates and other wooden containers; office and household furniture; and motor homes and recreational vehicles (Haltmaier, 1998).

4.2.5 Organization of the Industry

In 1992, 33,878 companies produced lumber and wood products and operated 35,807 facilities, as shown in Table 4-5. By way of comparison, in 1987, 32,014 companies controlled 33,987 facilities. About two-thirds of all establishments have nine or fewer employees. Between 1987 and 1992, the number of facilities with nine or fewer employees increased more than 10 percent to 23,590. These facilities' share of the value of shipments increased about 18.3 percent. Although the number of establishments employing 100 to 249 people decreased during that time, that category's shipment value jumped nearly 40 percent. The remaining facility categories lost both facilities and value of shipment.

Market structure can affect the size and distribution of regulatory impacts. Concentration ratios are often used to evaluate the degree of competition in a market, with low concentration indicating the presence of a competitive market, and higher concentration suggesting less-competitive markets. Firms in less-concentrated industries are more likely to be price takers, while firms in more-concentrated industries are more likely to influence market prices. Typical measures include four- and eight-firm concentration ratios (CR4 and CR8) and Herfindahl-Hirschmann indices (HHI). The CR4 for lumber and wood products subsectors represented in the boilers inventory database ranges between 13 and 50, meaning that, in each subsector, the top firms' combined sales ranged from 13 to 50 percent of that respective subsector's total sales. The CR8 ranges from 47 to 66 (U.S. Department of Commerce, 1995d).

Although there is no objective criterion for determining market structure based on the values of concentration ratios, the 1992 Department of Justice's (DOJ's) Horizontal Merger Guidelines provide criteria for doing so based on HHIs. According to these criteria, industries with

Table 4-5. Size of Establishments and Value of Shipments for the Lumber and Wood Products Industry (SIC 24/NAICS 321)

	1987		1992	
Average Number of Employees in Establishment	**Number of Facilities**	**Value of Shipments (1992 $$10^6$)**	**Number of Facilities**	**Value of Shipments (1992 $$10^6$)**
1 to 4 employees	14,562	2,769.7	15,921	3,288.9
5 to 9 employees	6,702	4,264.4	7,669	5,030.4
10 to 19 employees	5,353	6,982.3	5,331	6,902.8
20 to 49 employees	4,160	28,551.3	3,924	26,964.9
50 to 99 employees	1,702	(D)	1,615	(D)
100 to 249 employees	1,190	24,583.3	1,082	34,051.4
250 to 499 employees	260	12,093.4	219	(D)
500 to 999 employees	47	3,907.9	39	3,331.4
1,000 to 2,499 employees	4	2,231.3	4	598.6
2,500 or more employees	2	(D)	3	1,396.4
Total	33,987	85,383.4	35,807	81,564.8

(D) = undisclosed

Sources: U.S. Department of Commerce, Bureau of the Census. 1991. *1987 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.

HHIs below 1,000 are considered unconcentrated (i.e., more competitive), those with HHIs between 1,000 and 1,800 are considered moderately concentrated (i.e., moderately competitive), and those with HHIs above 1,800 are considered highly concentrated (i.e., less competitive) (DOJ, 1992). Firms in less-concentrated industries are more likely to be price takers, while firms in more-concentrated industries are more likely to be able to influence market prices. The unconcentrated nature of the markets is also indicated by HHIs of 1,000 or less (DOJ, 1992). Table 4-6 presents various measures of market concentration for sectors within the lumber and wood products industry. All lumber and wood products industries are considered unconcentrated and competitive.

Table 4-6. Measures of Market Concentration for Lumber and Wood Products Markets

SIC	Description	CR4	CR8	HHI	Number of Companies	Number of Facilities
2421	Saw Mills and Planing Mills	14	20	78	5,302	6004
2434	Wood Kitchen Cabinets	19	25	156	4,303	4323
2449	Wood Containers, N.E.C.	34	47	414	217	225
2491	Wood Preserving	17	28	152	408	486
2493	Reconstituted Wood Products	50	66	765	193	288
2499	Wood Products, N.E.C.	13	19	70	2,656	2754

Sources: U.S. Department of Commerce, Bureau of the Census. 1995d. *1992 Concentration Ratios in Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.

4.2.6 Markets and Trends

The U.S. market for lumber and wood products is maturing, and manufacturers are looking to enter other markets. Although 91 percent of the industry's products are consumed by the U.S. domestic market, the share of exports increases each year. Exports more than doubled in value from $3 billion in 1986 to $7.3 billion in 1996 (Haltmaier, 1998). The U.S. market grew only 2 percent between 1986 and 1996. American manufacturers are focusing on growing construction markets in Canada, Mexico, and the Pacific Rim, with products such as durable hardwood veneer products and reconstituted wood boards (EPA, 1995a).

4.3 Furniture and Related Product Manufacturing (SIC 25/NAICS 337)

More than 20,000 establishments in the United States produce furniture and furniture-related products. These establishments are located across the United States but are traditionally most concentrated in southern states, such as North Carolina, Mississippi, Alabama, and Tennessee. According to the "1997 Economic Census," these establishments employed more than 600,000 people and paid annual wages of nearly $15 billion. The overall industry-wide value of shipments was $63.9 billion that year (U.S. Department of Commerce, 2001).

This industry is in a state of change: rapid U.S. economic growth translated into vigorous sales of household and office furniture, but this trend is unlikely to continue as the U.S. economy cools after its record run. Adding to industry fluctuation is the merger of two large firms, Lay-Z-Boy and LADD Furniture. Although the industry includes a multitude of niche market players, it is really dominated by a few large companies that operate several subsidiaries, each with its own brand identity. It is unclear whether the merger between two key players in the market will compel other large manufacturers to pursue mergers and acquisitions.

What is clear, however, is that large U.S. manufacturers will seek to leverage their brand identities into wider profit margins by operating direct sales establishments and co-branding. Manufacturers that are moving into retail and distribution include Bassett Furniture, Thomasville Furniture, Ethan Allen Interiors, and Drexel. Co-branding efforts are aimed at capitalizing on the combined power of two identities, such as the Thomas Kinkade Collection from Lay-Z-Boy and popular artist Thomas Kinkade and the Ernest Hemingway Collection from Thomasville. The overarching goal is to enhance margins and ward off invigorated competition from foreign companies that have used this strategy to capture U.S. market share, such as the Swedish manufacturer Ikea (Lemm, 2000).

U.S. imports of household furniture totaled nearly $7 billion in 1998. Between 1992 and 1998, furniture imports grew at an annualized rate of nearly 15 percent. Jamie Lemm, an analyst with the U.S. Department of Commerce’s Office of Consumer Goods attributes this growth to changes in U.S. manufacturing and markets:

> A portion of [the] increase can be attributed to the labor-intensive furniture parts imported by U.S. manufacturers to enhance product lines, but the increase also signifies the growing importance of the U.S. market to foreign firms. While some U.S. manufacturers operate showrooms, galleries, and retail outlets in foreign markets, few sell internationally on a large scale. In 1998, U.S. furniture exports totaled $1.6 billion, accounting for only 6 percent of all U.S. product shipments.

4.4 Paper and Allied Products (SIC 26/NAICS 322)

The paper and allied products industry is one of the largest manufacturing industries in the United States. In 1996, the industry shipped nearly $150 billion in paper commodities. The industry produces a wide range of wood pulp, primary paper products, and paperboard products such as printing and writing papers, industrial papers, tissues, container board, and boxboard. The industry also includes manufacturers that "convert" primary paper and paperboard into finished products like envelopes, packaging, and shipping containers (EPA, 1995b). Paper and allied products industry subsectors that are likely to be affected by the proposed regulation are listed in Table 4-7.

Table 4-7. Paper and Allied Products Industry Markets Likely to Be Affected by Regulation

SIC	NAICS	Industry Description
2611	32211	Pulp Mills
2621	32212	Paper Mills
2676	322291	Sanitary Paper Products

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 4-8 lists the paper and allied products industry's value of shipments from 1987 to 1996. The industry's performance is tied to raw material prices, labor conditions, and worldwide inventories and demand (EPA, 1995b). Performance over the 10-year period was typical of most manufacturing industries. The industry expanded in the late 1980s, then contracted as demand tapered off as the industry suffered recessionary effects. In the two years after 1994, the industry's value of shipments increased 9.3 percent to $149.5 billion.

4.4.1 Supply Side of the Industry

4.4.1.1 Production Process

The manufacturing paper and allied products industry is capital- and resource-intensive, consuming large amounts of pulp wood and water in the manufacturing process. Approximately half of all paper and allied products establishments are integrated facilities, meaning that they produce both pulp and paper on-site. The remaining half produce only paper products; few facilities produce only pulp (EPA, 1995b).

Table 4-8. Value of Shipments for the Paper and Allied Products Industry (SIC 26/NAICS 322), 1987–1996

Year	Value of Shipments (1992 $\$10^6$)
1987	129,927.8
1988	136,829.4
1989	138,978.3
1990	136,175.7
1991	132,225.0
1992	133,200.7
1993	131,362.2
1994	136,879.9
1995	135,470.3
1996	149,517.1

Sources: U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summary*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures, [Multiple Years]*. Washington, DC: Government Printing Office.

The paper and paperboard manufacturing process can be divided into three general steps: pulp making, pulp processing, and paper/paperboard production. Paper and paperboard are manufactured using what is essentially the same process. The principal difference between the two products is that paperboard is thicker than paper's 0.3 mm.

Producers manufacture pulp mixtures by using chemicals, machines, or both to reduce raw material into small fibers. In the case of wood, the most common pulping material, chemical pulping actions release cellulose fibers by selectively destroying the chemical bonds that bind the fibers together (EPA, 1995b). Impurities are removed from the pulp, which then may be bleached to improve brightness. Only about 20 percent of pulp and paper mills practice bleaching (EPA, 1995b). The pulp may also be further processed to aid in the paper-making process.

During the paper-making stage, the pulp is strengthened and then converted into paper. Pulp can be combined with dyes, resins, filler materials, or other additives to better fulfill specifications for the final product. Next, the water is removed from the pulp, leaving the pulp on a wire or wire mesh conveyor. The fibers bond together as they are carried through heated presses and rollers. The paper is stored on large rolls before being shipped for conversion into another product, such as envelopes and boxes, or cut into paper sheets for immediate consumption.

4.4.1.2 Types of Output

The paper and allied products industry's output ranges from writing papers to containers and packaging. Paper products include printing and writing papers; paperboard boxes; corrugated and solid fiber boxes; fiber cans, drums, and similar products; sanitary food containers; building paper; packaging; bags; sanitary paper napkins; envelopes; stationary products; and other converted paper products.

4.4.1.3 Major By-Products and Co-Products

The paper and allied products industry is the largest user of industrial process water in the United States. In 1988, a typical mill used between 16,000 and 17,000 gallons of water per ton of paper produced. The equivalent amount of waste water discharged each day is about 16 million cubic meters (EPA, 1995b). Most facilities operate waste water treatment facilities on site to remove biological oxygen demand (BOD), total suspended solids (TSS), and other pollutants before discharging the water into a nearby waterway.

4.4.1.4 Costs of Production

Historical statistics for the costs of production for the paper and allied products industry are listed in Table 4-9. From 1987 to 1996, industry payroll generally ranged from approximately $19 to 20 billion. Employment peaked at 633,200 people in 1989 and declined slightly to 630,600 people by 1996. Materials costs averaged $74.4 billion a year and new capital investment averaged $8.3 billion a year.

4.4.1.5 Capacity Utilization

Table 4-10 presents the trend in capacity utilization for the paper and allied products industry. The varying capacities reflect adjusting production levels and new production facilities going on- or off-line. The average capacity utilization ratio for the paper and allied products industry between 1991 and 1996 was approximately 80, with capacity declining slightly in recent years.

Table 4-9. Inputs for the Paper and Allied Products Industry (SIC 26/NAICS 322), 1987–1996

Year	Labor		Materials (1992 10^6)	New Capital Investment (1992 10^6)
	Quantity (10^3)	Payroll (1992 10^6)		
1987	611.1	20,098.6	70,040.6	6,857.5
1988	619.8	19,659.0	73,447.4	8,083.8
1989	633.2	19,493.1	75,132.5	10,092.9
1990	631.2	19,605.2	74,568.8	11,267.2
1991	624.7	19,856.3	72,602.5	9,353.9
1992	626.3	20,491.9	73,188.0	7,962.4
1993	626.3	20,602.6	73,062.6	7,265.2
1994	621.4	20,429.7	76,461.6	6,961.7
1995	629.2	18,784.3	79,968.6	7,056.8
1996	630.6	19,750.0	75,805.9	8,005.9

Sources: U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures, Subject Series: General Summery*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures [Multiple Years]*. Washington, DC: Government Printing Office.

Table 4-10. Capacity Utilization Ratios for the Paper and Allied Products Industry, 1991–1996

1991	1992	1993	1994	1995	1996
78	80	81	80	77	78

Note: All values are percentages.
Source: U.S. Department of Commerce, Bureau of the Census. 1998. *Survey of Plant Capacity: 1996.* Washington, DC: Government Printing Office.

4.4.2 Demand Side of the Industry

4.4.2.1 Product Characteristics

Paper is valued for its diversity in product types, applications, and low cost due to ready access to raw materials. Manufacturers produce papers of varying durabilities, textures, and colors. Consumers purchasing large quantities of papers may have papers tailored to their specification. Papers may be simple writing papers or newsprint for personal consumption and for the printing and publishing industry or durable for conversion into shipping cartons, drums, or sanitary boxes. Inputs in the paper production process are readily available in the United States because one-third of the country is forested, and facilities generally have ready access to waterways.

4.4.2.2 Uses and Consumers of Products

The paper and allied products industry is an integral part of the U.S. economy; nearly every industry and service sector relies on paper products for its personal, education, and business needs. Among a myriad of uses, papers are used for correspondence, printing and publishing, packing and storage, and sanitary purposes. Common applications are all manners of reading material, correspondence, sanitary containers, shipping cartons and drums, and miscellaneous packing materials.

4.4.3 Organization of the Industry

In 1992, 4,264 companies produced paper and allied products and operated 6,416 facilities. By way of comparison, 4,215 companies controlled 1,732 facilities in 1987. Although the number of small firms and facilities increased during those 5 years, the industry is dominated by high-volume, low-cost producers (Haltmaier, 1998). Even though they account for only 45 percent of all facilities, those with 50 or more employees contribute more than 93 percent of the industry's total value of shipments (see Table 4-11). (According to the Small Business Administration, those companies employing fewer than 500 employees are "small.")

For paper and allied products markets likely to be affected by the proposed boilers regulation, the CR4 ranged between 29 and 68 in 1992 (see Table 4-12). This means that, in each subsector, the top firms' combined sales ranged from 29 to 68 percent of their respective industry's total sales. For example, in the sanitary paper products industry, the CR4 ratios indicate that a few

Table 4-11. Size of Establishments and Value of Shipments for the Paper and Allied Products Industry (SIC 26/NAICS 322)

	1987		1992	
Number of Employees in Establishment	Number of Facilities	Value of Shipments ($\$10^6$)	Number of Facilities	Value of Shipments ($\$10^6$)
1 to 4 employees	729	640.6	786	216
4 to 9 employees	531	(D)	565	483
10 to 19 employees	888	1,563.4	816	1,456.5
20 to 49 employees	1,433	18,328.6	1,389	6,366.6
50 to 99 employees	1,018	(D)	1,088	12,811.5
100 to 249 employees	1,176	32,141.7	1,253	35,114.0
250 to 499 employees	308	24,221.1	298	22,281.2
500 to 999 employees	145	28,129.1	159	31,356.5
1,000 to 2,499 employees	63	24,903.1	62	23,115.4
2,500 or more employees	1	(D)		
Total	1,732	129,927.8	6,416	133,200.7

(D) = undisclosed

Sources: U.S. Department of Commerce, Bureau of the Census. 1990c. *1987 Census of Manufactures, Industry Series: Pulp, Paper, and Board Mills*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995c. *1992 Census of Manufactures, Industry Series: Pulp, Paper, and Board Mills*. Washington, DC: Government Printing Office.

firms control 68 percent of the market. This sector's moderately concentrated nature is also indicated by its HHI of 1,451 (DOJ, 1992). The remaining two sectors' HHIs indicate that their respective markets are unconcentrated (i.e., competitive).

4.4.4 Markets and Trends

The Department of Commerce projects that shipments of paper and allied products will increase through 2002 by an annual average of 2.5 percent (Haltmaier, 1998). Because nearly all of the industry's products are consumer related, shipments will be most affected by the health of the U.S. and global economy. The United States is a key competitor in the international market for paper products and, after Canada, is the largest exporter of paper products. According to

Table 4-12. Measurements of Market Concentration for Paper and Allied Products Markets

SIC	Description	CR4	CR8	HHI	Number of Companies	Number of Facilities
2611	Pulp Mills	48	75	858	29	45
2621	Paper Mills	29	49	392	127	280
2676	Sanitary Paper Products	68	82	1,451	80	150

Sources: U.S. Department of Commerce, Bureau of the Census. 1995d. *1992 Concentration Ratios in Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995c. *1992 Census of Manufactures, Industry Series: Pulp, Paper, and Board Mills*. Washington, DC: Government Printing Office.

Haltmaier (1998), the largest paper and allied products exporters in the world are Canada (with 23 percent of the market), the United States (10 to 15 percent), Finland (8 percent), and Sweden (7 percent).

4.5 Medicinal Chemicals and Botanical Products and Pharmaceutical Preparations (SICs 2833, 2834/NAICS 32451)

The pharmaceutical preparations industry (SIC 2834/NAICS 32451) and the medicinal chemicals and botanical products industry (SIC 2833/NAICS 32451) are both primarily engaged in the research, development, manufacture, and/or processing of medicinal chemicals and pharmaceutical products. Apart from manufacturing drugs for human and veterinary consumption, the industries grind, grade, and mill botanical products that are inputs for other industries. Typically, most facilities cross over into both industries (EPA, 1997a). Products include drugs, vitamins, herbal remedies, and production inputs, such as alkaloids and other active medicinal principals.

Table 4-13 presents both industries' value of shipments from 1987 to 1996. Medicinals and botanicals' performance during the late 1980s and early 1990s was mixed. However, shipments increased steadily from 1994 to 1996, increasing 37.7 percent as natural products such as herbs and vitamins became more popular (EPA, 1997a). Pharmaceutical preparations' shipments increased steadily over the 10-year period. From 1987 to 1996, the industry's shipments increased 24.3 percent to $55.1 billion in 1996.

Table 4-13. Value of Shipments for the Medicinals and Botanicals and Pharmaceutical Preparations Industries, 1987–1996

Year	SIC 2833 Medicinals & Botanicals ($\$10^6$)	SIC 2834 Pharmaceutical Preparations ($\$10^6$)
1987	4,629.1	44,345.7
1988	5,375.4	46,399.1
1989	5,708.9	48,083.6
1990	5,535.8	49,718.0
1991	6,637.7	49,866.3
1992	6,438.5	50,417.9
1993	5,669.2	50,973.5
1994	5,774.7	53,144.7
1995	6,404.1	53,225.9
1996	7,952.8	55,103.6

Sources: U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures [Multiple Years]*. Washington, DC: Government Printing Office.

4.5.1 Supply Side of the Industry

4.5.1.1 Production Processes

The medicinals and botanical products industry and the pharmaceutical preparations industry share similar production processes. Many products of the former are inputs in the latter's production process. There are three manufacturing stages: research and development, preparation of bulk ingredients, and formulation of the final product.

The research and development stage is a long process both to ensure the validity and benefit of the end product and to satisfy the requirements of stringent federal regulatory committees. (The pharmaceutical industry operates under strict oversight of the Food and Drug Administration [FDA].) Therefore, every stage in the development of new drugs is thoroughly documented and studied. After a new compound is discovered, it is subjected to numerous laboratory and animal tests. Results are presented to the FDA via applications that present and fully disclose all findings to date. As research and development proceeds, studies are gradually expanded to involve human trials of the new compound. Should FDA approve the compound, the new product is readied for mass production.

To ensure a uniform product, all ingredients are prepared in bulk using batch processes. Companies produce enough of each ingredient to satisfy projected sales demand (EPA, 1997a). Prior to production, all equipment is thoroughly cleaned, prepared, and validated to prevent any contaminants from entering the production cycle. Most ingredients are prepared by chemical synthesis, a method whereby primary ingredients undergo a complex series of processes, including many intermediate stages and chemical reactions in a step-by-step fashion (EPA, 1997a).

After the bulk materials are prepared, they are converted into a final usable form. Common forms include tablets, pills, liquids, creams, and ointments. Equipment used in this final stage is prepared in the same manner as that involved in the bulk preparation process. Clean and validated machinery is used to process and package the pharmaceuticals for shipment and consumption.

4.5.1.2 Types of Output

Both industries produce pharmaceutical and botanical products for end consumption and intermediate products for the industries' own applications. Products include vitamins, herbal remedies, and alkaloids. Prescription and over-the-counter drugs are produced in liquid, tablet, cream, and other forms.

4.5.1.3 Major By-Products and Co-Products

Both industries produce many by-products because of the large number of primary inputs and the extensive chemical processes involved. Wastes and emissions vary by the process employed, raw materials consumed, and equipment used. In general, emissions originate during drying and heating stages and during process water discharge. Emissions controls are in place pursuant to environmental regulations. Other wastes include used filters, spent raw materials, rejected product, and reaction residues (EPA, 1997a).

4.5.1.4 Costs of Production

Table 4-14 presents SIC 2833 industry's costs of production and employment statistics from 1987 to 1996. Employment was stable during the late 1980s before steadily growing in the 1990s. In 1987, medicinals and botanicals employed 11,600 people. By 1996, the industry employed 16,800, an increase of nearly 45 percent. Materials costs matched the increase in

Table 4-14. Inputs for Medicinal Chemicals and Botanical Products Industry (SIC 2833/NAICS 32451), 1987–1996

	Labor			
Year	**Quantity (10^3)**	**Payroll ($\$10^6$)**	**Materials ($\$10^6$)**	**New Capital Investment ($\$10^6$)**
1987	11.6	520.2	2,229.3	158.2
1988	11.3	494.4	2,658.8	194.9
1989	11.4	504.9	3,118.4	263.4
1990	10.9	476.4	2,902.4	218.9
1991	12.5	568.6	3,368.2	512.9
1992	13.0	587.1	3,245.9	550.5
1993	13.0	584.3	2,638.4	470.0
1994	13.9	572.6	2,755.2	480.3
1995	14.1	625.0	3,006.0	356.2
1996	16.8	752.1	3,793.9	752.1

Sources: U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures, [Multiple Years]*. Washington, DC: Government Printing Office.

shipments over this same period. Industry growth also fed new capital investments, which averaged \$191.2 million a year in the late 1980s and \$515.6 million a year in the early to mid-1990s.

SIC 2834's costs of production and employment for 1987 to 1996 are presented in Table 4-15. The number of people employed by the industry ranged between 123,000 and 144,000; employment peaked in 1990 before declining by 21,000 jobs by the end of 1992. During this 10-year period, the cost of materials rose 42.1 percent. The increase is associated with increased product shipments and the development of new, more expensive medications (Haltmaier, 1998). New capital investment averaged \$2.3 billion a year.

4.5.1.5 Capacity Utilization

Table 4-16 presents the trend in these ratios from 1991 to 1996 for both industries. The varying capacity ratios reflect adjusting production volumes and new production facilities and

Table 4-15. Inputs for the Pharmaceutical Preparations Industry (SIC 2834/NAICS 32451), 1987–1996

Year	Labor: Quantity (10^3)	Labor: Payroll ($\$10^6$)	Materials ($\$10^6$)	New Capital Investment ($\$10^6$)
1987	131.6	5,759.2	11,693.7	2,032.7
1988	133.4	5,447.2	12,634.8	2,234.0
1989	141.8	6,177.5	12,874.2	2,321.4
1990	143.8	6,223.9	13,237.6	2,035.3
1991	129.1	5,275.8	13,546.6	1,864.7
1992	122.8	4,949.4	13,542.5	2,450.0
1993	128.2	5,184.2	13,508.7	2,385.2
1994	134.2	5,368.4	13,526.1	2,531.9
1995	143.0	5,712.4	15,333.6	2,856.1
1996	136.9	5,547.3	16,611.1	2,317.0

Sources: U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures, [Multiple Years]*. Washington, DC: Government Printing Office.

Table 4-16. Capacity Utilization Ratios for the Medicinal Chemicals and Botanical Products (SIC 2833/NAICS 32451) and Pharmaceutical Preparations (SIC 2834/NAICS 32451) Industries, 1991–1996

	1991	1992	1993	1994	1995	1996
SIC 2833/NAICS 32451	84	86	89	80	90	84
SIC 2834/NAICS 32451	76	74	70	67	63	67

Note: Capacity utilization ratio is the ratio of the actual production level to the full production level. All values are percentages.
Source: U.S. Department of Commerce, Bureau of the Census. 1998. *Survey of Plant Capacity: 1996*. Washington, DC: Government Printing Office.

capacity going both on- and off-line. In 1996, the capacity utilization ratios for SICs 2833 and 2834 were 84 and 67, respectively.

4.5.2 Demand Side of the Industry

New product introductions and improvements on older medications by the drug industry have greatly improved the health and well-being of the U.S. population (Haltmaier, 1998). Products help alleviate or reduce physical, mental, and emotional ailments or reduce the severity of symptoms associated with disease, age, and degenerative conditions. Dietary supplements, such as vitamins and herbal remedies, ensure that consumers receive nutrients of which they may not ordinarily consume enough. Products are available in a range of dosage types, such as tablets and liquids.

Although prescription medications are increasingly distributed through third parties, such as hospitals and health maintenance organizations, the general population remains the end user of pharmaceutical products. As the average age of the U.S. population adjusts to reflect large numbers of older people, the variety and number of drugs consumed increases. An older population will generally consume more medications to maintain and improve quality of life (Haltmaier, 1998).

4.5.3 Organization of the Industry

In 1992, 208 companies produced medicinal chemicals and botanical products and operated 225 facilities (see Table 4-17). The number of companies and facilities in 1992 was the same as that of 1987, although shipment values increased almost 40 percent. The average facility employed more people in 1992 than in 1987. In fact, the number of facilities employing 50 or more people grew from 37 to 45. These facilities accounted for the lion’s share of the industry’s shipments. According to the Small Business Administration, companies in this SIC code are considered small if they employ fewer than 750 employees. It is unclear what percentage of the facilities listed in Table 4-17 are small companies.

In 1992, 585 companies manufactured pharmaceutical preparations and operated 691 facilities. By way of comparison, 640 companies operated 732 facilities in 1987. Although the number of facilities declined by 41, no particular category lost or gained an exceptional number of facilities. The biggest movement was in the five to nine employees category, which lost 35 facilities.

Table 4-17. Size of Establishments and Value of Shipments for the Medicinal Chemicals and Botanical Products (SIC 2833/NAICS 32451) and Pharmaceutical Preparations (SIC 2834/NAICS 32451) Industries

Number of Employees in Establishment	1987 Number of Facilities	1987 Value of Shipments ($\$10^6$)	1992 Number of Facilities	1992 Value of Shipments ($\$10^6$)
SIC 2833/NAICS 32451				
1 to 4 employees	61	20.7	62	23.8
5 to 9 employees	34	38.6	42	58.3
10 to 19 employees	46	237.0	47	357.1
20 to 49 employees	47	287.3	29	182.0
50 to 99 employees	15	273.6	25	653.9
100 to 249 employees	12	520.6	10	5,163.4
250 to 499 employees	5	753.0	4	(D)
500 to 999 employees	4	2478.2	3	(D)
1,000 to 2,499 employees	1	(D)	3	(D)
Total	225	4629.1	225	6,438.5
SIC 2834/NAICS 32451				
1 to 4 employees	158	58.7	152	115.6
5 to 9 employees	108	178.8	73	105.4
10 to 19 employees	102	320.3	101	284.6
20 to 49 employees	117	932.5	110	815.7
50 to 99 employees	66	1231.0	65	1,966.8
100 to 249 employees	76	3596.0	77	2,912.4
250 to 499 employees	50	9239.7	56	11,394.6
500 to 999 employees	23	4946.9	30	10,077.7
1,000 to 2,499 employees	24	15,100.9	21	14,525.7
2,500 employees or more	8	8740.9	6	8,219.4
Total	732	44,345.7	691	50,417.9

(D) = undisclosed

Sources: U.S. Department of Commerce, Bureau of the Census. 1990a. *1987 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.

In both years, facilities with more than 50 employees accounted for at least 95 percent of the industry's shipments.

Table 4-18 presents the measures of market concentration for both industries. For the medicinals and botanicals industry, the CR4 was 76 in 1992, and the CR8 was 84 (U.S. Department of Commerce, 1995b). The highly concentrated nature of the market is further indicated by an HHI of 2,999 (DOJ, 1992). According to the Department of Justice's Horizontal Merger Guidelines, industries with HHIs above 1,800 are less competitive.

Table 4-18. Measures of Market Concentration for the Medicinal Chemicals and Botanical Products (SIC 2833/NAICS 32451) and Pharmaceutical Preparations (SIC 2834/NAICS 32451) Industries

SIC	NAICS	Industry	CR4	CR8	HHI	Number of Companies	Number of Facilities
2833	32451	Medicinal Chemicals and Botanical Products	76	84	2,999	208	225
2834	32451	Pharmaceutical Preparations	26	42	341	585	691

Sources: U.S. Department of Commerce, Bureau of the Census. 1995d. *1992 Concentration Ratios in Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995a. *1992 Census of Manufactures, Industry Series: Drug Industry*. Washington, DC: Government Printing Office.

The pharmaceuticals preparations industry is less concentrated than the medicinal chemicals and botanical products industry. For SIC 2834, the CR4 and CR8 were 26 and 42, respectively, in 1992. The industry's HHI was 341, indicating a competitive market.

4.5.4 Markets and Trends

According to the Department of Commerce, global growth in the consumption of pharmaceuticals is projected to accelerate over the coming decade as populations in developed countries age and those in developing nations gain wider access to health care. Currently, the United States remains the largest market for drugs, medicinals, and botanicals and produces more new products than any other country (Haltmaier, 1998). But, nearly two-fifths of American producers' sales are generated abroad. Top markets for American exports are China, Canada, Mexico, Australia, and Japan. Most imports originate in Canada, Russia, Mexico, Trinidad and Tobago, and Norway.

4.6 Industrial Organic Chemicals Industry (SIC 2869/NAICS 3251)

The industrial organic chemicals (not elsewhere classified) industry (SIC 2869/NAICS 3251) produces organic chemicals for end-use applications and for inputs into numerous other chemical manufacturing industries. In nominal terms, it was the single largest segment of the $367 billion chemical and allied products industry (SIC 28) in 1996, accounting for approximately 17 percent of the industry's shipments.

All organic chemicals are, by definition, carbon-based and are divided into two general categories: commodity and specialty. Commodity chemical manufacturers compete on price and produce large volumes of staple chemicals using continuous manufacturing processes. Specialty chemicals cater to custom markets, using batch processes to produce a diverse range of chemicals. Specialty chemicals generally require more technical expertise and research and development than the more standardized commodity chemicals industry (EPA, 1995c). Consequently, specialty chemical manufacturers have a greater value added to their products. End products for all industrial organic chemical producers are as varied as synthetic perfumes, flavoring chemicals, glycerin, and plasticizers.

Table 4-19 presents the shipments of industrial organic chemicals from 1987 to 1996. In real terms, the industry's shipments rose in the late 1980s to a high of $54.9 billion before declining in the early 1990s as the U.S. economy went into recession. By the mid-1990s, the industry recovered, as product values reached record highs (Haltmaier, 1998). Between 1993 and 1996, the industry's shipments grew 7.3 percent to $57.7 billion.

4.6.1 Supply Side of the Industry

4.6.1.1 Production Processes

Processes used to manufacture industrial organic chemicals are as varied as the end-products themselves. There are thousands of possible ingredients and hundreds of processes. Therefore, the discussion that follows is a general description of the ingredients and stages involved in a typical manufacturing process.

Table 4-19. Value of Shipments for the Industrial Organic Chemicals, N.E.C. Industry (SIC 2869/NAICS 3251), 1987-1996

Year	Value of Shipments (1992 $\$10^6$)
1987	48,581.7
1988	53,434.7
1989	54,962.9
1990	53,238.8
1991	51,795.6
1992	54,254.2
1993	53,805.2
1994	57,357.1
1995	59,484.3
1996	57,743.3

Sources: U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Manufactures, Industry Series: Industrial Organic Chemicals*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures, Multiple Years*. Washington, DC: Government Printing Office.

Essentially a set of ingredients (feedstocks) is combined in a series of reactions to produce end products and intermediates (EPA, 1995c). The typical chemical synthesis processes incorporate multiple feedstocks in a series of chemical reactions. Commodity chemicals are produced in a continuous reactor, and specialty chemicals are produced in batches. Specialty chemicals may undergo a series of reaction steps, as opposed to commodity chemicals' one continuous reaction because a finite amount of ingredients are prepared and used in the production process. Reactions usually take place at high temperatures, with one or two additional components being intermittently added. As the production advances, by-products are removed using separation, distillation, or refrigeration techniques. The final product may undergo a drying or pelletizing stage to form a more manageable substance.

4.6.1.2 Types of Output

Miscellaneous industrial organic chemicals comprise nine general categories of products:

- aliphitic and other acyclic organic chemicals (ethylene); acetic, chloroaceptic, adipic, formic, oxalic, and tartaric acids and their metallic salts; chloral, formaldehyde, and methylamine;
- solvents (ethyl alcohol etc.); methanol; amyl, butyl, and ethyl acetates; ethers; acetone, carbon disulfide and chlorinated solvents;
- polyhydric alcohols (synthetic glycerin, etc.);
- synthetic perfume and flavoring materials (citral, methyl, oinone, etc.);
- rubber processing chemicals, both accelerators and antioxidants (cyclic and acyclic);
- cyclic and acyclic plasticizers (phosphoric acid, etc.);
- synthetic tanning agents;
- chemical warfare gases; and
- esters, amines, etc., of polyhydric alcohols and fatty and other acids.

4.6.1.3 Major By-Products and Co-Products

Co-products, by-products, and emissions vary according to the ingredients, processes, maintenance practices, and equipment used (EPA, 1997b). Frequently, residuals from the reaction process that are separated from the end product are resold or possibly reused in the manufacturing process. A by-product from one process may be another’s input. The industry is strictly regulated because it emits chemicals through many types of media, including discharges to air, land, and water, and because of the volume and composition of these emissions.

4.6.1.4 Costs of Production

Of all the factors of production, employment in industrial organic chemicals fluctuated most often between 1987 and 1996 (see Table 4-20). During that time, employment fell 8.18 percent to 92,100, after a high of 101,000 in 1991. Most jobs lost were at the production level (Haltmaier, 1998). Facilities became far more computerized, incorporating advanced technologies into the production process. Even with the drop in employment, payroll was $200 million more in 1995

Table 4-20. Inputs for the Industrial Organic Chemicals Industry (SIC 2869/NAICS 3251), 1987–1996

Year	Labor		Materials (1992 $\$10^6$)	New Capital Investment (1992 $\$10^6$)
	Quantity (10^3)	Payroll (1992 $\$10^6$)		
1987	100.3	4,295.8	28,147.7	2,307.4
1988	97.1	4,045.1	29,492.8	2,996.5
1989	97.9	3,977.4	29,676.4	3,513.0
1990	100.3	4,144.6	29,579.2	4,085.5
1991	101.0	4,297.3	29,335.2	4,428.7
1992	100.1	4,504.2	31,860.6	4,216.6
1993	97.8	4,540.2	30,920.1	3,386.1
1994	89.8	4,476.5	33,267.4	2,942.8
1995	92.1	4,510.4	33,163.9	3,791.0
1996	100.3	5,144.8	36,068.9	4,794.7

Sources: U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Manufactures*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990–1998. *Annual Survey of Manufactures*. Washington, DC: Government Printing Office.

than in 1987. The cost of materials fluctuated between $29 and $36 billion for these years, and new capital investment averaged $3,646 million a year.

4.6.1.5 Capacity Utilization

Table 4-21 presents the trend in capacity utilization ratios from 1991 to 1996 for the industrial organic chemicals industry. The varying capacity utilization ratios reflect changes in production volumes and new production facilities and capacities going on- and off-line. The capacity utilization ratio for the industry averaged 85.3 over the 6-year period presented.

4.6.2 Demand Side of the Industry

Industrial organic chemicals are components of many chemical products. Most of the chemical sectors (classified under SIC 28) are downstream users of organic chemicals. These sectors either purchase commodity chemicals or enter into contracts with industrial organic chemical producers to obtain specialty chemicals. Consumers include inorganic chemicals (SIC 281), plastics and synthetics (SIC 282), drugs (283), soaps and cleaners (SIC 284), paints and allied products (SIC 286), and miscellaneous chemical products (SIC 289).

Table 4-21. Capacity Utilization Ratios for the Industrial Organic Chemicals Industry (SIC 2869/NAICS 3251), 1991–1996

	1991	**1992**	**1993**	**1994**	**1995**	**1996**
SIC 2869/NAICS 3251	86	81	91	89	84	84

Note: The capacity utilization ratio is the ratio of the actual production level to the full production level. All values are percentages.

Source: U.S. Department of Commerce, Bureau of the Census. 1998. *Survey of Plant Capacity: 1996.* Washington, DC: Government Printing Office.

4.6.3 Organization of the Industry

Although the industry's value of shipments increased nearly 12 percent between 1987 and 1992, the number of facilities producing industrial organic chemicals only increased by 6 percent. Facilities with 100 or more employees continued to account for the majority of the industry's shipment values. For example, in 1992, 28 percent of all facilities had 100 or more employees (see Table 4-22), and these facilities produced 89 percent of the industry's shipment values. The average number of facilities per firm was 1.4 in both years. According to the Small Business Administration, an industrial organic chemicals company is considered small if the total number of employees does not exceed 500. It is unclear what percentage of facilities are owned by small businesses.

The industrial organic chemicals (not elsewhere classified) industry is unconcentrated and competitive. The CR4 was 29 and the CR8 43; the industry's HHI was 336.

Table 4-22. Size of Establishments and Value of Shipments for the Industrial Organic Chemicals Industry (SIC 2869/NAICS 3251)

	1987		1992	
Number of Employees in Establishment	Number of Facilities	Value of Shipments (1992 $$10^6$)	Number of Facilities	Value of Shipments (1992 $$10^6$)
1 to 4 employees	97	552.8	100	102.6
5 to 9 employees	80	200.9	80	208.7
10 to 19 employees	91	484.7	97	533.9
20 to 49 employees	137	1,749.9	125	1,701.5
50 to 99 employees	99	2556.3	106	3,460.9
100 to 249 employees	110	10,361.2	111	8,855.9
250 to 499 employees	41	17,156.9	41	9,971.1
500 to 999 employees	27	9,615.5	30	13,755.0
1,000 to 2,499 employees	11	9,184.6	10	9,051.0
2,500 or more employees	6	7,156.9	5	6,613.5

Sources: U.S. Department of Commerce, Bureau of the Census. 1995b. *1992 Census of Manufactures, Industry Series: Industrial Organic Chemicals*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1990b. *1987 Census of Manufactures, Industry Series, Paints and Allied Products*. Washington, DC: Government Printing Office.

4.6.4 Markets and Trends

The U.S. industrial organic chemical industry is expected to expand through 2002 at an annual rate of 1.4 percent (Haltmaier, 1998). U.S. producers face increasing competition domestically and abroad as chemical industries in developing nations gain market share and increase exports to the United States. American producers will, however, benefit from decreasing costs for raw materials and energy and productivity gains.

4.7 Electric Services (SIC 4911/NAICS 22111)

The ongoing process of deregulation of wholesale and retail electric markets is changing the structure of the electric power industry. Deregulation is leading to the functional unbundling of generation, transmission, and distribution and to competition in the generation segment of the industry. This profile provides background information on the U.S. electric power industry and discusses current industry characteristics and trends that will influence the future generation and consumption of electricity. It is important to note that through out this report the terms “boilers,” “process heaters,” and “units” are synonymous with “ICI boilers” and “process heaters.” Boilers primarily engaged in the generation of electricity are not covered by the NESHAP under analysis and are therefore excluded from this analysis. Utility sources are not affected by this NESHAP except for a small number of nonfossil fuel units within this industry. Those units in this industry that are affected may be engaged in activities such as heating and mechanized work.

4.7.1 Electricity Production

Figure 4-1 illustrates the typical structure of the electric utility market. Even with the technological and regulatory changes in the 1970s and 1980s, at the beginning of the 1990s the structure of the electric utility industry could still be characterized in terms of generation, transmission, and distribution. Commercial and retail customers were in essence “captive,” and rates and service quality were primarily determined by public utility commissions.

The majority of utilities are interconnected and belong to a regional power pool. Pooling arrangements enable facilities to coordinate the economic dispatch of generation facilities and manage transmission congestion. In addition, pooling diverse loads can increase load factors and decrease costs by sharing reserve capacity.

4.7.1.1 Generation

As shown in Table 4-23, coal-fired plants have historically accounted for the bulk of electricity generation in the United States. With abundant national coal reserves and advances in pollution abatement technology, such as advanced scrubbers for pulverized coal and flue gas-desulfurization systems, coal will likely remain the fuel of choice for most existing generating facilities over the near term.

Natural gas accounts for approximately 10 percent of current generation capacity but is expected to grow; advances in natural gas exploration and extraction technologies and new coal gasification have contributed to the use of natural gas for power generation.

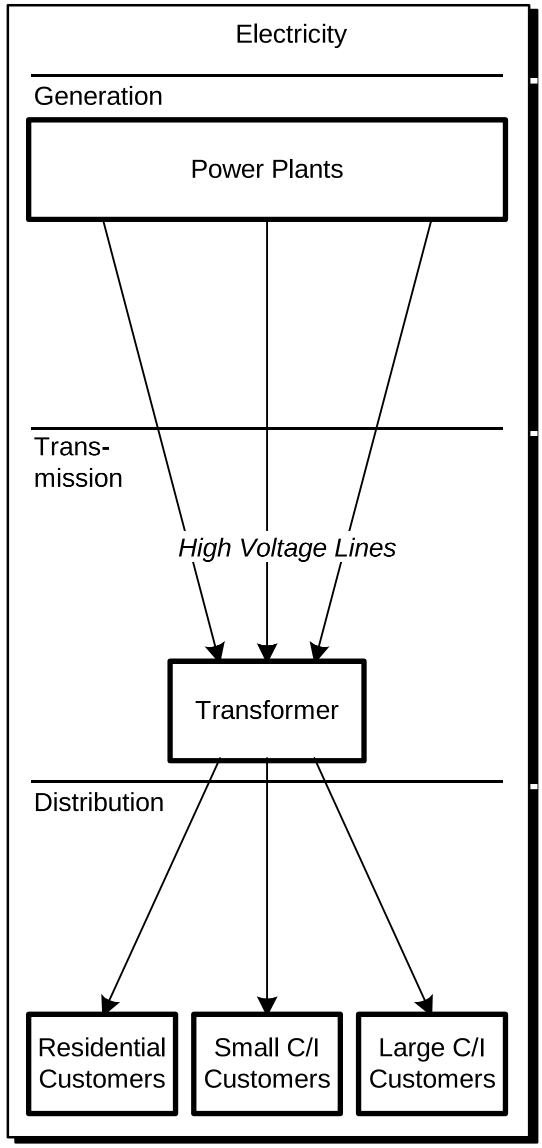


Figure 4-1. Traditional Electric Power Industry Structure

Table 4-23. Net Generation by Energy Source, 1995

Energy Source	Utility Generators (MWh)	Nonutility Generators (MWh)	Total (MWh)
Fossil fuels	2,021,064	287,696	2,308,760
Coal	1,652,914	63,440	
Natural gas	307,306	213,437	
Petroleum	60,844	3,957	
Nuclear	673,402	—	673,402
Hydroelectric	293,653	14,515	308,168
Renewable/other	6,409	98,295	104,704
Total	2,994,582	400,505	3,395,033

Sources: U.S. Department of Energy, Energy Information Administration. 1996. *Electric Power Annual, 1995*. Vol. 1. DOE/EIA-0348(95/1). Washington, DC: U.S. Department of Energy.
U.S. Department of Energy, Energy Information Administration. 1999b. *The Changing Structure of the Electric Power Industry 1999: Mergers and Other Corporate Combinations*. Washington, DC: U.S. Department of Energy.

Nuclear plants and renewable energy sources (e.g., hydroelectric, solar, wind) provide approximately 20 percent and 10 percent of current generating capacity, respectively. However, there are no plans for new nuclear facilities to be constructed, and there is little additional growth forecasted in renewable energy.

4.7.1.2 Transmission

Transmission refers to high voltage lines used to link generators to substations where power is stepped down for local distribution. Transmission systems have been traditionally characterized as a collection of independently operated networks or grids interconnected by bulk transmission interfaces.

Within a well-defined service territory, the regulated utility has historically had responsibility for all aspects of developing, maintaining, and operating transmissions. These responsibilities included

- system planning and expanding,

- maintaining power quality and stability, and
- responding to failures.

Isolated systems were connected primarily to increase (and lower the cost of) power reliability. Most utilities maintained sufficient generating capacity to meet customer needs, and bulk transactions were initially used only to support extreme demands or equipment outages.

4.7.1.3 Distribution

Low-voltage distribution systems that deliver electricity to customers comprise integrated networks of smaller wires and substations that take the higher voltage and step it down to lower levels to match customers' needs.

The distribution system is the classic example of a natural monopoly because it is not practical to have more than one set of lines running through neighborhoods or from the curb to the house.

4.7.2 Cost of Production

Table 4-24 shows total industry expenditures by production activities. Generation accounts for approximately 75.6 percent of the cost of delivered electric power in 1996. Transmission and distribution accounted for 2.5 percent and 5.6 percent, respectively. Customer accounts and sales and administrative costs accounted for the remaining 16.3 percent of the cost of delivered power.

4.7.3 Organization of the Industry

Because the restructuring plans and time tables are made at the state level, the issues of asset ownership and control throughout the current supply chain in the electric power industry vary from state to state. However, the activities conducted throughout the supply chain are generally the same. This section focuses on the generation segment of the market because all the boilers affected by the regulation are involved in generation.

As part of deregulation, the transmission and distribution of electricity are being separated from the business of generating electricity, and a new competitive market in electricity generation is evolving. As power generators prepare for the competitive market, the share of electricity generation attributed to nonutilities and utilities is shifting.

Table 4-24. Total Expenditures in 1996 ($$10^3$)

Utility Ownership	Generation	Transmission	Distribution	Customer Accounts and Sales	Administration and General Expenses
Investor-owned	80,891,644	2,216,113	6,124,443	6,204,229	13,820,059
Publicly owned	12,495,324	840,931	1,017,646	486,195	1,360,111
Federal	3,685,719	327,443	1,435	55,536	443,809
Cooperatives	15,105,404	338,625	1,133,984	564,887	1,257,015
	112,178,091	3,723,112	8,277,508	7,310,847	16,880,994
	75.6%	2.5%	5.6%	4.9%	11.4%
	148,370,552				

Sources: U.S. Department of Energy, Energy Information Administration (EIA). 1998b. *Financial Statistics of Major Publicly Owned Electric Utilities, 1997*. Washington, DC: U.S. Department of Energy.
U.S. Department of Energy, Energy Information Administration (EIA). 1997. *Financial Statistics of Major U.S. Investor-Owned Electric Utilities, 1996*. Washington, DC: U.S. Department of Energy.

More than 7,000 electricity suppliers currently operate in the U.S. market. As shown in Table 4-25, approximately 42 percent of suppliers are utilities and 58 percent are nonutilities. Utilities include investor-owned, cooperatives, and municipal systems. Of the approximately 3,100 utilities operating in the United States, only about 700 generate electric power. The majority of utilities distribute electricity that they have purchased from power generators via their own distribution systems.

Utility and nonutility generators produced a total of 3,369 billion kWh in 1995. Although utilities generate the vast majority of electricity produced in the United States, nonutility generators are quickly eroding utilities' shares of the market. Nonutility generators include private entities that generate power for their own use or to sell to utilities or other end users. Between 1985 and 1995, nonutility generation increased from 98 billion kWh (3.8 percent of total generation) to 374 billion kWh (11.1 percent). Figure 4-2 illustrates this shift in the share of utility and nonutility generation.

Table 4-25. Number of Electricity Suppliers in 1999

Electricity Suppliers	Number	Percent
Utilities	3,124	42%
Investor-owned utilities	222	
Cooperatives	875	
Municipal systems	1,885	
Public power districts	73	
State projects	55	
Federal agencies	14	
Nonutilities	4,247	58%
Nonutilities (excluding EWGs)	4,103	
Exempt wholesale generators	144	
Total	7,371	100%

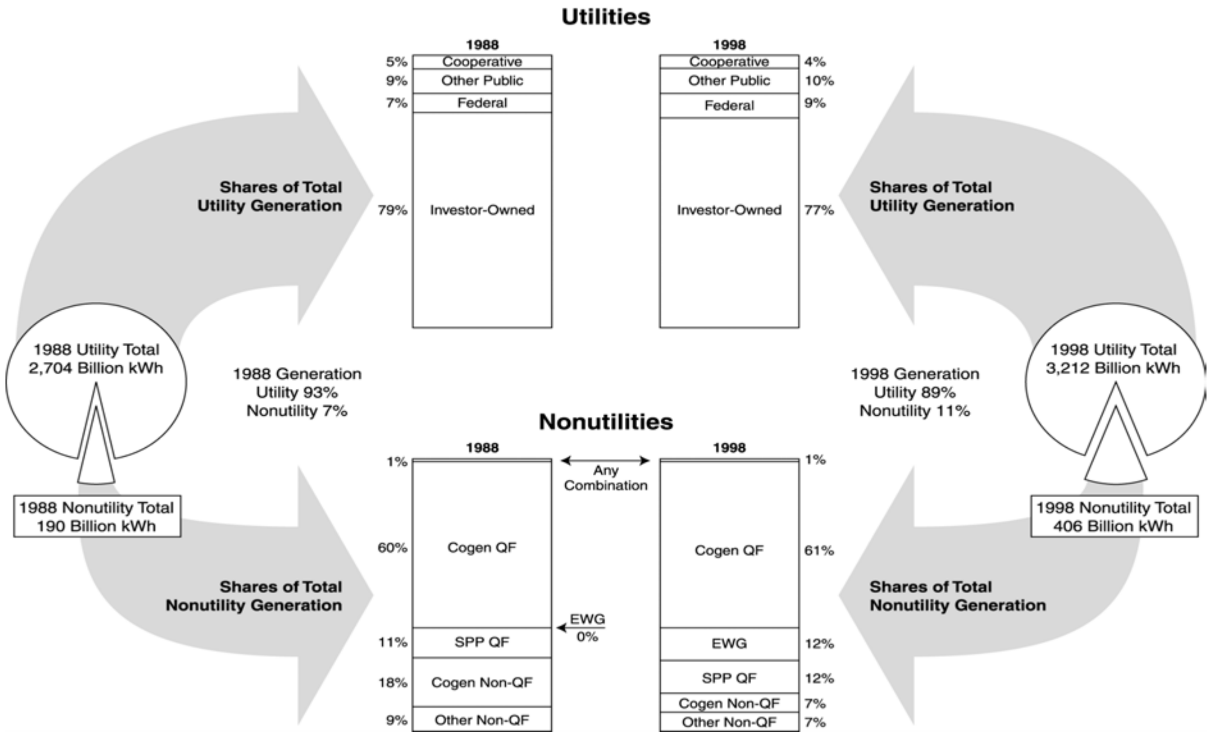
Source: U.S. Department of Energy, Energy Information Administration (EIA). 1999b. *The Changing Structure of the Electric Power Industry 1999: Mergers and Other Corporate Combinations*. Washington, DC: U.S. Department of Energy.

4.7.3.1 Utilities

There are four categories of utilities: investor-owned utilities (IOUs), publicly owned utilities, cooperative utilities, and federal utilities. Of the four, only IOUs always generate electricity.

IOUs are increasingly selling off generation assets to nonutilities or converting those assets into nonutilities (Haltmaier, 1998). To prepare for the competitive market, IOUs have been lowering their operating costs, merging, and diversifying into nonutility businesses.

In 1995, utilities generated 89 percent of electricity, a decrease from 96 percent in 1985. IOUs generate the majority of the electricity produced in the United States. IOUs are either individual corporations or a holding company, in which a parent company operates one or more utilities integrated with one another. IOUs account for approximately three-quarters of utility generation, a percentage that held constant between 1985 and 1995.



[a] Includes facilities classified in more than one of the following FERC designated categories: cogenerator QF, small power producer QF, or exempt wholesale generator.
Cogen = Cogenerator.
EWG = Exempt wholesale generator.
Other Non-QF = Nocogenerator Non-QF.
QF = Qualifying facility.
SPP = Small power producer.

Note: Sum of components may not equal total due to independent rounding. Classes for nonutility generation are determined by the class of each generating unit.

Sources: **Utility data:** U.S. Department of Energy, Energy Information Administration (EIA). 1996. *Electric Power Annual 1995*. Volumes I and II. DOE/EIA-0348(95)/1. Washington, DC: U.S. Department of Energy; Table 8 (and previous issues); **1985 nonutility data:** Shares of generation estimated by EIA; total generation from Edison Electric Institute (EEI). 1998. *Statistical Yearbook of the Electric Utility Industry 1998*. November. Washington, DC; **1995 nonutility data:** U.S. Department of Energy, Energy Information Administration (EIA). 1996. *Electric Power Annual 1995*. Volumes I and II. DOE/EIA-0348(95)/1. Washington, DC: U.S. Department of Energy.

Figure 4-2. Utility and Nonutility Generation and Shares by Class, 1988 and 1998

Many states, municipalities, and other government organizations also own and operate utilities, although the majority do not generate electricity. Those that do generate electricity operate capacity to supply some or all of their customers' needs. They tend to be small, localized outfits and can be found in 47 states. These publicly owned utilities accounted for about one-tenth of utility generation in 1985 and 1995. In a deregulated market, these generators may be in direct competition with other utilities to service their market.

Rural electric cooperatives are formed and owned by groups of residents in rural areas to supply power to those areas. Cooperatives generally purchase from other utilities the energy that they sell to customers, but some generate their own power. Cooperatives only produced 5 percent of utility generation in 1985 and only 6 percent in 1995.

Utilities owned by the federal government accounted for about one-tenth of generation in both 1985 and 1995. The federal government operated a small number of large utilities in 1995 that supplied power to large industrial consumers or federal installations. The Tennessee Valley Authority is an example of a federal utility.

4.7.3.2 Nonutilities

Nonutilities are private entities that generate power for their own use or to sell to utilities or other establishments. Nonutilities are usually operated at mines and manufacturing facilities, such as chemical plants and paper mills, or are operated by electric and gas service companies (DOE, EIA, 1998a). More than 4,200 nonutilities operate in the United States.

4.7.4 Demand Side of the Industry

4.7.4.1 Electricity Consumption

This section analyzes the growth projections for electricity consumption as well as the price elasticity of demand for electricity. Growth in electricity consumption has traditionally paralleled gross domestic product growth. However, improved energy efficiency of electrical equipment, such as high-efficiency motors, has slowed demand growth over the past few decades. The magnitude of the relationship has been decreasing over time, from growth of 7 percent per year in the 1960s down to 1 percent in the 1980s. As a result, determining what the future growth will be is difficult, although it is expected to be positive (DOE, EIA, 1999a). Table 4-26 shows consumption by sector of the economy over the past 10 years. The table shows that since 1989 electricity sales have increased at least 10 percent in all four sectors. The commercial sector has experienced the largest increase, followed by residential consumption.

Table 4-26. U.S. Electric Utility Retail Sales of Electricity by Sector, 1989 Through 1998 (10^6 kWh)

Period	Residential	Commercial	Industrial	Other[a]	All Sectors
1989	905,525	725,861	925,659	89,765	2,646,809
1990	924,019	751,027	945,522	91,988	2,712,555
1991	955,417	765,664	946,583	94,339	2,762,003
1992	935,939	761,271	972,714	93,442	2,763,365
1993	994,781	794,573	977,164	94,944	2,861,462
1994	1,008,482	820,269	1,007,981	97,830	2,934,563
1995	1,042,501	862,685	1,012,693	95,407	3,013,287
1996	1,082,491	887,425	1,030,356	97,539	3,097,810
1997	1,075,767	928,440	1,032,653	102,901	3,139,761
1998	1,124,004	948,904	1,047,346	99,868	3,220,121
Percentage change 1989–1998	19%	24%	12%	10%	18%

[a] Includes public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales.

Sources: U.S. Department of Energy, Energy Information Administration (EIA). 1999d. *Electric Power Annual 1998*. Volumes I and II. Washington, DC: U.S. Department of Energy.
U.S. Department of Energy, Energy Information Administration (EIA). 1996. *Electric Power Annual 1995*. Volumes I and II. Washington, DC: U.S. Department of Energy.

In the future, residential demand is expected to be at the forefront of increased electricity consumption. Between 1997 and 2020, residential demand is expected to increase at 1.6 percent annually. Commercial growth in demand is expected to be approximately 1.4 percent, while industry is expected to increase demand by 1.1 percent (DOE, EIA, 1999a). Figure 4-3 shows the annual electricity sales by sector from 1970 with projections through 2020.

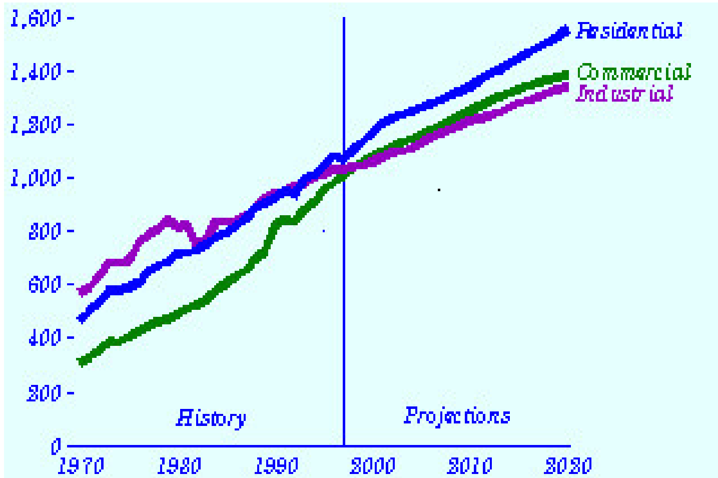


Figure 4-3. Annual Electricity Sales by Sector

The literature suggests that electricity consumption is relatively price inelastic. Consumers are generally unable or unwilling to forego a large amount of consumption as the price increases. Numerous studies have investigated the short-run elasticity of demand for electricity. Overall, the studies suggest that, for a 1 percent increase in the price of electricity, demand will decrease by 0.15 percent. However, as Table 4-27 shows, elasticities vary greatly, depending on the demand characteristics of end users and the price structure. Demand elasticities are estimated to range from a –0.05 percent elasticity of demand for a "flat rates" case (i.e., no time-of-use assumption) up to a –0.50 percent demand elasticity for a "high consumer response" case (DOE, EIA, 1999c).

4.7.4.2 Trends in the Electricity Market

Beginning in the latter part of the 19th century and continuing for about 100 years, the prevailing view of policymakers and the public was that the government should use its power to require or prescribe the economic behavior of "natural monopolies" such as electric utilities. The traditional argument is that it does not make economic sense for there to be more than one supplier—running two sets of wires from generating facilities to end users is more costly than one set. However, since monopoly supply is not generally regarded as likely to provide a socially

Table 4-27. Key Parameters in the Cases

	Key Assumptions			
Case Name	**Cost Reduction and Efficiency Improvements**	**Short-Run Elasticity of Demand (Percent)**	**Natural Gas Prices**	**Capacity Additions**
AEO97 Reference Case	AEO97 Reference Case	—	AEO97 Reference Case	As needed to meet demand
No Competition	No change from 1995	—	AEO97 Reference Case	As needed to meet demand
Flat Rates (no time-of-use rates)	AEO97 Reference Case	–0.05	AEO97 Reference Case	As needed to meet demand
Moderate Consumer Response	AEO97 Reference Case	–0.15	AEO97 Reference Case	As needed to meet demand
High Consumer Response	AEO97 Reference Case	–0.50	AEO97 Reference Case	As needed to meet demand
High Efficiency	Increased cost savings and efficiencies	–0.15	AEO97 Reference Case	As needed to meet demand
No Capacity Additions	AEO97 Reference Case	–0.15	AEO97 Low Oil and Gas Supply Technology Case	Not allowed
High Gas Price	AEO97 Reference Case	–0.15	AEO97 High Oil and Gas Supply Technology Case	As needed to meet demand
Low Gas Price	AEO97 Reference Case	–0.15	AEO97 Reference Case	As needed to meet demand
High Value of Reliability	AEO97 Reference Case	–0.15	AEO97 Reference Case	As needed to meet demand
Half O&M	AEO97 Reference Case	–0.15	AEO97 Reference Case	As needed to meet demand
Intense Competition	AEO97 Reference Case	–0.15	AEO97 Reference Case	As needed to meet demand

— = not applicable.

Source: U.S. Department of Energy, Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting. "Competitive Electricity Price Projections." <http://www.eia.doe.gov/oiaf/elepri97/chap3.html>. As obtained on November 15, 1999c.

optimal allocation of resources, regulation of rates and other economic variables was seen as a necessary feature of the system.

Beginning in the 1970s, the public policy view shifted against traditional regulatory approaches and in favor of deregulation for many important industries including transportation, communications, finance, and energy. The major drivers for deregulation of electric power included the following:

- existence of rate differentials across regions offering the promise of benefits from more efficient use of existing generation resources if the power can be transmitted across larger geographic areas than was typical in the era of industry regulation;
- the erosion of economies of scale in generation with advances in combustion turbine technology;
- complexity of providing a regulated industry with the incentives to make socially efficient investment choices;
- difficulty of providing a responsive regulatory process that can quickly adjust rates and conditions of service in response to changing technological and market conditions; and
- complexity of monitoring utilities' cost of service and establishing cost-based rates for various customer classes that promote economic efficiency while at the same time addressing equity concerns of regulatory commissions.

Viewed from one perspective, not much changes in the electric industry with restructuring. The same functions are being performed, essentially the same resources are being used, and in a broad sense the same reliability criteria are being met. In other ways, the very nature of restructuring, the harnessing of competitive forces to perform a previously regulated function, changes almost everything. Each provider and each function become separate competitive entities that must be judged on their own.

This move to market-based provision of generation services is not matched on the transmission and distribution side. Network interactions on AC transmission systems have made it impossible to have separate transmission paths compete. Hence, transmission and distribution remain regulated. Transmission and generation heavily interact, however, and transmission congestion can prevent specific generation from getting to market. Transmission expansion planning becomes an open process with many interested parties. This open process, coupled with frequent public opposition to transmission expansion, slows transmission enhancement. The net result is greatly increased pressure on the transmission system.

Restructuring of the electric power industry could result in any one of several possible market structures. In fact, different parts of the country will probably use different structures, as the current trend indicates. The eventual structure may be dominated by a power exchange, bilateral contracts, or a combination. A strong Regional Transmission Organization (RTO) may operate in the area, or a vertically integrated utility may continue to operate a control area. In any case, several important characteristics will change:

- Commercial provision of generation-based services (e.g., energy, regulation, load following, voltage control, contingency reserves, backup supply) will replace regulated service provision. This drastically changes how the service provider is assessed.
- Individual transactions will replace aggregated supply meeting aggregated demand. It will be necessary to continuously assess each individual's performance.
- Transaction sizes will shrink. Instead of dealing only in hundreds and thousands of MW, it will be necessary to accommodate transactions of a few MW and less.
- Supply flexibility will greatly increase. Instead of services coming from a fixed fleet of generators, service provision will change dynamically among many potential suppliers as market conditions change.

SECTION 5

ECONOMIC ANALYSIS METHODOLOGY

The proposed rule to control emissions of HAPs from industrial, commercial, and institutional boilers and process heaters will affect almost all sectors of the U.S. economy. Several markets will bear the direct compliance costs. In addition, sectors that consume energy will also bear indirect costs through higher prices for energy. Finally, consumers of goods and services will experience impacts from higher market prices.

This section presents the methodology for analyzing the economic impacts of the proposed NESHAP. This economic analysis provides the economic data and supporting information needed by EPA to support its regulatory determination. The methodology to operationalize this theory is based on microeconomic theory and the methods developed for earlier EPA studies. These methods are tailored to and extended for this analysis, as appropriate, to meet EPA's requirements for an EIA of controls placed on boilers and process heaters.

This methodology section includes background information on typical economic modeling approaches, the conceptual approach selected for this EIA, and an overview of the computerized market model used in the analysis with emphasis on the links between energy markets and the markets for goods and services. Appendix A includes a description of the model's baseline data set and specification.

5.1 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.

5.1.1 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 5-1 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.

Table 5-1. 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

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.

5.1.2 Modeling Dimension 2: Interaction Between Economic Sectors

Because of the large number of markets potentially affected by the regulation on boilers and process heaters, 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, the regulation affects all commodities and markets to some extent. For example, controls on boilers and process heaters 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.

5.2 Selected Modeling Approach for Boilers and Process Heaters Analysis

To conduct the analysis for the boilers and process heaters 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 boilers and process heaters primarily 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 energy, agriculture, manufacturing, mining, commercial, and transportation markets affected by the controls placed on boilers and process heaters.[1] The energy markets are divided into natural gas, petroleum products, coal, and electricity. The residential sector is treated as a single representative demander in the energy markets.

Figure 5-1 presents an overview of the key market linkages included in the economic impact model used for analyzing the boilers and process heaters MACT. The analysis' emphasis is on the energy supply chain and the consumption of energy by producers of goods and services. The industries most directly affected by the boilers and process heaters MACT are the electricity industry, chemical industry and pulp and paper industry. However, changes in the equilibrium prices and quantities of energy and goods and services affect all sectors of the economy. (See Figure 5-1.) This analysis explicitly models the linkages between these market segments to capture both the direct costs of compliance and the indirect costs due to changes in prices. For example, production costs will increase for chemical companies using boilers and process heaters as a result of the capital investments and monitoring costs, as well as the resulting increase in the price of electricity used as an energy input in the production process.

The economic model also captures behavioral changes of producers of goods and services that feedback into the energy markets. Changes in production levels and fuel switching in the manufacturing process affect the demand for Btus in fuel markets. The change in output is determined by the size of the cost increase per Btu (typically variable cost per output), the facility's production function (slope of supply curve), and the demand characteristics of the facility's downstream market (other market suppliers and market demanders). For example, if consumers' demand for a product is not very sensitive to price, then producers can pass the majority of the cost of the regulation through to consumers and output may not change appreciably. However, if only a small proportion of market output is produced by producers affected by the regulation, then competition will prevent the affected producers from raising their prices significantly.

One possible feedback pathway that this analysis does *not* model 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

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[1]These markets are defined at the two- and three-digit NAICS 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 NAICS code may still underestimate the impacts on the subset of producers affected by the regulation.

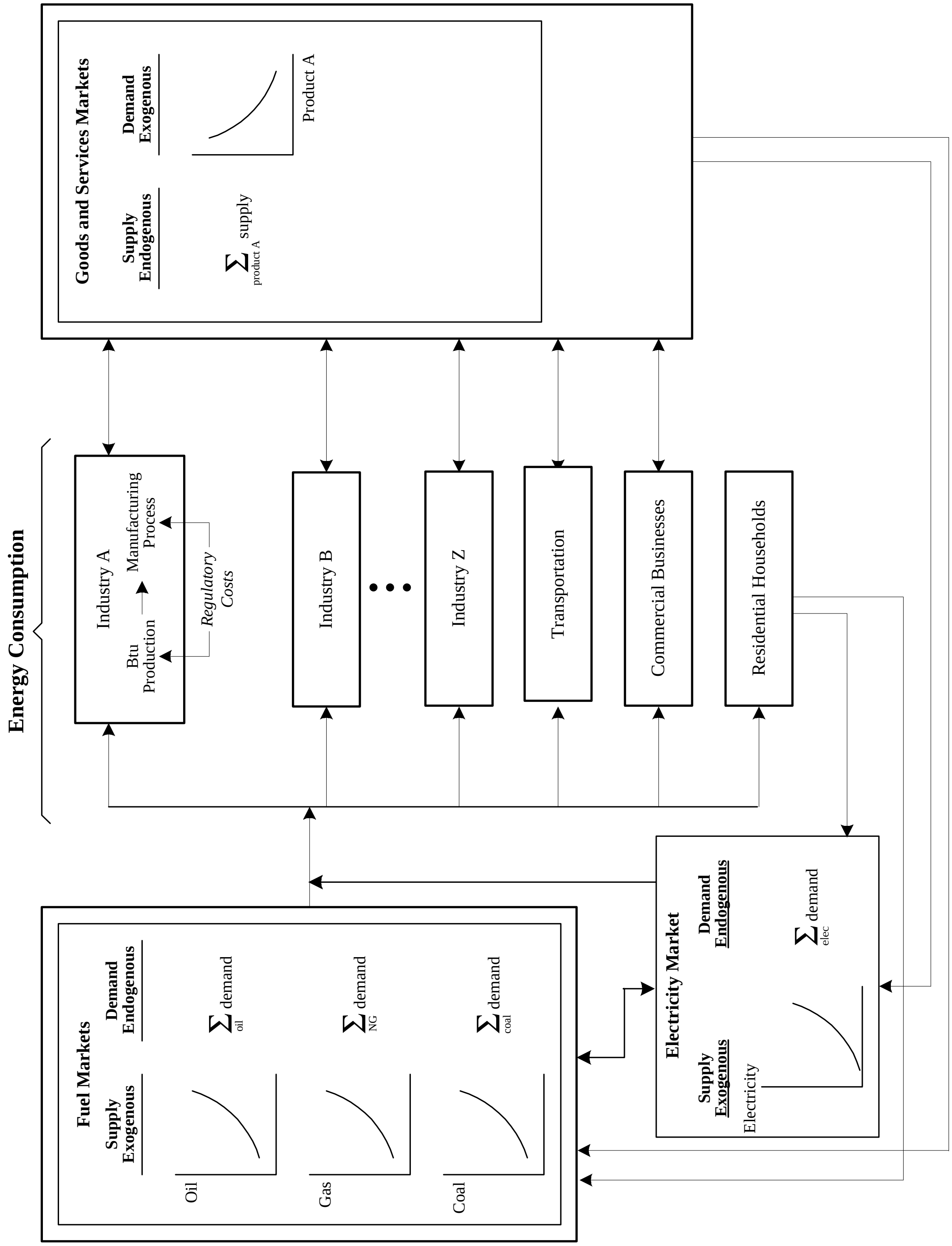


Figure 5-1. Links Between Energy and Goods and Services Markets

input mix that they use, substituting other inputs for fuel. These facility-level responses will also act to reduce pollution, but including these responses is beyond the scope of this analysis.

5.2.1 Directly Affected Markets

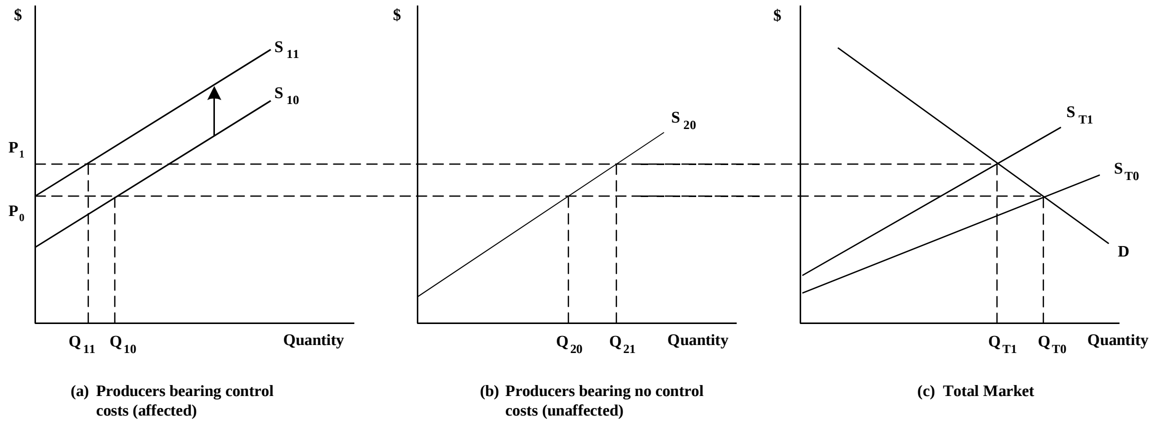
Markets where boilers and process heaters are used as an input to production are considered to be directly affected. As outlined in Section 2, facilities using several types of boilers or process heaters will be required to add controls. In addition, a larger population of boilers and process heaters will incur monitoring costs to comply with the regulation. 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.

5.2.1.1 Electricity Market

Boilers are used to generate power throughout the electricity industry. Even though utility boilers are not covered under this regulation, the Agency estimates over 300 industrial, commercial, and institutional boilers involved in providing electric services (SIC 4911/NAICS22111) will be affected. Most of these are owned by municipal electric service providers.

For this study, the electricity market was modeled as a nationally competitive market. The direct costs of compliance on affected boilers lead to an upward shift in the total market supply for electricity. Figure 5-2 illustrates the shifts in the supply curve for a representative energy market. In addition to the direct costs, the market for electricity will also be indirectly affected through changes in fuel prices. Electricity generators are extremely large consumers of coal, natural gas, and petroleum products. For example, some of the impact of control costs on the petroleum industry will be on the electricity industry in the form of higher prices. Indirect costs will also lead to an upward shift in the supply curve.

The demand for electricity is derived by aggregating across the goods and services markets and the residential sector. Because of direct compliance costs on the goods and services markets, the demand curve for electricity will shift downward. Therefore, it is ambiguous whether equilibrium quantity will rise or fall. The changes in the price and quantity are determined by the relative magnitude of the shifts in the price elasticities of the supply and demand curves.



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 5-2. Market Effects of Regulation-Induced Costs

5.2.1.2 Petroleum Market

Control costs associated with boilers and process heaters will increase the cost of refining petroleum products. The supply curve for petroleum products will shift upward by the proportional increase in total production costs caused by the control costs on boilers and process heaters. For petroleum products, a single composite product was used to model market adjustment because boilers and process heaters are used throughout the refinement process, from distillation to reformulation. As a result, assigning costs to specific end products, such as fuel oil #2 or reformulated gasoline, is difficult. The use of a composite product tends to understate the impacts for petroleum products where compliance costs as a percentage of production costs are greater than average and overstate impacts for products where compliance costs as a percentage of production costs are less than average.

5.2.1.3 Goods and Services Markets: Agriculture, Manufacturing, Mining, Commercial, and Transportation

Many manufacturing facilities use boilers and process heaters in their production processes to generate steam and process heat. Commercial entities use boilers for space heating and to generate supplementary electricity. In addition to the direct costs of the regulation, goods and services markets are indirectly affected through price increases in the energy markets.

Directly affected producers are segmented into sectors defined at the two- or three-digit NAICS code level. A partial equilibrium analysis was conducted for each sector to model the supply and demand. 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.

The impact of the regulation on producers in these sectors was modeled as an increase in the cost of Btus used in the production process. In this context, Btus refer to the generic energy requirements 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 because of both direct control costs on boilers and process heaters 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 5-2, leading to a change in the equilibrium market price and quantity.

The changes in equilibrium supply and demand in each market are modeled to estimate the regulation's impact on each 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 is a function of the total direct control costs associated with boilers and process heaters and the indirect fuel costs (determined by the change in fuel price and intensity of use) in each goods and services market. The proportional shift in the supply curve is determined by the ratio of total control costs (both direct and indirect) to total revenue.

This impact on the price of Btus facing industrial users feeds back to the fuel market in two ways (see Figure 5-3). The first is through the company's input decision concerning the fuel(s) that

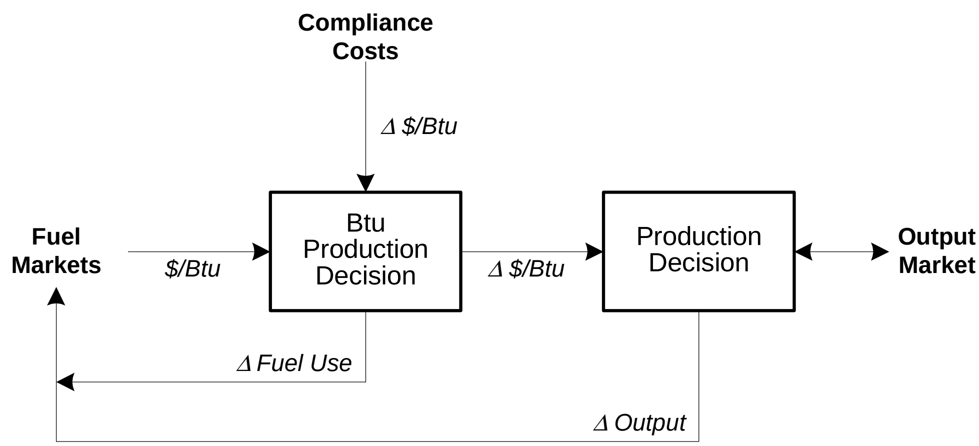


Figure 5-3. Fuel Market Interactions with Facility-Level Production Decisions

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 were modeled 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, energy 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 new market price and quantity. The Agency modeled the feedback into the energy market by assuming that the percentage change in output in the manufacturing sectors translates into a equivalent percentage change in the demand for energy (Btus). This implies that there are constant returns to scale from energy inputs in the manufacturing process over the relevant range of output and time period of analysis. This is an appropriate assumption for this analysis because the output changes in these sectors being modeled are relatively small (always less than 1 percent) and reflect short-run production decisions.[2]

The Agency assumed that the demand curves for goods and services in all 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 are the elasticities of demand with respect to changes in the price of goods and services. 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.

5.2.2 Indirectly Affected Markets

In addition to the many markets that are directly affected by the regulation on boilers and process heaters, 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.

5.2.2.1 Market for Coal

The coal market is not directly affected by the regulation, but it has the potential to be significantly affected through indirect costs. Although boilers and process heaters 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. However, the indirect impacts on coal production costs are relatively small compared to the direct impacts on the production costs in the electricity and petroleum markets; thus, the "relative" price of coal (per Btu) will decrease compared with other energy sources.

The demand for coal from the industrial sectors will be affected by differences in compliance costs by fuel type applied to boilers and process heaters in the industrial sectors.

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[2]Long-run production decisions of fuel switching and increased energy efficiency are captured by the cross- and own-price elasticities in the energy markets.

Because compliance costs are high for coal-fired units, manufacturers will switch away from coal units toward natural gas units with lower compliance costs. However, the overall impact on the demand for coal is ambiguous because the relative increase in the cost of producing Btus by burning coal will be offset by the relative decrease in the price of coal. Similarly, the demand for coal by utility generators will be affected through changes in the relative price of alternative (noncoal) energy sources and direct costs on coal boilers.

5.2.2.2 Natural Gas Market

The natural gas market is included in the economic model to complete coverage of the energy markets. EPA projects that there are no direct and minimal indirect impacts on the production costs of natural gas. However, the demand for natural gas will increase because of the relative decrease in the price of natural gas and the lower relative compliance costs for gas-fired boilers and process heaters.

5.2.2.3 Goods and Services Markets

Some goods and services markets do not include any boilers or process heaters and are therefore not directly affected by the regulation. However, these markets will still be affected indirectly because of the changes in energy prices that they will face following the regulation. There will be a tendency for these users to shift away from electricity and petroleum products and towards natural gas and coal.

5.2.2.4 Impact on Residential Sector

The residential sector does not bear any direct costs associated with the regulation because this sector does not own boilers or process heaters. 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.

5.3 Operationalizing the Economic Impact Model

Figure 5-4 illustrates the linkages used to operationalize the estimation of economic impacts associated with the compliance costs. Compliance costs placed on boilers and process heaters

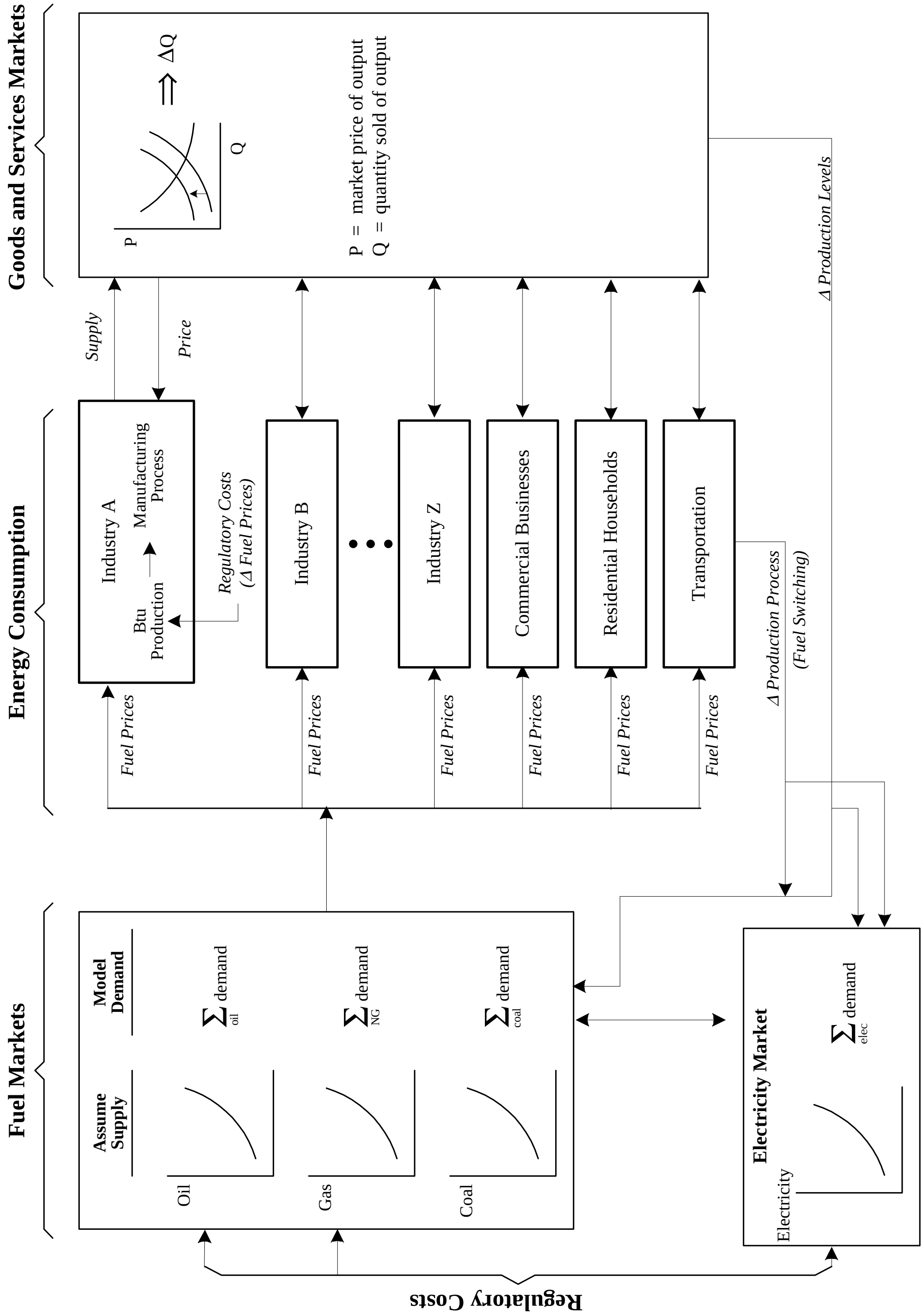


Figure 5-4. Operationalizing the Estimation of Economic Impact

shift the supply curve for electricity and petroleum products. Adjustments in the electricity and petroleum energy markets determine the share of the cost increases that producers (electric service providers and petroleum companies) and consumers (product manufacturers, commercial business, and residential households) bear.

The supply and demand relationships between the energy markets are fully modeled. For example, changes in electricity production feed back and affect the demand for coal, natural gas and petroleum products. Similar changes in refinery production affect the petroleum industry's demand for electricity.

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

Adjustments in price and quantity in all 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.

5.3.1 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 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. Table 5-2 lists the supply elasticities for the markets used in the model.

The demand curves for the energy markets are the sum of demand responses across all markets. 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 output levels. Similarly, the energy demand in residential sectors is obtained through mathematical specification of a demand function (see Appendix A).

The demand for goods and service in the two- and three-digit NAICS code manufacturing sectors is obtained by using a mathematical specification of the demand function. Table 5-2 lists the demand elasticities for the markets used in the model.

EPA modeled fuel switching using secondary data developed by the U.S. Department of Energy for the National Energy Modeling System (NEMS). Table 5-3 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.

5.3.2 Calculating Changes in Social Welfare

The boilers and process heaters 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 goods and services markets and borne by both the producers and consumers of their

Table 5-2. Supply and Demand Elasticities

	Supply Elasticities	Demand Elasticities			
		Industrial	Residential[a]	Transportation	Commercial
Petroleum	0.58[b]	Derived	–0.28	Derived	Derived
Natural Gas	0.41[b]	Derived	–0.26	Derived	Derived
Electricity	0.75[c]	Derived	–0.23	Derived	Derived
Coal	1.00[b]	Derived	–0.26	Derived	Derived

NAICS	Description	Supply[d]	Demand[d]
311	Food	0.75[c]	–0.30
312	Beverage and Tobacco Products	0.75[c]	–1.30
313	Textile Mills	0.37[e]	–0.85[e]
314	Textile Product Mills	0.37[e]	–0.85[e]
315	Apparel	0.75[c]	–1.80
316	Leather and Allied Products	0.75[c]	–1.20
321	Wood Products	0.75[d]	–0.20
322	Paper	1.20[c]	–1.09
323	Printing and Related Support	0.75[c]	–1.80
325	Chemicals	0.75[c]	–1.50
326	Plastics and Rubber Products	0.75[c]	–1.80
327	Nonmetallic Mineral Products	0.75[c]	–0.90
331	Primary Metals	3.50[f]	–0.80
332	Fabricated Metal Products	0.75[c]	–0.20
333	Machinery	0.75[c]	–0.50
334	Computer and Electronic Products	0.75[c]	–0.30
335	Electrical Equipment, Appliances, and Components	0.75[c]	–0.50
336	Transportation Equipment	0.75[c]	–1.00[c]
337	Furniture and Related Products	0.75[c]	–3.40
339	Miscellaneous	0.75[c]	–0.60
11	Agricultural Sector	0.75[c]	–1.80

(continued)

Table 5-2. Supply and Demand Elasticities (continued)

NAICS	Description	Supply[d]	Demand[d]
23	Construction Sector	0.75[c]	–1.00[c]
21	Other Mining Sector	0.43	–0.30
48	Transportation	0.75[c]	–0.70
Commercial	Commercial	0.75[c]	–1.00[c]

[a] U.S. Department of Energy, Energy Information Administration (EIA). "Issues in Midterm Analysis and Forecasting 1999—Table 1." <http://www.eia.doe.gov/oaif/issues/pricetbl1.html>. As obtained on May 8, 2000a.
[b] Dahl, Carol A., and Thomas E. Duggan. 1996. "U.S. Energy Product Supply Elasticities: A Survey and Application to the U.S. Oil Market." *Resource and Energy Economics*18:243-263.
[c] Assumed value.
[d] E.H. Pechan & Associates, Inc. 1997. Qualitative Market Impact Analysis for Implementation of the Selected Ozone and PM NAAQS. Appendix B. Prepared for the U.S. Environmental Protection Agency.
[e] Warfield, et al. 2001. "Multifiber Arrangement Phaseout: Implications for the U.S. Fibers/Textiles/Fabricated Products Complex." www.fibronet.com.tw/mirron/ncs/9312/mar.html> As obtained September 19, 2001.
[f] U.S. International Trade Commission (USITC). November 21, 2001. Memorandum to the Commission from Craig Thomsen, John Giamalua, John Benedetto, Joshua Levy, International Economists. Investigation No. TA-201-73: STEEL-Remedy Memorandum.

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 goods and services markets;
- change in consumer surplus in the goods and services markets; and
- change in consumer surplus in the residential sector.

Figure 5-5 illustrates the change in producer and consumer surplus in the intermediate energy market and the goods and services markets. For example, assume a simple world with only one energy market, wholesale electricity, and one product market, pulp and paper. If the regulation increases 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 5-5(a), the pulp and paper manufacturers are the consumers of electricity, so the change in consumer surplus is displayed. This

Table 5-3. Fuel Price Elasticities

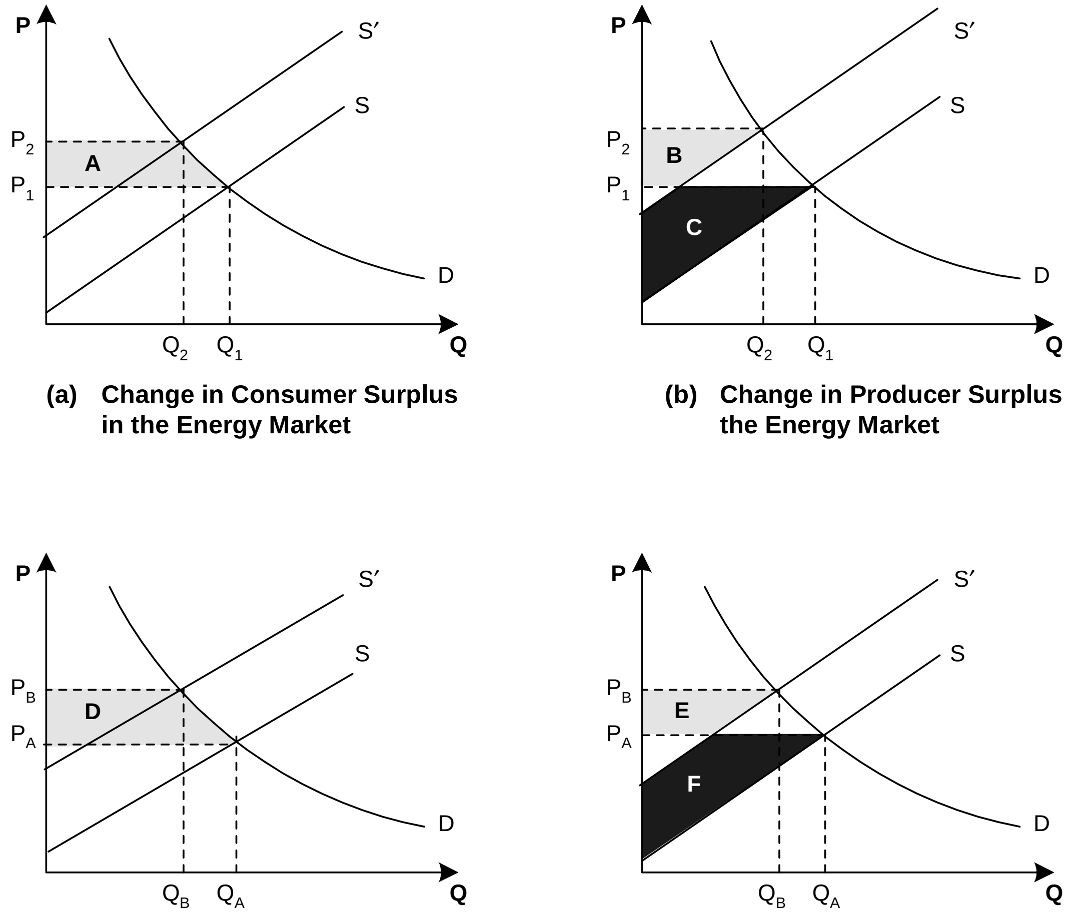
	Own and Cross Elasticities				
Inputs	**Electricity**	**Natural Gas**	**Coal**	**Residual**	**Distillate**
Electricity	–0.074	0.092	0.605	0.080	0.017
Natural Gas	0.496	–0.229	1.087	0.346	0.014
Steam Coal	0.021	0.061	–0.499	0.151	0.023
Residual	0.236	0.036	0.650	–0.587	0.012
Distillate	0.247	0.002	0.578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

Source: U.S. Department of Energy, Energy Information Administration (EIA). January 2000b. *Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System.* DOE/EIA-M064(2000). Washington, DC: U.S. Department of Energy.

change in consumer surplus in the energy market is captured by the 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 5-5(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 5-5(c) and 5-5(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 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

$$\text{Change in Social Welfare} = \sum \Delta PSE + \sum \Delta PSF + \sum \Delta CSF + \sum \Delta CSR \qquad (5.1)$$



(a) Change in Consumer Surplus in the Energy Market

(b) Change in Producer Surplus in the Energy Market

(c) Change in Consumer Surplus in Goods and Services Markets

(d) Change in Producer Surplus in Goods and Services Markets

Figure 5-5. Changes in Economic Welfare with Regulation

where

ΔPSE = change in producer surplus in the energy markets;

ΔPSF = change in producer surplus in the goods and services markets;

ΔCSF = change in consumer surplus in the goods and services 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 markets. The market analysis is conducted for the year 2005 and incorporates both growth in supply and demand. As a result, both new and existing sources are evaluated using the same analysis approach.

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).

SECTION 6

ECONOMIC IMPACT ANALYSIS RESULTS

The underlying objective of the EIA is to evaluate the effect of the proposed regulation on the welfare of affected stakeholders and society in general. Although the engineering cost analysis presented in Section 3 does represent an estimate of the resources required to comply with the proposed rule under baseline economic conditions, the analysis does not account for the fact that the regulations may cause the economic conditions to change. For instance, producers may reduce production in the face of higher production costs, thereby reducing market supply. Moreover, the control costs may be passed along to other parties through various economic exchanges. Therefore, EPA developed an analytical structure and economic model to measure and track these effects (described in detail in Section 5 and Appendix A). In this section, we report quantitative estimates of these welfare impacts and their distribution across stakeholders.

6.1 Social Cost Estimates

Table 6-1 summarizes the economic impact estimates for existing and new source units. Under the MACT floor alternative, EPA estimates the total change in social welfare is estimated to be $862.9 million. Under the Option 1A, welfare impacts are over twice as high as the MACT floor alternative with social welfare changes estimated to equal $1,995.5 million. Both of these estimates are slightly smaller (less than $0.3 million) than the estimated baseline engineering costs as a result of behavior changes by producers and consumers that reflect lower cost alternatives. Possible behavior responses include changes in consumption and production patterns and fuel switching.

EPA also estimated the distribution of social costs between producers and consumers and report the distribution of impacts across sectors/markets in Tables 6-2 and 6-3. Values in the text are impacts from the floor alternative; those in parentheses are impacts from the Option 1A alternative. The market analysis estimates that consumers will bear $414.3 million ($955.3 million), or 48 (48) percent of the total social cost, because of the increased prices and lower consumption levels in these markets. Producer surplus is projected to decrease by $448.7 million

Table 6-1. Social Cost Estimates ($1998 10^6)

	Change in Social Welfare, MACT Floor	Change in Social Welfare, Option 1A
Baseline engineering costs	$863.0	$1,995.8
Social costs with market adjustments	$862.9	$1,995.5
Difference between engineering and social costs	$0.1	$0.3

($1,040.2 million), or 52 (52) percent of the total social cost as result of direct control costs, higher energy costs, and reductions in output.

With exception of the natural gas market, energy producers are expected to experience producer surplus losses. Under the MACT floor, electricity, petroleum, and coal producer surplus is projected to decline by approximately $35 million. This value increases to $113 million under Option 1A. In contrast, natural gas producer surplus is projected to increase by $2 to $4 million as they benefit from increased demand from industries switching from petroleum and electricity.

The majority welfare impacts fall on the agriculture, manufacturing, and mining industries. EPA estimates total welfare losses of $609.8 million ($1,444.3 million) for these sectors. Manufacturing industries with large number of boilers and process heaters and industries that consume electricity experience the majority these losses (e.g., chemicals and allied products, paper, textile mill products, and food). Consumers in these industries experience losses of $295.2 million ($709.9 million) and producers bear $314.6 million ($734.4 million). The cost of this rule to producers as a percentage of baseline 2005 shipments is 0.011 (0.026) percent.

EPA also examined the impact on the commercial, transportation and residential sectors. The total welfare loss for the commercial sector is estimated to be $167.1 million ($301.8 million). Therefore, the regulatory burden associated with the MACT is estimated as 0.001 (0.002) total 2005 commercial sector revenues. Consumers in this sector bear approximately $71.6 million ($129.3 million) and producers bear $95.5 million ($172.5 million) of these impacts. In contrast, the total welfare loss for the transportation sector is estimated to be $9.0 million ($46.5 million). The regulatory burden associated with the rule is estimated as 0.003 (0.015) percent of total 2005

Table 6-2. Distribution of Social Costs by Sector/Market: Floor Alternative ($1998 10^6)

Sectors/Markets			Change in: Producer Surplus	Consumer Surplus	Social Welfare
Energy Markets					
Petroleum			–$1.9		
Natural gas			$4.1		
Electricity			–$33.7		
Coal			–$2.7		
Subtotal			–$34.2		
NAICS Code	**SIC Code**	**Description**			
311	20 (pt)	Food	–$28.2	–$11.3	–$39.4
312	20 (pt); 21	Beverage and Tobacco Products	–$2.4	–$4.1	–$6.5
313	22 (pt)	Textile Mills	–$22.7	–$52.0	–$74.7
314	22 (pt)	Textile Product Mills	–$0.1	–$0.1	–$0.2
315	23	Apparel	–$0.4	–$1.1	–$1.5
316	31	Leather and Allied Products	–$0.3	–$0.4	–$0.7
321	24	Wood Products	–$39.1	–$10.4	–$49.5
322	26	Paper	–$66.1	–$60.0	–$126.1
323	27	Printing and Related Support	–$0.2	–$0.4	–$0.6
325	28	Chemicals	–$40.9	–$81.8	–$122.8
326	30	Plastics and Rubber Products	–$2.2	–$5.4	–$7.6
327	32	Nonmetallic Mineral Products	–$3.4	–$4.0	–$7.4
331	33	Primary Metals	–$25.2	–$5.7	–$30.9
332	34	Fabricated Metal Products	–$8.5	–$2.3	–$10.8
333	35	Machinery	–$7.3	–$4.9	–$12.2
334	36 (pt)	Computer and Electronic Products	–$3.6	–$1.4	–$5.0
335	36 (pt)	Electrical Equipment, Appliances, and Components	–$2.5	–$1.6	–$4.1
336	37	Transportation Equipment	–$24.6	–$32.8	–$57.3
337	25	Furniture and Related Products	–$5.4	–$24.6	–$30.1
339	39	Miscellaneous	–$0.8	–$0.7	–$1.5
11	01-08	Agricultural Sector	–$0.6	–$1.3	–$1.9
23	15-17	Construction Sector	–$0.8	–$1.1	–$1.9
21	10; 14	Other Mining Sector	–$10.1	–$7.0	–$17.2
48	40-47 (pt)	Transportation	–$4.7	–$4.3	–$9.0
42; 44-45; 49; 51-56; 61-62; 71-72; 81	40-48 (pt); 50-99	Commercial	–$71.6	–$95.5	–$167.1
		Residential	NA	–$42.7	–$42.7
Grand Total			–$414.3	–$448.7	–$862.9

NA = Not applicable.
pt = Part.

Table 6-3. Distribution of Social Costs by Sector/Market: Option 1A Alternative ($1998 10^6)

Sectors/Markets			Change in: Producer Surplus	Consumer Surplus	Social Welfare
Energy Markets					
Petroleum			–$27.3		
Natural gas			$2.4		
Electricity			–$79.5		
Coal			–$6.4		
Subtotal			–$110.8		
NAICS Code	**SIC Code**	**Description**			
311	20 (pt)	Food	–$90.0	–$36.0	–$126.0
312	20 (pt); 21	Beverage and Tobacco Products	–$5.4	–$9.3	–$14.7
313	22 (pt)	Textile Mills	–$45.0	–$103.2	–$148.2
314	22 (pt)	Textile Product Mills	–$0.1	–$0.3	–$0.4
315	23	Apparel	–$0.9	–$2.1	–$3.0
316	31	Leather and Allied Products	–$2.7	–$4.3	–$7.1
321	24	Wood Products	–$72.0	–$19.2	–$91.2
322	26	Paper	–$173.1	–$157.2	–$330.3
323	27	Printing and Related Support	–$0.4	–$1.0	–$1.4
325	28	Chemicals	–$102.4	–$204.7	–$307.1
326	30	Plastics and Rubber Products	–$6.1	–$14.6	–$20.7
327	32	Nonmetallic Mineral Products	–$9.1	–$10.9	–$20.0
331	33	Primary Metals	–$59.5	–$13.6	–$73.1
332	34	Fabricated Metal Products	–$18.6	–$5.0	–$23.6
333	35	Machinery	–$17.1	–$11.4	–$28.5
334	36 (pt)	Computer and Electronic Products	–$12.0	–$4.8	–$16.8
335	36 (pt)	Electrical Equipment, Appliances, and Components	–$11.7	–$7.8	–$19.6
336	37	Transportation Equipment	–$47.8	–$63.7	–$111.4
337	25	Furniture and Related Products	–$9.2	–$41.8	–$51.0
339	39	Miscellaneous	–$3.2	–$2.5	–$5.7
11	01-08	Agricultural Sector	–$1.5	–$3.6	–$5.1
23	15-17	Construction Sector	–$3.2	–$4.3	–$7.5
21	10; 14	Other Mining Sector	–$18.9	–$13.1	–$32.0
48	40-47 (pt)	Transportation	–$24.1	–$22.5	–$46.5
42; 44-45; 49; 51-56; 61-62; 71-72; 81	40-48 (pt); 50-99	Commercial	–$129.3	–$172.5	–$301.8
		Residential	NA	–$92.0	–$92.0
Grand Total			–$955.3	–$1,040.2	–$1,995.5

NA = Not applicable.
pt = Part

transportation sector revenues. Transportation consumers bear approximately $4.7 million ($24.1 million) and producers bear $4.3 million ($22.5 million) of these impacts. Finally, the social cost burden to residential consumers of energy, $42.7 million ($92.0 million), is 0.037 (0.078) percent of annual residential energy expenditures in 2005.

6.2 National Market-Level Impacts

Increases in the costs of production in the energy and final product markets due to the regulation are expected to result in changes in prices, production, and consumption from baseline levels. As shown in Table 6-4, the electricity market price increases by 0.050 (0.108) percent, while production/consumption decreases by 0.011 (0.026) percent as a result of additional control costs. A significant share of electricity is produced in the United States using coal as a primary input. Therefore, projected reductions in electricity production also lead to a decrease in demand for coal. As a result, the price and quantities of coal are projected to fall by 0.007 (0.020) percent and 0.010 (0.024) percent, respectively. In the petroleum market, the model projects small price and quantity effects (i.e., less than 0.01 percent). In the natural gas market, the model projects the market price will rise in response to increased demand (0.005 percent under both alternatives). The price increase is the result of additional control costs and increased demand. Production and consumption quantities also increase in this market (0.002 under the floor alternative and 0.001 percent under Option 1A) as a result of increased demand.

Additional control costs and higher energy costs associated with the regulation lead to higher goods and services prices in all markets and a decline in output. However, the changes are generally very small. Under the MACT Floor, three markets have price increases greater than or equal to 0.02 percent—Wood Product(NAICS 321), Paper (NAICS 322), and Textile Mills (NAICS 313). Under Option 1A, these three markets have price increases greater than or equal to 0.05 percent. The producers in these sectors are expected to face higher per-unit control costs relative to other industries. In addition, These industries are also electricity-intensive; therefore, costs of production also increase as a result of higher electricity prices.

Although the impacts on price and quantity in the goods and services markets are estimated to be small, one possible effect of modeling market impacts at the two and three digit NAICS code level is that fuel-intensive industries within the larger NAICS code definition may be affected more significantly than the average industry for that NAICS code. Thus, the changes in price and

Table 6-4. Market-Level Impacts

Sectors/Markets			MACT Floor Percent Change		Option 1A Percent Change	
			Price	Quantity	Price	Quantity
Energy Markets						
Petroleum			0.002%	0.000%	0.019%	–0.005%
Natural gas			0.005%	0.002%	0.005%	0.001%
Electricity			0.050%	–0.011%	0.108%	–0.026%
Coal			–0.007%	–0.010%	–0.020%	–0.024%
NAICS Code	**SIC Code**	**Description**				
311	20 (pt)	Food	0.006%	–0.002%	0.019%	–0.006%
312	20 (pt); 21	Beverage and Tobacco Products	0.003%	–0.004%	0.007%	–0.009%
313	22 (pt)	Textile Mills	0.025%	–0.021%	0.050%	–0.043%
314	22 (pt)	Textile Product Mills	0.000%	0.000%	0.000%	0.000%
315	23	Apparel	0.000%	–0.001%	0.001%	–0.001%
316	31	Leather and Allied Products	0.002%	–0.003%	0.025%	–0.030%
321	24	Wood Products	0.041%	–0.008%	0.075%	–0.015%
322	26	Paper	0.026%	–0.028%	0.068%	–0.074%
323	27	Printing and Related Support	0.000%	0.000%	0.000%	–0.001%
325	28	Chemicals	0.009%	–0.013%	0.021%	–0.032%
326	30	Plastics and Rubber Products	0.001%	–0.002%	0.003%	–0.005%
327	32	Nonmetallic Mineral Products	0.003%	–0.003%	0.009%	–0.008%
331	33	Primary Metals	0.011%	–0.009%	0.026%	–0.021%
332	34	Fabricated Metal Products	0.003%	–0.001%	0.007%	–0.001%
333	35	Machinery	0.002%	–0.001%	0.005%	–0.002%
334	36 (pt)	Computer and Electronic Products	0.001%	0.000%	0.002%	–0.001%
335	36 (pt)	Electrical Equipment, Appliances, and Components	0.002%	–0.001%	0.009%	–0.004%
336	37	Transportation Equipment	0.004%	–0.004%	0.007%	–0.007%
337	25	Furniture and Related Products	0.008%	–0.026%	0.013%	–0.044%
339	39	Miscellaneous	0.001%	0.000%	0.003%	–0.002%
11	01-08	Agricultural Sector	0.000%	0.000%	0.001%	–0.001%
23	15-17	Construction Sector	0.000%	0.000%	0.000%	0.000%
21	10; 14	Other Mining Sector	0.012%	–0.004%	0.023%	–0.007%
48	40-47 (pt)	Transportation	0.001%	–0.001%	0.007%	–0.005%
42; 44-45; 49; 51-56; 61-62; 71-72; 81	40-48 (pt); 50-99	Commercial	0.000%	0.000%	0.001%	–0.001%

pt = Part.

quantity should be interpreted as an average for the whole NAICS code, not necessarily for each disaggregated industry within that NAICS code.

6.3 Executive Order 13211 (Energy Effects)

Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 Fed. Reg. 28355 [May 22, 2001]), requires EPA to prepare and submit a Statement of Energy Effects to the Administrator of the Office of Information and Regulatory Affairs, Office of Management and Budget, for certain actions identified as "significant energy actions." Section 4(b) of Executive Order 13211 defines "significant energy actions" as "any action by an agency (normally published in the *Federal Register*) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking:

- that is a significant regulatory action under Executive Order 12866 or any successor order, and is likely to have a significant adverse effect on the supply, distribution, or use of energy; or

- that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action."

EPA has provided additional information on the impacts of the proposed rule on affected energy markets below.[1]

Energy Price Effects. As described in the market-level results section, electricity prices are projected to increase by less than 1 percent. Petroleum and natural gas prices are all projected to increase by less than 0.1 percent. The price of coal is projected to decrease slightly.

Impacts on Electricity Supply, Distribution, and Use. We project the increased compliance costs for the electricity market will result in an annual production decline of approximately 415 million kWh under the MACT floor and 980 million kWh under Option 1A.

Impacts on Petroleum, Natural Gas, and Coal Supply, Distribution, and Use. The model projects decreases in petroleum production/consumption of approximately 68 barrels per day under the MACT floor and 975 barrels per day under Option 1A. In contrast, natural gas

[1]Conversion factors for heat rates were obtained from AEO 2002, Appendix H. These factors vary by year to year; 2010 values are reported in this Appendix.

production/consumption is projected to increase by 1.1 million cubic feet per day under the MACT floor and 600,000 cubic feet per day under Option 1A This is the result of fuel switching in response to relative price changes. Finally, the model also projects less than a 1,000 tons per day decrease in coal production/consumption under both scenarios in response to reduced output from the electricity sector (a significant consumer of coal).

6.4 Conclusions

The decrease in social surplus estimated using the market analysis is $862.9 million ($1,955.5 million). This estimate is slightly smaller than the estimated baseline engineering costs because the market model accounts for behavioral changes of producers and consumers. Although the rule affects boilers and process heaters used in energy industries, energy producers only incur less than 6 percent of the total social cost of the regulation. This 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 remaining share of the social cost is mostly borne by the manufacturing sectors which operate the majority of the boilers and process heaters affected by the regulation. Manufacturing industries bearing the largest social costs include percent—Wood Products (NAICS 321), Paper (NAICS 322), and Textile Mills (NAICS 313). However, the market model predicts that changes in these industries' price and quantity do not exceed 0.02 percent under the floor alternative and 0.05 percent under Option 1A..

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 industrial boilers and process heaters MACT are generally too small to significantly influence trade patterns. 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.

SECTION 7

SMALL BUSINESS IMPACTS

This section investigates the potential impact the proposed regulation will have on small entities. The Agency has identified 185 small entities that will be affected by the MACT floor alternative for the ICI boilers and process heaters NESHAP. For these entities, the average cost-to-sales ratio (CSR) is 0.78 percent and the average annual control cost is $198,675. Ten entities will incur annual costs that are greater than or equal to 3 percent of their annual sales (see Table 7-1).

Table 7-1. Summary of Small Entity Impacts

	Floor Alternative	Option 1A Alternative
Number of small entities	185	369
Total number of entities	576	970
Average annual control cost per small entity	$198,675	$269,842
Average control cost/sales ratio	0.78%	1.65%
Number of small entities with cost-to-sales ratios ≥1 percent	34	148
Number of small entities with cost-to-sales ratios ≥3 percent	10	45

7.1 Background on Small Business Screenings

The regulatory costs imposed on domestic producers and government entities to reduce air emissions from boilers and process heaters will have a direct impact on owners of the affected facilities. Firms or individuals that own the facilities with boilers and process heaters are typically 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 potentially affect all sizes of businesses, but small businesses may have special problems relative to large businesses in complying with such regulations.

The Regulatory Flexibility Act (RFA) generally requires an agency to prepare a regulatory flexibility analysis of any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For purposes of assessing the impacts of today's rule on small entities, small entity is defined as: (1) a small business according to Small Business Administration (SBA) size standards by the North American Industry Classification System (NAICS) category of the owning entity. The range of small business size standards for the 40 affected industries ranges from 500 to 1,000 employees, except for petroleum refining and electric utilities. In these latter two industries, the size standard is 1,500 employees and a mass throughput of 75,000 barrels/day or less, and 4 million kilowatt-hours of production or less, respectively. (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

This section investigates characteristics of businesses and government entities that own existing boilers and process heaters affected by this proposed rule and provides a preliminary screening-level analysis to assist in determining whether this rule is likely to impose a significant impact on a substantial number of the small businesses within this industry. The screening-level analysis employed here is a "sales test," which computes the annualized compliance costs as a share of sales/revenue for existing companies/government entities.

7.2 Identifying Small Businesses

To support the economic impact analysis of the proposed regulation, EPA identified 2,186 (3,580) boilers and process heaters located at commercial, industrial, and government facilities that would be affected by the proposed regulation. The population of boilers and process heaters was developed from the EPA ICCR Inventory Database version 4.1.[1] The list of boilers and process heaters 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 ICI boilers and process heaters NESHAP. This modified database containing information on only boilers and process heaters is referred to as the Inventory Database.

The small entities screening analysis for the proposed regulation is based on the evaluation of existing owners of boilers and process heaters for which information was available. It is assumed that the size and ownership distribution of units in the Inventory Database is representative of the entire estimated population of existing boilers and process heaters. In addition, it is assumed that new sources included in the 2005 population will also be representative of the Inventory Database. However, because our analysis is based on a subset of the total population of boilers and process heaters, the number of entities identified as highly affected in this analysis may not be identical to the actual impact of the regulation on small entities.

The remainder of this section presents cost and sales information on small companies and government organizations that own existing boilers and process heaters. Also, in this section, as in previous sections, the values from the Inventory Database in the text are for the floor alternative. Following in parentheses are those for the Option 1A alternative.

7.3 Analysis of Facility-Level and Parent-Level Data

The 2,186 (3,580) units in the Inventory Database with full information were linked to 1,214 (1,881) existing facilities. As shown in Table 7-2, these 1,186 (1,521) facilities are owned by 576 (970) parent companies. The average number of facilities per company is approximately 2.0 (2.2); however, as is also illustrated in Table 7-2, several large entities in the health services industry and government sectors own many facilities with boilers and process heaters.

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

Table 7-2. Facility-Level and Parent-Level Data by Industry

			Floor Alternative				Option 1A Alternative			
SIC Code	NAICS Code	Description	Number of Units	Number of Facilities	Number of Parent Companies	Avg. Number of Facilities Per Parent Entity	Number of Units	Number of Facilities	Number of Parent Companies	Avg. Number of Facilities Per Parent Entity
01	111	Agriculture—Crops	3	3	3	1.0	6	6	6	1.0
02	112	Agriculture—Livestock	—	—	—	—	—	—	—	—
07	115	Agricultural Services	—	—	—	—	—	—	—	—
10	212	Metal Mining	9	4	2	2.0	11	5	2	2.5
12	212	Coal Mining	2	1	—	—	2	1	—	—
13	211	Oil and Gas Extraction	—	—	—	—	18	4	1	4.0
14	212	Mining/Quarrying—Nonmetallic Minerals	8	4	3	1.3	10	5	4	1.3
17	235	Construction—Special Trade	—	—	—	—	2	1	1	1.0
20	311	Food and Kindred Products	138	60	32	1.9	163	72	38	1.9
21	312	Tobacco Products	11	7	4	1.8	22	11	6	1.8
22	313	Textile Mill Products	135	71	33	2.2	250	134	73	1.8
23	315	Apparel & Other Products from Fabrics	2	2	1	2.0	4	4	3	1.3
24	321	Lumber and Wood Products	360	262	122	2.1	462	337	175	1.9
25	337	Furniture and Fixtures	234	154	67	2.3	310	209	100	2.1
26	322	Paper and Allied Products	321	194	68	2.9	503	272	100	2.7
27	511	Printing, Publishing, and Related Industries	—	—	—	—	8	6	3	2.0
28	325	Chemicals and Allied Products	174	70	41	1.7	433	163	91	1.8
29	324	Petroleum Refining and Related Industries	11	8	9	0.9	162	50	31	1.6
30	326	Rubber and Misc. Plastics Products	17	13	9	1.4	56	37	24	1.5

(continued)

Table 7-2. Facility-Level and Parent-Level Data by Industry (continued)

SIC Code	NAICS Code	Description	Floor Alternative: Number of Units	Floor Alternative: Number of Facilities	Floor Alternative: Number of Parent Companies	Floor Alternative: Avg. Number of Facilities Per Parent Entity	Option 1A Alternative: Number of Units	Option 1A Alternative: Number of Facilities	Option 1A Alternative: Number of Parent Companies	Option 1A Alternative: Avg. Number of Facilities Per Parent Entity
31	316	Leather and Leather Products	1	1	1	1.0	22	12	8	1.5
32	327	Stone, Clay, Glass, and Concrete Products	9	7	4	1.8	42	25	15	1.7
33	331	Primary Metal Industries	41	16	10	1.6	85	33	22	1.5
34	332	Fabricated Metal Products	16	10	7	1.4	44	28	18	1.6
35	333	Industrial Machinery and Computer Equip.	23	12	9	1.3	46	25	20	1.3
36	335	Electronic and Electrical Equipment	5	5	3	1.7	45	29	19	1.5
37	336	Transportation Equipment	102	41	12	3.4	158	61	26	2.3
38	334	Scientific, Optical, and Photographic Equipment	8	4	3	1.3	33	16	9	1.8
39	339	Misc. Manufacturing Industries	2	2	2	1.0	14	10	9	1.1
40	482	Railroad Transportation	4	1	1	1.0	4	1	1	1.0
42	484	Motor Freight and Warehousing	5	1	1	1.0	7	3	3	1.0
46	486	Pipelines, Except Natural Gas	—	—	—	—	6	5	1	5.0
49	221	Electric, Gas, and Sanitary Services	318	160	80	2.0	372	185	98	1.9
50	421	Wholesale Trade—Durable Goods	3	2	1	2.0	3	2	1	2.0
51	422	Wholesale Trade—Nondurable Goods	2	1	1	1.0	2	1	1	1.0
55	441	Automotive Dealers and Gasoline Service Stations	—	—	—	—	1	1	1	1.0
58	722	Eating and Drinking Places	—	—	—	—	—	—	—	—
59	445–454	Miscellaneous Retail	—	—	—	—	1	1	1	1.0
60	522	Depository Institutions	—	—	—	—	—	—	—	—

(continued)

Table 7-2. Facility-Level and Parent-Level Data by Industry (continued)

SIC Code	NAICS Code	Description	Floor Alternative: Number of Units	Floor Alternative: Number of Facilities	Floor Alternative: Number of Parent Companies	Floor Alternative: Avg. Number of Facilities Per Parent Entity	Option 1A Alternative: Number of Units	Option 1A Alternative: Number of Facilities	Option 1A Alternative: Number of Parent Companies	Option 1A Alternative: Avg. Number of Facilities Per Parent Entity
70	721	Hotels and Other Lodging Places	1	1	1	1.0	1	1	1	1.0
72	812	Personal Services	—	—	—	—	—	—	—	—
76	811	Misc. Repair Services	2	1	—	—	2	1	—	—
80	621	Health Services	37	18	2	9.0	40	19	2	9.5
81	541	Legal Services	—	—	—	—	—	—	—	—
82	611	Educational Services	105	45	30	1.5	114	50	35	1.4
83	624	Social Services	2	1	—	—	3	2	2	1.0
86	813	Membership Organizations	—	—	—	—	—	—	—	—
87	541	Engineering, Accounting, Research, Management and Related Services	2	2	1	2.0	6	5	2	2.5
89	711/514	Services, N.E.C.	2	1	—	—	2	1	—	—
91	921	Executive, Legislative, and General Administration	1	1	—	—	2	2	1	2.0
92	922	Justice, Public Order, and Safety	29	9	—	—	33	10	—	—
94	923	Administration of Human Resources	1	1	—	—	1	1	—	—
96	926	Administration of Economic Programs	4	3	1	3.0	4	3	1	3.0
97	928	National Security and International Affairs	29	11	2	5.5	41	13	2	6.5
NA		SIC Information Not Available	7	4	—	—	24	18	2	9.0
State		Parent is a state government	—	—	10	—	—	—	11	—
		Total	2,186	1,214	576	2.0	3,580	1,881	970	2.2

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.

Employment and sales are typically used as measures of business size. Employment, sales, population, and tax revenue data (when applicable) were collected for the 576 (970) parent companies and government entities.[2] Figure 7-1 shows the distribution of employees by parent company for the floor alternative. Employment for parent companies ranges from 5 to 608,000 employees. One hundred seventy-eight or more of the firms have fewer than 500 employees, and 55 companies have more than 25,000 employees. The distribution of parents by employment range for the above-the-floor alternative is similar to the floor alternative.

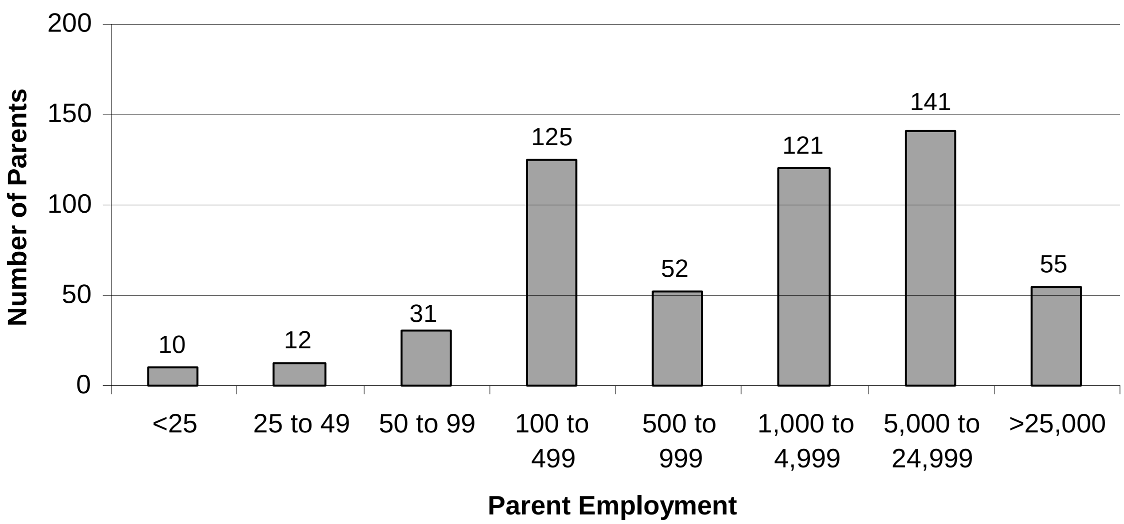

Figure 7-1. Parent Size by Employment Range, Floor Alternative

*Excludes 29 parent entities for which employment information was unavailable.

Sales provide another measure of business size. Figure 7-2 presents the sales distribution for affected parent companies for the floor alternative. The median sales figure for affected companies is $300 million ($200 million), and the average sales figure is $4.1 billion ($3.5 billion) (excluding the federal government). As shown in Figure 7-2, revenue and sales figures vary greatly across the population: 209 firms and governments affected by the floor alternative have annual revenues less than $100 million per year. These figures include all sales associated with the parent

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

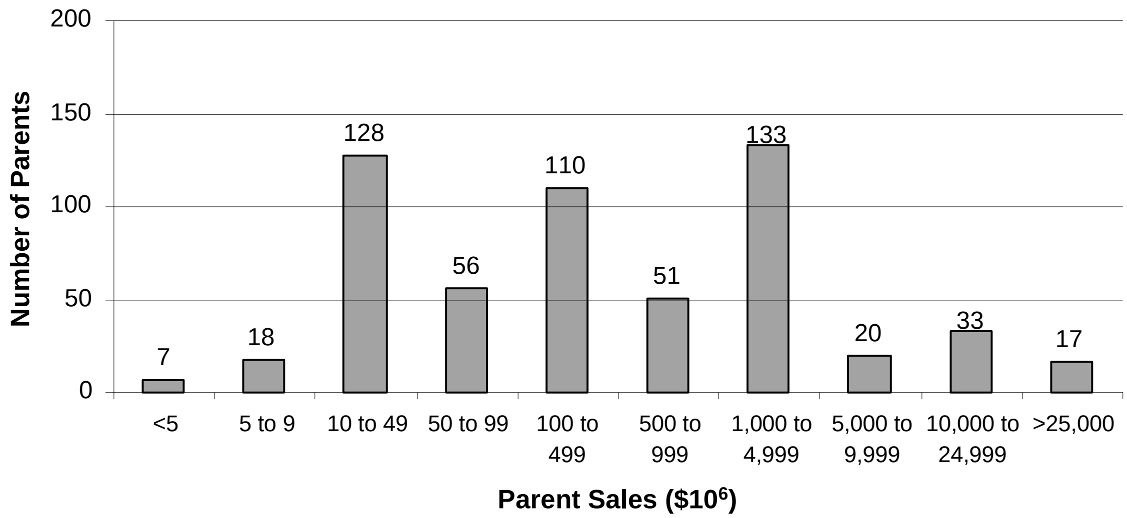

Figure 7-2. Number of Parents by Sales Range, Floor Alternative

*Excludes 3 parent entities for which sales or revenue information was unavailable.

company, not just facilities affected by the regulation (i.e., facilities with boilers or process heaters). The distribution for the Option 1A above-the-floor alternative is similar to that for the floor alternative.

Based on SBA guidelines, 185 (369) of the companies were identified as small businesses.[3] Small businesses by business type are presented in Table 7-3. The lumber and wood products industry contains the largest number of the small businesses with 84 (134), followed by furniture and fixtures with 28 (55), electric services with 26 (30), and paper and allied products with 13 (30). The remaining small businesses are distributed across 40 different two-digit SIC code groupings.

[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 7-3. Small Parent Companies by Industry

SIC Code	NAICS Code	Description	Floor Alternative: Number of Parent Companies	Floor Alternative: Number of Small Parent Companies	Option 1A Alternative: Number of Parent Companies	Option 1A Alternative: Number of Small Parent Companies
01	111	Agriculture—Crops	3	—	6	1
02	112	Agriculture—Livestock	—	—	—	—
07	115	Agricultural Services	—	—	—	—
10	212	Metal Mining	2	2	2	2
12	212	Coal Mining	—	—	—	—
13	211	Oil and Gas Extraction	—	—	1	1
14	212	Mining/Quarrying—Nonmetallic Minerals	3	—	4	—
17	235	Construction—Special Trade Contractors	—	—	1	1
20	311	Food and Kindred Products	32	12	38	15
21	312	Tobacco Products	4	—	6	—
22	313	Textile Mill Products	33	5	73	27
23	315	Apparel and Other Products from Fabrics	1	—	3	2
24	321	Lumber and Wood Products	122	84	175	134
25	337	Furniture and Fixtures	67	28	100	55
26	322	Paper and Allied Products	68	13	100	30
27	511	Printing, Publishing, and Related Industries	—	—	3	2
28	325	Chemicals and Allied Products	41	4	91	19
29	324	Petroleum Refining and Related Industries	9	2	31	9
30	326	Rubber and Misc. Plastics Products	9	1	24	4
31	316	Leather and Leather Products	1	1	8	4
32	327	Stone, Clay, Glass, and Concrete Products	4	—	15	3
33	331	Primary Metal Industries	10	1	22	3
34	332	Fabricated Metal Products	7	3	18	5

(continued)

Table 7-3. Small Parent Companies by Industry (continued)

SIC Code	NAICS Code	Description	Floor Alternative: Number of Parent Companies	Floor Alternative: Number of Small Parent Companies	Option 1A Alternative: Number of Parent Companies	Option 1A Alternative: Number of Small Parent Companies
35	333	Industrial Machinery and Computer Equip.	9	1	20	5
36	335	Electronic and Electrical Equipment	3	—	19	—
37	336	Transportation Equipment	12	1	26	5
38	334	Scientific, Optical, and Photographic Equip.	3	—	9	1
39	339	Miscellaneous Manufacturing Industries	2	—	9	1
40	482	Railroad Transportation	1	—	1	—
42	484	Motor Freight and Warehousing	1	—	3	1
46	486	Pipelines, Except Natural Gas	—	—	1	—
49	221	Electric, Gas, and Sanitary Services	80	26	98	30
50	421	Wholesale Trade—Durable Goods	1	—	1	—
51	422	Wholesale Trade—Nondurable Goods	1	—	1	—
55	441	Automotive Dealers and Gasoline Service Stations	—	—	1	1
58	722	Eating and Drinking Places	—	—	—	—
59	445–454	Miscellaneous Retail	—	—	1	1
60	522	Depository Institutions	—	—	—	—
70	721	Hotels and Other Lodging Places	1	—	1	—
72	812	Personal Services	—	—	—	—
76	811	Misc. Repair Services	—	—	—	—
80	621	Health Services	2	1	2	1
81	541	Legal Services	—	—	—	—
82	611	Educational Services	30	—	35	3
83	624	Social Services	—	—	2	1

(continued)

Table 7-3. Small Parent Companies by Industry (continued)

SIC Code	NAICS Code	Description	Floor Alternative: Number of Parent Companies	Floor Alternative: Number of Small Parent Companies	Option 1A Alternative: Number of Parent Companies	Option 1A Alternative: Number of Small Parent Companies
86	813	Membership Organizations	—	—	—	—
87	541	Engineering, Accounting, Research, Management and Related Services	1	—	2	—
89	711/514	Services, N.E.C.	—	—	—	—
91	921	Executive, Legislative, and General Administration	—	—	1	—
92	922	Justice, Public Order, and Safety	—	—	—	—
94	923	Administration of Human Resources	—	—	—	—
96	926	Administration of Economic Programs	1	—	1	—
97	928	National Security and International Affairs	2	—	2	—
NA		SIC Information Not Available	—	—	2	2
State		Parent is a State Government	10	—	11	—
		Total	576	185	970	369

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.

Fifty-nine governmental jurisdictions are affected by the floor alternative. The entities operate 290 unites located at 121 facilities. Thirteen of these jurisdictions are classified as small because they serve a population of 50,000 or fewer. The affected small governments operate 13 units at 13 facilities.

7.4 Small Business Impacts

Table 7-4 presents a summary of the ratio of floor and above-the-floor control costs to sales for affected large and small entities. The average CSR is 0.14 (0.23) percent for large entities

Table 7-4. Summary Statistics for SBREFA Screening Analysis: Floor and Above-the-Floor Cost-to-Sales Ratios

	Floor	Option 1A
Total Number of Small Entities	185	369
Average Annual Compliance Cost per Small Entity	$198,675	$269,842
Entities with Sales/Revenue Data		
Compliance costs are <1% of sales	141	176
Compliance costs are ≥1 to 3% of sales	34	148
Compliance costs are ≥3% of sales	10	45
Compliance Cost-to-Sales/Revenue Ratios		
Average	0.78	1.65
Median	0.50	0.77
Maximum	7.83	38.83
Minimum	0.011	0.009

(excluding the federal government) and 0.78 (1.65) percent for small entities. Forty-four (193) small parents had floor CSRs greater than 1 percent, assuming add-on control is employed to meet the standard. For these 44 (193) parent companies, the CSRs ranged from 1.00 (1.00) percent to 7.83 (38.83) percent. Ten (45) entities out of these 44 (193) had CSRs ratios greater than 3 percent.

7.5 Assessment of SBREFA Screening

This analysis indicates that over two-thirds of the parent companies affected by the proposed industrial boilers and process heaters standard are large companies.[4] The relatively small proportion of small businesses affected by the proposed regulation at the floor level is due in part to the exclusion of ICI boilers and process heaters with less than 10 MMBtu input capacity that also use a fossil fuel liquid or gas as primary fuel. As a result, a large share of small boilers and process heaters, which are presumably owned disproportionately by smaller entities, will not incur compliance costs. The Agency estimates that approximately 57 percent of the U.S. population are less than 10 MMBtus or are emergency units and, hence, are excluded from the proposed regulation for the floor alternative. These units are included, however, in the Option 1A above-the-floor alternative, except where they consume a fossil fuel liquid or gas other than residual fuel oil.

Of the small businesses affected by the proposed regulation, the majority are in the lumber and wood products, furniture and fixtures, paper and allied products, and electric, gas and sanitary services sectors. As shown in Table 7-5, the median profit margin for these four sectors is approximately 3 percent. Table 7-5 also shows the profit margins for the other industry sectors with affected small businesses. All profit margins of industry sectors with affected small businesses are above 2 percent.

After considering the economic impact of today’s proposed rule on small entities, EPA certifies that this action will not have a significant impact on a substantial number of small entities. In accordance with the RFA, as amended by the SBREFA, 5 U.S.C. 601, et. seq., EPA conducted an assessment of the proposed standard on small businesses within the industries affected by the rule. Based on SBA size definitions for the affected industries and reported sales and employment data, the Agency identified 185 of the 576 companies, or 32 percent, owning affected facilities as small businesses. Although small businesses represent 32 percent of the companies within the

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[4]Based on SBA guidelines for determining small businesses.

Table 7-5. Profit Margins for Industry Sectors with Affected Small Businesses

SIC Code	NAICS Code	Description	Median Profit Margin
20	311	Food and Kindred Products	3.6%
22	313	Textile Mill Products	2.1%
24	321	Lumber and Wood Products	3.0%
25	337	Furniture and Fixtures	3.0%
26	322	Paper and Allied Products	3.3%
28	325	Chemicals and Allied Products	2.7%
49	221	Electric, Gas, and Sanitary Services	7.5%

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

SBREFA screening population, they are expected to incur only 8 percent of the total compliance costs of $445.6 million (1998$) for the evaluated 576 firms. Only ten small firms have compliance costs equal to or greater than 3 percent of their sales. In addition, only 34 small firms have CSRs between 1 and 3 percent.

An EIA was performed to estimate the changes in product price and production quantities for this rule. As mentioned in the summary of economic impacts earlier in this report, the estimated changes in prices and output for affected firms are no more than 0.04 percent.

This analysis indicates that the proposed rule should not generate a significant impact on a substantial number of small entities for following reasons. First, only 31 small firms (or 17 percent of all affected small firms) have compliance costs equal to or greater than 1 percent of their sales. Of these, only ten small firms (or 5 percent of all affected small firms) have compliance costs equal to or greater than 3 percent of their sales. Second, the EIA results show minimal impacts on prices and output from affected firms, including small entities, due to implementing this rule. This analysis therefore allows us to certify that there will not be a significant impact on a substantial number of small entities from the implementing this proposed rule.

This proposed rule will not have a significant economic impact on a substantial number of small entities as a result of several decisions EPA made regarding the development of this rulemaking which resulted in limiting the impact of this rule on small entities. First, as mentioned earlier, EPA identified small units (heat input of 10 MMBtu/hr or less) and limited-use boilers (operate less than 10 percent of the time) as separate subcategories from large units. Many small and limited-use units are located at small entities. As also discussed earlier, the result of the MACT floor analysis for these subcategories of existing sources was that no MACT floor could be identified except for the limited-use solid fuel subcategory, which is less stringent than the MACT floor for large units. Furthermore, the results of the above-the-floor analysis for these subcategories indicated that the costs would be too high to be considered feasible. Consequently, this proposed rule contains no emission limitations for any of the existing small and limited-use subcategories except the existing limited-use solid fuel subcategory. In addition, the proposed alternative metals emission limit resulted in minimizing the impacts on small entities because some of the potential entities burning a fuel containing very little metals are small entities. We continue to be interested in the potential impacts of the proposed rule on small entities and welcome comments on issues related to such impacts.

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APPENDIX A:

ECONOMIC MODEL OF MARKETS AFFECTED BY THE BOILERS AND PROCESS HEATERS MACT

The primary purpose of the EIA for the proposed rule is to describe and quantify the economic impacts associated with the rule. The Agency used a basic framework that is consistent with economic theory and the analyses performed for other rules to develop estimates of these impacts. This approach employs standard microeconomic concepts to model behavioral responses expected to occur with regulation. This appendix describes the spreadsheet model in more detail and discusses how the Agency

- collected the baseline data set from the Annual Energy Outlook 2002 (DOE, EIA, 2002), U.S. Census Bureau (U.S. Department of Commerce, 2001), and U.S. Department of Agriculture (USDA, 2002).
- characterized market supply and demand for each market and specified links between the energy and agricultural, manufacturing, mining, and commercial markets.
- introduced a policy "shock" into the model by using control cost-induced shifts in the supply functions, and
- used a solution algorithm to determine a new with-regulation equilibrium for each market.

A.1 Baseline Data Set

EPA collected the following data to characterize the baseline year, 2005:

- *Energy Market Data*—The Department of Energy's Supplemental Tables to the Annual Energy Outlook 2002 report forecasts of price, quantity, and fuel intensities used to calibrate the model.
- *Agriculture, Mining, Manufacturing, Commercial Sectors*—EPA obtained shipment data from the 1997 Economic Census and 1997 Agriculture Census. We then used annual growth rates reported by the Bureau of Economic Analysis (BEA, 1997) to estimate baseline shipment data for 2005. The Agency selected units for output such that the price in each market equals one. We computed energy demand using fuel intensity data reported in the AEO 2002.
- *Supply and Demand Elasticities*—The supply and demand elasticity values used in the market model are reported in Table 5-2 of this report. Given the

uncertainties regarding these parameters, EPA also conducted several sensitivity analyses and report these results in Appendix B.

A.2 Multi-Market Model

The model includes four energy markets (coal, electricity, natural gas, and petroleum) and 24 goods and service markets. The following sections describe model equations the Agency developed to characterize these markets and estimate welfare changes resulting from the rule.

A.1.1 Supply Side Modeling

EPA estimated the change in quantity supplied as follows:

$$\Delta q^S = q_0^S \cdot \varepsilon^S \cdot \frac{\Delta p - c - \sum_{j=1}^{n} \alpha_j \Delta p_j}{p_0} \qquad \text{(A.1)}$$

where q_0^S is the baseline quantity, ε^S is the domestic supply elasticity, the term $\Delta p - c - \sum_{j=1}^{n} \alpha_j \Delta p_j$ is the change in the producer's net price, and p_0 is the baseline price. The change in net price is composed of the change in baseline price resulting from the regulation, the direct shift in the supply function resulting from compliance costs, and the indirect shift in the supply function resulting from changes in input prices in energy market (j). The fuel share is allowed to vary using a fuel switching rule relying on cross-price elasticities of demand between energy sources.

A.1.1.2 Producer Welfare Measurement

EPA approximated the change in producer surplus with the following equation:

$$\Delta PS = q_1 \cdot (\Delta p - c - \sum_{j=1}^{n} \alpha_j \Delta p_j) - 0.5 \cdot \Delta q \cdot (\Delta p - c - \sum_{j=1}^{n} \alpha_j \Delta p_j) \qquad \text{(A.2)}$$

Increased control costs, higher energy input costs, and output declines have a negative effect on domestic producer surplus. However, these losses are mitigated to some degree as a result of higher market prices.

A.1.2 Energy Demand Side Modeling

Market demand in the energy markets is expressed as the sum of the energy, residential, agriculture, manufacturing, mining, commercial, and transportation sectors:

$$Q_{Dj} = \sum_{i=1}^{n} q_{Dji} \ , \tag{A.3}$$

where j indexes the energy market and i indexes the consuming sector. The change in residential quantity demanded of energy market j can be approximated as follows:

$$\Delta q^{D_j} = q_0^{D_j} \cdot \eta^{D_j} \cdot \frac{\Delta p_j}{p_{j0}} \tag{A.4}$$

where $q_0^{D_j}$ is baseline consumption, η^{Dj} is the residential demand elasticity and (Δp) is the change in the market price.

In contrast, energy demand from energy, agricultural, manufacturing, mining, commercial, and transportation sectors is modeled as a derived demand resulting from the production and consumption choices in these industries. Energy demand responds to changes in sector output and fuel switching that occurs in response to changes in relative energy prices. For each of these sectors, energy demand is expressed as follows:

$$BTU_{ji1} = \frac{BTU_{ji}}{q_{i0}} \cdot FSW \cdot q_{i1} \tag{A.5}$$

where BTU is demand for energy market j from sector i, q is sector i's output, and FSW is a factor generated by the fuel switching algorithm. The subscripts 0 and 1 represent baseline and with regulation conditions, respectively.

A.1.3 Agriculture, Manufacturing, Mining, Commercial, and Transportation Demand Side Modeling

The change in quantity demanded in these markets can be approximated as follows:

$$\Delta q^{D_i} = q_0^{D_i} \cdot \eta^{D_i} \cdot \frac{\Delta p_i}{p_{i0}} \tag{A.6}$$

where $q_0^{D_i}$ is baseline output, η^D is the demand elasticity of the respective market (i) and (Δ

p_i) is the change in the market price.

The change in consumer surplus in markets is approximated as follows:

$$\Delta CS = - q_1 \cdot \Delta p + 0.5 \cdot \Delta q \cdot \Delta p \qquad (A.7)$$

As shown, higher market prices and reduced consumption lead to welfare losses for consumers.

A.2 With-Regulation Market Equilibrium Determination

Market adjustments can be conceptualized as an interactive feedback process. Supply segments face increased production costs as a result of the rule and are willing to supply smaller quantities at the baseline price. This reduction in market supply leads to an increase in the market price that all producers and consumers face, which leads to further responses by producers and consumers and thus new market prices. The new with-regulation equilibrium is the result of a series of iterations in which price is adjusted and producers and consumers respond, until a set of stable market prices arises where total market supply equals market demand (i.e., $Qs = Q_D$) in each market. Market price adjustment takes place based on a price revision rule that adjusts price upward (downward) by a given percentage in response to excess demand (excess supply).

The algorithm for determining with-regulation equilibria can be summarized by seven recursive steps:

1. Impose the control costs on affected supply segments, thereby affecting their supply decisions.
2. Recalculate the market supply in each market. Excess demand currently exists.
3. Determine the new prices via a price revision rule.
4. Recalculate market supply with new prices, accounting for fuel switching choices associated with new energy prices.
5. Compute market demand in each market.

6. Compare supply and demand in each markets. If equilibrium conditions are not satisfied, go to Step 3, resulting in a new set of market prices. Repeat until equilibrium conditions are satisfied (i.e., the ratio of supply to demand is arbitrarily close to one).

APPENDIX B

ASSUMPTIONS AND SENSITIVITY ANALYSIS

In developing the economic model to estimate the impacts of the industrial/ commercial/institutional boilers and process heaters NESHAP, several assumptions were necessary to make the model operational. This appendix lists and explains the major model assumptions and describes their potential impact on the analysis results. Sensitivity analyses are presented for numeric assumptions.

Assumption: The domestic markets for goods and services 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: Market Supply and Demand Elasticity Uncertainty

Explanation: The goods and service markets are modeled at the two or three-digit NAICS code level to operationalize the economic model. Because of the high level of aggregation, only limited data on elasticities of supply and demand estimates are available. However, these elasticities strongly influence the distribution of economic impacts between producers and consumers.

Sensitivity Analysis: Tables B-1a and Table B-1b show how the economic impact estimates vary as the supply and demand elasticities for goods and services change by 25 percent.

Table B-1a. Sensitivity Analysis: Supply and Demand Elasticities in the Goods and Services Markets

Change Supply Demand Constant	25% Decrease	Elasticities Reported in Section 6	25% Increase
Change in consumer surplus	–367.8	–414.3	–450.5
Change in producer surplus	–495.2	–448.7	–412.4
Change in social welfare	–862.9	–862.9	–862.9

Table B-1b. Sensitivity Analysis: Supply and Demand Elasticities in the Goods and Services Markets

Supply Constant Demand Change	25% Decrease	Elasticities Reported in Section 6	25% Increase
Change in consumer surplus	–462.7	–414.3	–364.4
Change in producer surplus	–400.2	–448.7	–498.5
Change in social welfare	–862.9	–862.9	–862.9

Assumption: Cross-price elasticities of demand for fuels are based on 2015 NEMS projections.

Explanation: Cross- and own-price elasticities of demand from NEMS were used to capture fuel switching in the manufacturing sectors in the economic model. As shown in Table 5-2, allowing manufacturers to switch fuels in response to changes in relative energy prices decreases the change in social welfare by approximately 10 percent. 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.

Sensitivity Analysis: Table B-2 shows how the economic impact estimates vary as the own- and cross-price elasticities used in the EIA are reduced by 50 percent and 75 percent.

Table B-2. Sensitivity Analysis: Own- and Cross-Price Elasticities Used to Model Fuel Switching

	Fuel Price Elasticities Presented in Table 5-2	Reduced by 50 Percent	Reduced by 75 Percent
Change in consumer surplus	–414.3	–414.6	–414.9
Change in producer surplus	–448.7	–448.4	–448.0
Change in social welfare	–862.9	–862.9	–862.9

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 elasticity of supply in the electricity market for existing sources is approximately 0.75.

Explanation: 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. This is in part because, under traditional regulation, the electric utility industry had a mandate to serve all its customers and utilities were compensated on a rate-based rate of return. As a result, the market concept of supply elasticity was not the driving force in utilities' capital investment decisions. This has changed under 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.

***Sensitivity Analysis*:** Table B-3 shows how the economic impact estimates vary as the elasticity of supply in the electricity markets varies.

Table B-3. Sensitivity Analysis: Elasticity of Supply in the Electricity Markets

	ES = 0.5	**ES = 0.75**	**ES = 1.0**
Change in consumer surplus	–405.0	–414.3	–419.6
Change in producer surplus	–457.9	–448.7	–443.4
Change in social welfare	–862.9	–862.9	–862.9