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Air

# Economic Impact Analysis of Proposed Coke Ovens NESHAP

## Final Report

# Economic Impact Analysis
# of Proposed Coke Ovens NESHAP

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

**Prepared Under Contract By:**

**Research Triangle Institute**
**Center for Economics Research**
**Research Triangle Park, NC 27711**

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# SECTION 1

# INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is developing a maximum achievable control technology (MACT) standard to reduce hazardous air pollutants (HAPs) from the integrated iron and steel manufacturing source categories. To support this rulemaking, EPA's Innovative Strategies and Economics Group (ISEG) has conducted an economic impact analysis (EIA) to assess the potential costs of the rule. This report documents the methods and results of this EIA. Finished steel products are primarily used as a major input to consumer products such as automobile and appliances. In 1997, the United States produced 105.9 million short tons of steel mill products. This National Emission Standard for Hazardous Air Pollutants (NESHAP) (or MACT standard) addresses emissions from pushing, quenching, and battery stacks. These proposed standards will implement Section 112(d) of the Clean Air Act (CAA) by requiring all major sources to meet HAP emission standards reflecting the application of the MACT. The HAPs emitted by this source category include coke oven emissions, polycyclic organic matter, and volatile organic compounds such as benzene and toluene.

## 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.[1] ISEG's *Economic Analysis Resource Document* provides detailed guidelines and expectations for economic

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[1] In addition, Executive Order (EO) 12866 requires a more comprehensive analysis of benefits and costs for proposed *significant* regulatory actions. 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. 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.

analyses that support MACT rulemaking (EPA, 1999). In the case of the coke MACT, these requirements are fulfilled by examining the following:

- facility-level impacts (e.g., changes in output rates, profitability, and facility closures),
- market-level impacts (e.g., changes in market prices, domestic production, and imports),
- industry-level impacts (e.g., changes in revenue, costs, and employment), and
- societal-level impacts (e.g., estimates of the consumer burden as a result of higher prices and reduced consumption levels and changes in domestic and foreign profitability).

## 1.2 Overview of Coke, Iron and Steel, and Foundry Industries

In the United States, furnace and foundry coke are produced by two producing sectors—integrated producers and merchant producers. Integrated producers are part of integrated iron and steel mills and primarily produce furnace coke for captive use in blast furnaces. In 1997, integrated producers accounted for approximately three-fourths of U.S. coke capacity, and merchant producers accounted for the remaining one-fourth. Merchant producers sell furnace and foundry coke on the open market to integrated steel producers (i.e., furnace coke) and iron foundries (i.e., foundry coke). Some merchant producers sell both furnace and foundry coke, while others specialize in only one.

Figure 1-1 summarizes the interactions between source categories and markets within the broader iron and steel industry. As shown, captive coke plants are colocated at integrated iron and steel mills providing furnace coke for its blast furnaces, while merchant coke plants supply the remaining demand for furnace coke at integrated iron and steel mills and supply the entire demand for foundry coke at iron foundries. These integrated mills compete with nonintegrated mills (i.e., mini-mills) and foreign imports in the markets for these steel products typically consumed by the automotive, construction, and other durable goods producers. Alternatively, iron foundries use foundry coke, pig iron, and scrap in their ironmaking furnaces (cupolas) to produce iron castings, and steel foundries use pig iron and scrap in their steelmaking furnaces (electric arc and electric induction) to produce steel castings. The markets for iron and steel castings are distinct with different product characteristics and end users.

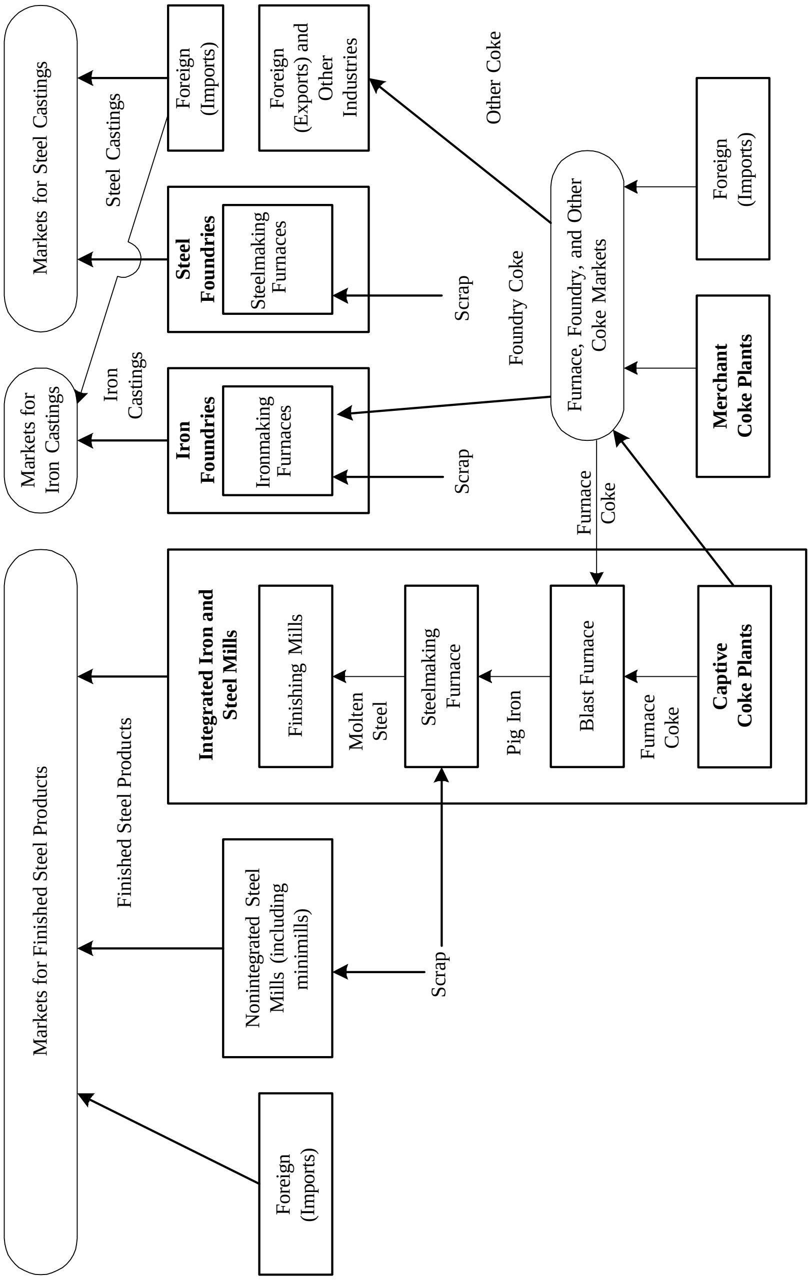

**Figure 1-1. Summary of Interactions Between Producers and Commodities in the Iron and Steel Industry**

The EIA models the specific links between these models. The analysis to support the coke EIA focuses on four specific markets:

- furnace coke,
- foundry coke,
- steel mill products, and
- iron castings.

Changes in price and quantity in these markets are used to estimate the facility, market, industry, and social impacts of the coke regulation.

## 1.3 Summary of EIA Results

The rule requires coke manufacturers to implement good management practices and ongoing maintenance that will increase the costs of producing furnace and foundry coke at affected facilities. The increased production costs will lead to economic impacts in the form of small increases in market prices and decreases in domestic coke production. The impacts of these price increases will be borne largely by integrated producers of finished steel mill products as well as consumers of finished steel mill products and foundry products. Nonintegrated steel mills and foreign producers of coke will earn higher profits. Key results of the EIA for the coke MACT are as follows:

- *Engineering Costs*: The engineering analysis estimates annual costs for existing sources of $14.3 million.
- *Sales Test*: A simple "sales test," in which the annualized compliance costs are computed as a share of sales for affected companies that own coke batteries, shows that all of these companies' facilities are affected by less than 3 percent of sales. The cost-to-sales ratio (CSR) for the median company is 0.05 percent.
- *Price and Quantity Impacts*: The EIA model predicts the following:
  - — The market price for furnace coke is projected to increase by 1.5 percent ($1.56/short ton), and domestic furnace coke production is projected to decrease by 2.3 percent (180,000 tons/year).

The market price for foundry coke is projected to increase by 2.9 percent ($4.17/short ton), and domestic foundry coke production is projected to decrease by 0.1 percent (1,400 tons/year).

  - — The market price for steel mill products is projected to increase by 0.02 percent ($0.12/short ton), and domestic production of steel mill products is projected to decrease by 0.02 percent (22,000 tons/year).
  - — The market price for iron castings is projected to increase by 0.04 percent ($0.35/short ton), and domestic production of iron castings is projected to decrease by 0.03 percent (3,400 tons/yr).

- *Plant Closures:* One furnace coke battery is projected to close.

- *Small Businesses*: The Agency identified three small companies that own and operate coke batteries, or 17 percent of the total. The average CSR for these firms is 1.3 percent. No small businesses are projected to have CSRs greater than 3 percent. Two small businesses are projected to have CSRs greater than 1 percent. No facilities or batteries owned by a small business are projected to close as a result of the regulation.

- *Social Costs*: The annual social costs are projected to be $14.0 million.
  - — The consumer burden as a result of higher prices and reduced consumption levels is $21.1 million annually.
  - — The aggregate producer profit gain is expected to increase by $7.1 million.
    - ✓ The profit losses are $1.7 million annually for domestic producers.
    - ✓ Foreign producer profits increase by $8.8 million due to higher prices and level of impacts.

## 1.4 Organization of this Report

The remainder of this report supports and details the methodology and the results of the EIA of the coke MACT.

- Section 2 presents a profile of the coke industry.
- Section 3 describes the regulatory controls and presents engineering cost estimates for the regulation.
- Section 4 reports market-, industry-, and societal-level impacts.

- Section 5 contains the small business screening analysis.
- Appendix A describes the EIA methodology.
- Appendix B describes the development of the coke battery cost functions.
- Appendix C includes the econometric estimation of the demand elasticity for steel mill products.
- Appendix D reports the results of the joint economic impacts of the Iron and Steel and Coke MACTs.

# SECTION 2

# INDUSTRY PROFILE

Coke is metallurgical coal that has been baked into a charcoal-like substance that burns more evenly and has more structural strength than coal. Coke manufacture is included under Standard Industrial Classification (SIC) code 3312—Blast Furnaces and Steel Mills; however, coke production is a small fraction of this industry. In 1997, the U.S. produced 23.4 million short tons of coke. Coke is primarily used as an input for producing steel in blast furnaces at integrated iron and steel mills (i.e., furnace coke) and as an input for gray, ductile, and malleable iron castings in cupolas at iron foundries (i.e., foundry coke). Therefore, the demand for coke is a derived demand that is largely dependent on production of steel from blast furnaces and iron castings.

In the remainder of this section, we provide a summary profile of the coke industry in the United States, including the technical and economic aspects of the industry that must be addressed in the economic impact analysis. Section 2.1 provides an overview of the production processes and the resulting types of coke. Section 2.2 summarizes the organization of the U.S. coke industry, including a description of U.S. manufacturing plants and batteries, the companies that own these plants, and the markets for coke products. Finally, Section 2.3 presents historical data on the coke industry, including U.S. production and consumption and foreign trade.

## 2.1 Production Overview

This section provides an overview of the by-product coke manufacturing process and types of coke produced in the United States. Although not discussed in this section, several substitute technologies for by-product cokemaking have been developed in the United States and abroad, including nonrecovery cokemaking, formcoke, and jumbo coking ovens. Of these alternatives to by-product coke batteries, the nonrecovery method is the only substitute in terms of current market share in the United States.

### *2.1.1 By-Product Coke Production Process*

Cokemaking involves heating coal in the absence of air resulting in the separation of the non-carbon elements of the coal from the product (i.e., coke). The process essentially bakes the coal into a charcoal-like substance for use as fuel in blast furnaces at integrated iron and steel mills and cupolas at iron foundries. Figure 2-1 summarizes the multi-step production process for by-product cokemaking, which includes the following steps:

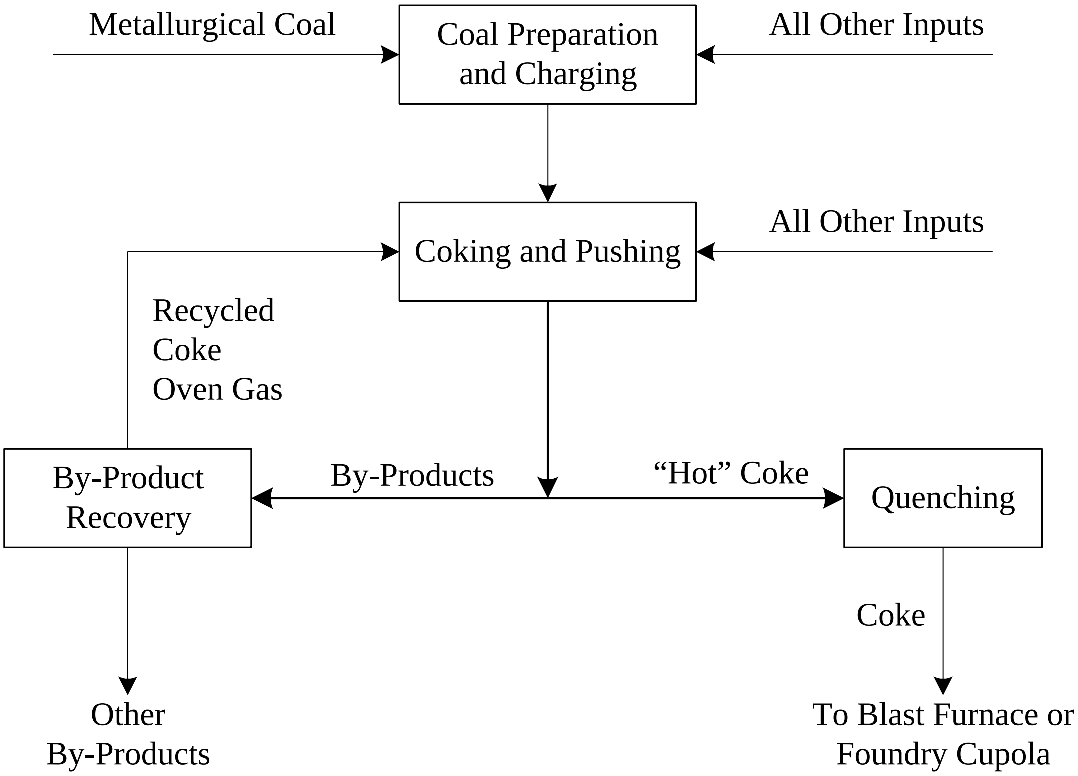

**Figure 2-1. The By-Product Coke Production Process**

- coal preparation and charging,
- coking and pushing,
- quenching, and
- by-product recovery.

In by-product cokemaking, coal is converted to coke in long, narrow by-product coke ovens that are constructed in groups with common side walls, called batteries (typically consisting of 10 to 100 coke ovens).

Figure 2-2 provides a schematic of a by-product coke battery. Metallurgical coal is pulverized and fed into the oven (or charged) through ports at the top of the oven, which are then covered with lids. The coal undergoes destructive distillation in the oven at 1,650°F to 2,000°F for 15 to 30 hours. A slight positive back-pressure maintained on the oven prevents air from entering the oven during the coking process. After coking, the incandescent or “hot” coke is then pushed from the coke oven into a special railroad car and transported to a quench tower at the end of the battery where it is cooled with water and screened to a uniform size. During this process, raw coke oven gas is removed through an offtake system, by-products such as benzene, toluene, and xylene are recovered, and the cleaned gas is used to underfire the coke ovens and for fuel elsewhere in the plant.

As shown in Table 2-1, pollutants may be emitted into the atmosphere from several sources during by-product cokemaking. For the proposed MACT standards, the sources of environmental concern to EPA are the pushing of coke from the ovens, the quenching of incandescent coke, and battery stacks. Coke pushing results in fugitive particulate emissions, which may include VOCs, while coke quenching results in particulate emissions with traces of organic compounds. EPA will focus on these three areas of emissions as HAP-emitting source categories to be regulated.

### *2.1.2 Types of Coke*

The particular mix of high- and low-volatile coals used and the length of time the coal is heated (i.e., coking time) determine the type of coke produced: (1) furnace coke, which is used in blast furnaces as part of the traditional steelmaking process, or (2) foundry coke, which is used in the cupolas of foundries in making gray, ductile, or malleable iron castings.

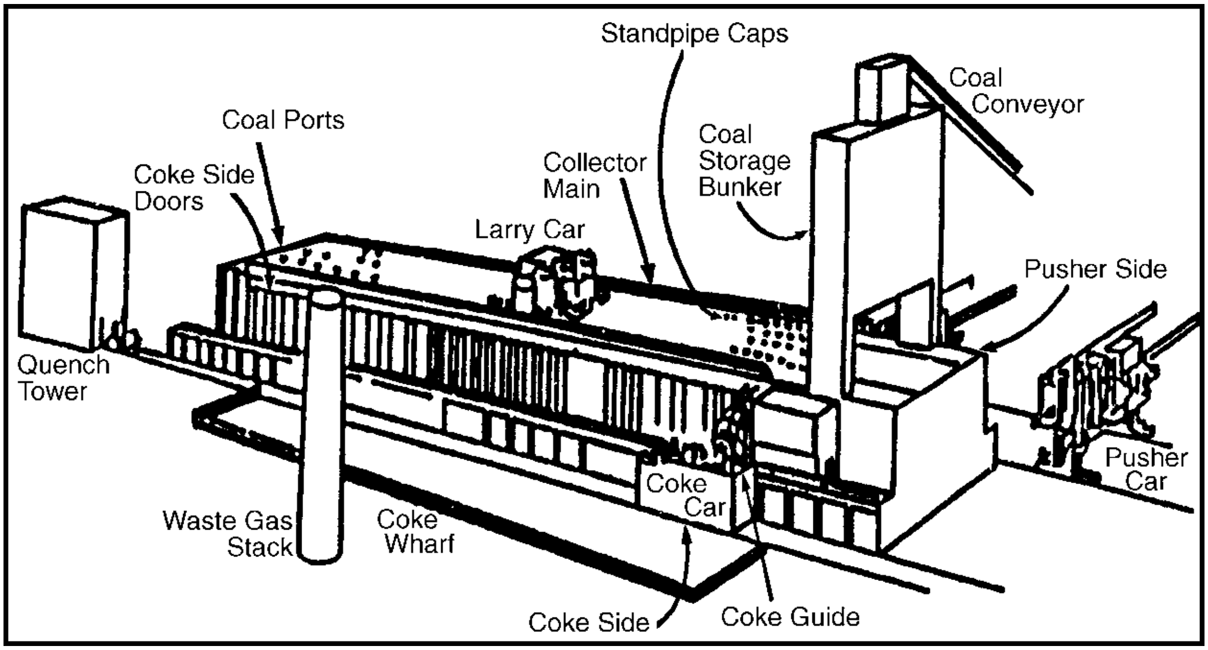

**Figure 2-2. A Schematic of a By-Product Coke Battery**

Source: U.S. International Trade Commission. 1994. *Metallurgical Coke: Baseline Analysis of the U.S. Industry and Imports.* Publication No. 2745. Washington, DC: U.S. International Trade Commission.

Furnace coke is produced by baking a coal mix of 10 to 30 percent low-volatile coal for 16 to 18 hours at oven temperatures of 2,200°F. Most blast furnace operators prefer coke sized between 0.75 inches and 3 inches. Alternatively, foundry coke is produced by baking a mix of 50 percent or more low-volatile coal for 27 to 30 hours at oven temperatures of 1,800°F. Coke size requirements in foundry cupolas are a function of the cupola diameter (usually based on a 10:1 ratio of cupola diameter to coke size) with foundry coke ranging in size from 4 inches to 9 inches (Lankford et al., 1985). Because the longer coking times and lower temperatures required for foundry coke are more favorable for long-term production, foundry coke batteries typically remain in acceptable working condition longer than furnace coke batteries (Hogan and Koelble, 1996).

Figure 2-3 shows the distribution of U.S. coke production by furnace and foundry coke as of 1997. As shown, furnace coke accounts for the vast majority of coke produced in

**Table 2-1. Air Emissions from U.S. Coke Manufacturing Plants by Emission Point**

| Emission Point | Example Pollutants |
|---|---|
| Oven charging and leaks from doors, lids, and offtakes[1] | Polycyclic organic matter (e.g., benzo(a)pyrene and many others), volatile organic compounds (e.g., benzene, toluene), and particulate matter |
| Coke pushing, coke quenching, and battery stacks (oven underfiring)[2] | |
| By-product recovery plant[3] | Benzene, toluene, zylene, napthalene, and other volatile organic compounds |

[1] A NESHAP was promulgated for these emission points in 1993—see 40 CFR Part 63, Subpart L.
[2] The proposed MACT standard evaluated in this economic analysis will address hazardous pollutants from these emission points and is scheduled for promulgation in 2001 in 40 CFR Part 63, Subpart CCCCC.
[3] A NESHAP for the by-product recovery plant was promulgated in 1989 in 40 CFR Part 61, Subpart L.

the United States. In 1997, furnace coke production was roughly 21.8 million short tons, or 93 percent of total U.S. coke production, while foundry coke production was only 1.6 million short tons. Integrated iron and steel producers that use furnace coke in their blast furnaces may either produce this coke on-site (i.e., captive coke producers) or purchase it on the market from merchant coke producers. As shown in Table 2-2, almost 90 percent of U.S. furnace coke capacity in 1995 was from captive operations at integrated steel producers (Hogan and Koelble, 1996). Alternatively, there are no captive coke operations at U.S. iron foundries so these producers purchase all foundry coke on the market from merchant coke producers. In summary, captive coke production occurs at large integrated iron and steel mills and accounts for the vast majority of domestic furnace coke production, while merchant coke production occurs at smaller merchant plants and accounts for a small share of furnace coke production and all of the foundry coke produced in the United States.

Co-products of the by-product coke production process are (1) coke breeze, the fine screenings that result from the crushing of coke; and (2) “other coke,” the coke that does not meet size requirements of steel producers that is sold as a fuel source to non-steel producers. In addition, the by-product cokemaking process results in the recovery of some salable crude materials such as coke oven gas, ammonia liquor, tar, and light oil. The cleaned coke oven gas is used to underfire the coke ovens with excess gas used as fuel in other parts of the plant

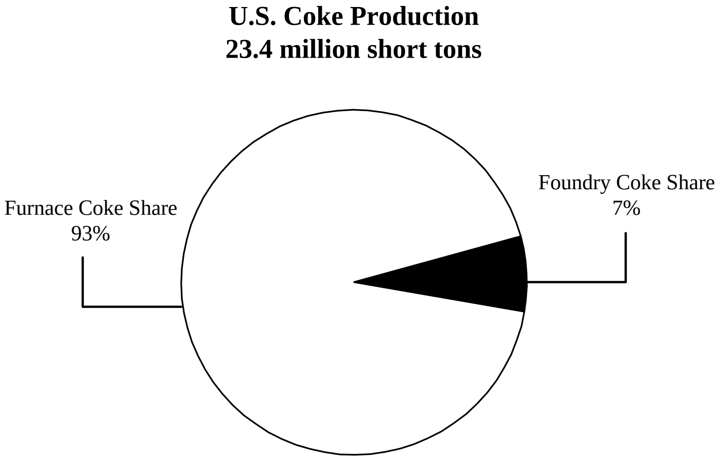

**Figure 2-3. Distribution of U.S. Coke Production by Type: 1997**

or sold. The remaining crude by-products may be further processed and separated into secondary products such as anhydrous ammonia, phenol, ortho cresol, and toluene. In the past, coke plants were a major source of these products (sometimes referred to as coal chemicals); however, today their output is overshadowed by chemicals produced from petroleum manufacturing (DOE, 1996).

## 2.2 Industry Organization

This section provides an overview of the U.S. coke industry, including the manufacturing plants and batteries, the companies that own them, and the markets in which they compete.

### *2.2.1 Manufacturing Plants*

Figure 2-4 identifies the location of U.S. coke manufacturing plants by type of producer (i.e., integrated and merchant). As shown, coke is currently manufactured at 25 plants, with 14 integrated plants and 11 merchant plants. These manufacturing plants are located near their end-users or customers and concentrated in the north-central United States and Alabama. Integrated and merchant manufacturing plants are characterized in the

## Table 2-2. Summary Data for Coke Manufacturing Plants: 1997

| Plant Name | Location | Number of Batteries | Number of Coke Ovens | Total Coke Capacity (short tons/yr) | Coke Production by Type (short tons/yr) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Furnace | Foundry | Other | Total |
| *Integrated Producers* | | | | | | | | |
| Acme Steel | Chicago, IL | 2 | 100 | 500,000 | 493,552 | 0 | 19,988 | 513,538 |
| AK Steel | Ashland, KY | 2 | 146 | 1,000,000 | 942,986 | 0 | 0 | 942,986 |
| AK Steel | Middletown, OH | 1 | 76 | 429,901 | 410,000 | 0 | 0 | 410,000 |
| Bethlehem Steel | Burns Harbor, IN | 2 | 164 | 1,877,000 | 1,672,701 | 0 | 82,848 | 1,755,549 |
| Bethlehem Steel | Lackawanna, NY | 2 | 152 | 750,000 | 747,686 | 0 | 0 | 747,686 |
| Geneva Steel | Provo, UT | 4 | 252 | 800,000 | 700,002 | 0 | 16,320 | 716,322 |
| Gulf States Steel | Gadsden, AL | 2 | 130 | 500,000 | 521,000 | 0 | 0 | 521,000 |
| LTV Steel | Chicago, IL | 1 | 60 | 615,000 | 590,250 | 0 | 0 | 590,250 |
| LTV Steel | Warren, OH | 1 | 85 | 549,000 | 543,156 | 0 | 0 | 543,156 |
| National Steel | Ecorse, MI | 1 | 85 | 924,839 | 908,733 | 0 | 0 | 908,733 |
| National Steel | Granite City, IL | 2 | 90 | 601,862 | 570,654 | 0 | 0 | 570,654 |
| U.S. Steel | Clairton, PA | 12 | 816 | 5,573,185 | 4,854,111 | 0 | 0 | 4,854,111 |
| U.S. Steel | Gary, IN | 4 | 268 | 2,249,860 | 1,813,483 | 0 | 0 | 1,813,483 |
| Wheeling-Pittsburgh | Follansbee, WV | 4 | 224 | 1,247,000 | 1,249,501 | 0 | 36,247 | 1,285,748 |
| Total, Integrated Producers | | 40 | 2,648 | 17,617,647 | 16,017,815 | 0 | 155,403 | 16,173,216 |

(continued)

## Table 2-2. Summary Data for Coke Manufacturing Plants: 1997 (Continued)

| Plant Name | Location | Number of Batteries | Number of Coke Ovens | Total Coke Capacity (short tons/yr) | Coke Production by Type (short tons/yr) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Furnace | Foundry | Other | Total |
| *Merchant Producers* | | | | | | | | |
| ABC Coke | Tarrant, AL | 3 | 132 | 699,967 | 25,806 | 727,720 | 0 | 753,526 |
| Citizens Gas | Indianapolis, IN | 3 | 160 | 634,931 | 173,470 | 367,798 | 93,936 | 635,204 |
| Empire Coke | Holt, AL | 2 | 60 | 162,039 | 0 | 142,872 | 0 | 142,872 |
| Erie Coke | Erie, PA | 2 | 58 | 214,951 | 0 | 122,139 | 19,013 | 141,152 |
| Indiana Harbor Coke[a,b] | East Chicago, IN | 4 | 268 | 1,300,000 | 0 | 0 | 0 | 0 |
| Jewell Coke and Coal[a] | Vansant, VA | 4 | 142 | 649,000 | 649,000 | 0 | 0 | 649,000 |
| Koppers | Monessen, PA | 2 | 56 | 372,581 | 358,105 | 0 | 0 | 358,105 |
| New Boston Coke | Portsmouth, OH | 1 | 70 | 346,126 | 317,777 | 0 | 4,692 | 322,469 |
| Shenango, Inc. | Pittsburgh, PA | 1 | 56 | 514,779 | 354,137 | 0 | 0 | 354,137 |
| Sloss Industries | Birmingham, AL | 3 | 120 | 451,948 | 268,304 | 131,270 | 33,500 | 433,074 |
| Tonawanda | Buffalo, NY | 1 | 60 | 268,964 | 0 | 136,225 | 63,822 | 200,047 |
| Total, Merchant Producers | | 26 | 1,182 | 5,615,286 | 2,146,599 | 1,628,024 | 214,963 | 3,989,586 |
| Total, All Producers | | 66 | 3,830 | 23,232,933 | 18,164,414 | 1,628,024 | 370,366 | 20,162,802 |

[a] Operates nonrecovery coke batteries not subject to the regulations.
[b] Newly built coke operations coming on-line during 1998.

Sources: U.S. Environmental Protection Agency. 1998. *Coke Industry Responses to Information Collection Request (ICR) Survey*. Database prepared for EPA's Office of Air Quality Planning and Standards. Research Triangle Park, NC.
Association of Iron and Steel Engineers (AISE). 1998. "1998 Directory of Iron and Steel Plants: Volume 1 Plants and Facilities." Pittsburgh, PA: AISE.

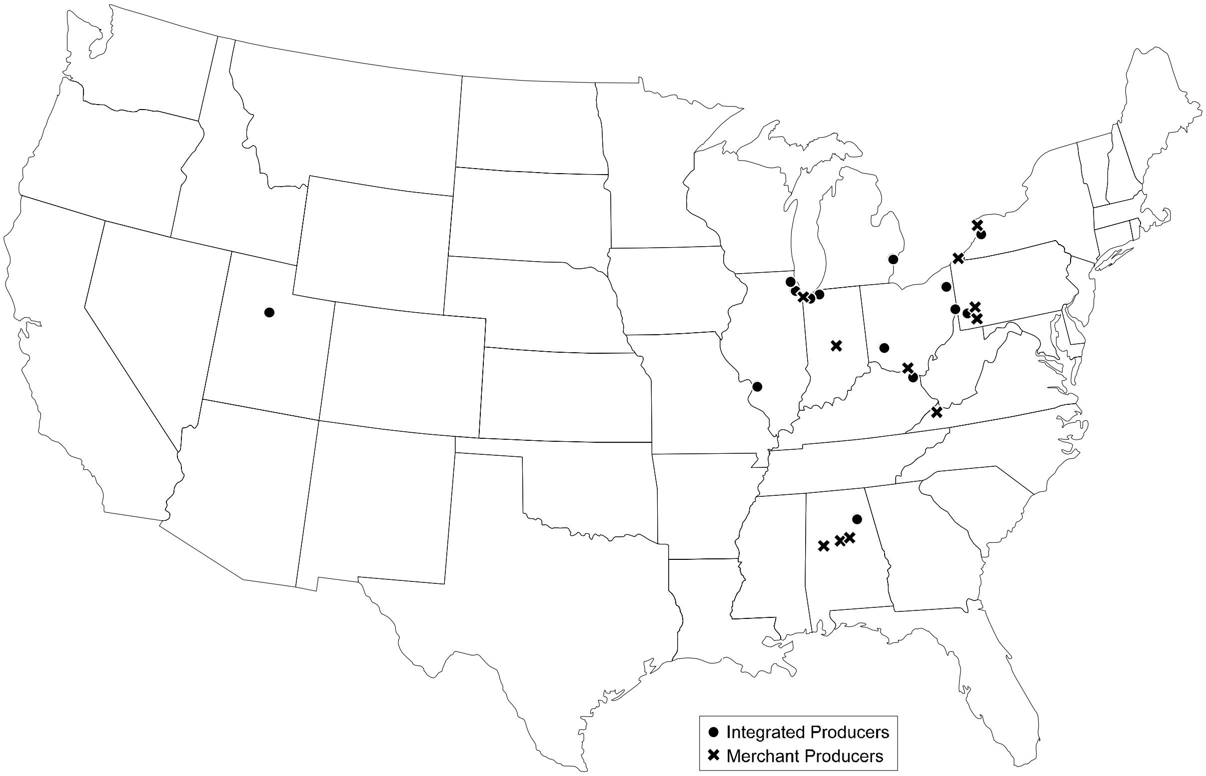

**Figure 2-4. Location of Coke Manufacturing Plants by Type of Producer: 1997**

Source: U.S. Environmental Protection Agency. 1998. *Coke Industry Responses to Information Collection Request (ICR) Survey*. Database prepared for EPA's Office of Air Quality Planning and Standards. Research Triangle Park, NC.

remainder of this section using facility responses to EPA's industry survey and industry data sources. Table 2-2 presents summary data for individual U.S. coke manufacturing plants, while Table 2-3 provides summary data by type of producer.

As of 1997, there were 14 integrated plants operating 40 coke batteries with 2,648 coke ovens. Total coke capacity at these plants was 17.6 million short tons with production devoted entirely to furnace coke. These integrated plants are owned and operated by large integrated steel companies and accounted for 80 percent of total U.S. coke production in 1997 (all furnace coke). U.S. Steel is the largest integrated producer, operating

## Table 2-3. Coke Industry Summary Data by Type of Producer: 1997

| Item | Integrated Producers | | Merchant Producers | | Total |
|---|---|---|---|---|---|
| | **Total** | **Share** | **Total** | **Share** | |
| Coke Plants (#) | 14 | 56.0% | 11 | 44.0% | 25 |
| Coke Batteries (#) | | | | | |
| Total number | 40 | 60.6% | 26 | 39.4% | 66 |
| Average per plant | 2.86 | | 2.36 | | 2.64 |
| Coke Ovens (#) | | | | | |
| Total number | 2,648 | 69.1% | 1,182 | 30.9% | 3,830 |
| Average per plant | 189.1 | | 107.5 | | 153.2 |
| Coke Capacity (short tons/yr) | | | | | |
| Total capacity | 17,617,647 | 75.8% | 5,615,286 | 24.2% | 23,232,933 |
| Average per plant | 1,258,403 | | 510,481 | | 929,317 |
| Coke Production (short tons/yr) | | | | | |
| Total production | | | | | |
| Furnace | 16,017,815 | 88.2% | 2,146,599 | 11.8% | 18,164,414 |
| Foundry | 0 | 0.0% | 1,628,024 | 100.0% | 1,628,024 |
| Other | 155,403 | 42.0% | 214,963 | 58.0% | 370,366 |
| Total | 16,173,218 | 80.2% | 3,989,586 | 19.8% | 20,162,804 |
| Average per Plant | | | | | |
| Furnace | 1,144,130 | | 195,145 | | 726,577 |
| Foundry | 0 | | 148,002 | | 65,121 |
| Other | 11,100 | | 19,542 | | 14,815 |
| Total | 1,155,230 | | 362,690 | | 806,512 |

Sources: U.S. Environmental Protection Agency. 1998. *Coke Industry Responses to Information Collection Request (ICR) Survey*. Database prepared for EPA's Office of Air Quality Planning and Standards. Research Triangle Park, NC.
Association of Iron and Steel Engineers (AISE). 1998. "1998 Directory of Iron and Steel Plants: Volume 1 Plants and Facilities." Pittsburgh, PA: AISE.

two coke manufacturing plants in Clairton, Pennsylvania and Gary, Indiana. The Clairton facility is the largest single coke plant in the United States, accounting for roughly 24 percent of U.S. cokemaking capacity. Together, the two U.S. Steel plants have a total of 16 coke batteries with 1,084 coke ovens accounting for roughly 40 percent of all coke batteries and ovens at integrated plants. As shown in Table 2-3, integrated coke plants had an average of 2.9 coke batteries, 189 coke ovens, and coke capacity of 1.26 million short tons per plant. These plants produced an average of 1.14 million short tons of furnace coke and accounted for 88 percent of the 18.2 million short tons of furnace coke produced in 1997.

As of 1997, there were 11 merchant plants operating 26 coke batteries with 1,182 coke ovens. Total coke capacity at these plants was 5.6 million short tons with production split between furnace and foundry coke. Merchant coke plants are typically owned by smaller, independent companies that rely solely on the sale of coke and coke by-products to generate revenue. These plants accounted for 20 percent of total U.S. coke production in 1997. Sun Coal and Coke is the largest merchant furnace producer, operating Jewell Coke and Coal in Vansant, Virginia and newly constructed operations at Indiana Harbor Coke in East Chicago, Illinois (both plants employ the nonrecovery cokemaking processes). Although listed as a merchant producer, the Indiana Harbor Coke plant is co-located with Inland Steel’s integrated plant in East Chicago, Illinois and has an agreement to supply 1.2 million short tons of coke to Inland and sell the residual furnace coke production (Ninneman, 1997). As shown in Table 2-3, merchant coke plants are smaller than integrated plants with an average of 2.4 coke batteries, 108 coke ovens, and coke capacity of only 0.5 million short tons per plant. In 1997, these plants produced an average of 195,000 short tons of furnace coke and 148,000 short tons of foundry coke per plant, accounting for 12 percent of U.S. furnace coke and 100 percent of foundry coke produced.

### *2.2.2 Companies*

The proposed MACT will potentially affect business entities that own coke manufacturing facilities. Facilities comprise a land site with plant and equipment that combine inputs (raw materials, energy, labor) to produce outputs (coke). Companies that own these facilities are legal business entities that have capacity to conduct business transactions and make business decisions that affect the facility. The terms facility, establishment, plant, and mill are synonymous in this analysis and refer to the physical location where products are manufactured. Likewise, the terms company and firm are synonymous and refer to the legal business entity that owns one or more facilities.

As shown in Table 2-4, 18 companies operated the 25 U.S. coke manufacturing plants in 1997. These companies ranged from small, single-facility merchant coke producers to large integrated steel producers. As shown, integrated producers are large, publicly owned integrated steel companies including USX Corporation, Bethlehem Steel Corporation, National Steel Corporation, LTV Corporation, and AK Steel Corporation. HMK Enterprises, which owns Gulf States Steel, is the only integrated producer that is privately owned. Alternatively, merchant producers are smaller, typically privately owned and operated companies including Koppers Industries, Drummond Company (which owns ABC Coke), McWane Incorporated (which owns Empire Coke), and Citizens Gas and Coke. These potentially affected companies range in size from 130 to over 22,000 employees.

Companies are grouped into small and large categories using Small Business Administration (SBA) general size standard definitions for NAICS codes. Under these guidelines, SBA establishes 1,000 or fewer employees as the small business threshold for Iron and Steel Mills (i.e., NAICS 331111), while coke ovens not integrated with steel mills are classified under All Other Petroleum and Coal Products Manufacturing (i.e., NAICS 324199) with a threshold of 500. Figure 2-5 illustrates the distribution of affected U.S. companies by size based on reported employment data. As shown, three companies (all merchant producers), or 16.7 percent, are categorized as small, and 15 companies, or 83.3 percent, are categorized as large. As expected, the companies owning integrated coke plants are generally larger than the companies owning merchant coke plants. None of the nine companies owning integrated operations have fewer than 1,000 employees or are classified as small businesses. Alternatively, three of the nine companies owning merchant operations have fewer than 1,000 employees and are classified as small businesses. However, not all companies owning merchant coke plants are small; for example, the Sun Company is one of the largest companies with over 10,000 employees.

### *2.2.3 Industry Trends*

During the 1970s and 1980s, integrated steelmakers shut down blast furnaces in response to reduced demand for steel, thereby reducing the demand for furnace coke. During the same period, many coke batteries were also shut down, thereby reducing the supply of coke. During the 1990s, the improved U.S. economy has produced strong demand for steel, and domestic coke consumption currently exceeds production. This deficit may increase because many domestic furnace coke batteries are approaching their life expectancies and may be shut down rather than rebuilt. However, no new coke batteries have been built and

## Table 2-4. Summary of Companies Owning Potentially Affected Coke Manufacturing Plants: 1997

| Company Name | Legal Form of Organization | Producer Type | Total Sales ($\$10^6$) | Total Employment | Small Business |
|---|---|---|---|---|---|
| Acme Metals Inc. | Public | Integrated | 488 | 2,471 | No |
| AK Steel Corporation | Public | Integrated | 2,441 | 5,800 | No |
| Aloe Holding Company[a] | Holding company | Merchant | 79 | 435 | Yes |
| Bethlehem Steel Corporation | Public | Integrated | 4,631 | 15,600 | No |
| Citizens Gas and Coke | Private | Merchant | 450 | 1,500 | No |
| Drummond Company Inc.[b] | Private | Merchant | 700 | 2,700 | No |
| Geneva Steel Company | Public | Integrated | 727 | 2,600 | No |
| HMK Enterprises Inc.[c] | Private | Integrated | 530 | 3,000 | No |
| Koppers Industries Inc. | Private | Merchant | 465 | 1,800 | No |
| LTV Corporation | Public | Integrated | 4,446 | 15,500 | No |
| McWane Inc.[d] | Private | Merchant | 560 | 4,200 | No |
| National Steel Corporation | Public subsidiary | Integrated | 3,114 | 9,417 | No |
| New Boston Coke Corporation | NA | Merchant | 35 | 239 | Yes |
| Sun Company Inc.[e] | Public | Merchant | 10,464 | 10,900 | No |
| Tonawanda Coke Corporation [f] | NA | Merchant | 23 | 130 | Yes |
| USX Corporation | Public | Integrated | 22,588 | 41,620 | No |
| Walter Industries Inc.[g] | Public | Merchant | 1,507 | 7,584 | No |
| WHX Corporation[h] | Public | Integrated | 642 | 5,706 | No |

[a] Owns Shenango Inc.
[b] Owns ABC Coke.
[c] Owns Gulf States Steel, Inc.
[d] Owns Empire Coke.
[e] Owns Indiana Harbor Coke Company and Jewell Coke and Coal Company, which are not subject to proposed regulations.
[f] Owns Erie Coke Corporation.
[g] Owns Sloss Industries Corporation.
[h] Owns Wheeling-Pittsburgh Corporation.

Source: Dun & Bradstreet. 1998. Dun’s Market Identifier Electronic Database. Dialog Corporation.
Information Access Corporation. 1997. Business & Company Profile ASAP [computer file]. Foster City, CA: Information Access Corporation.

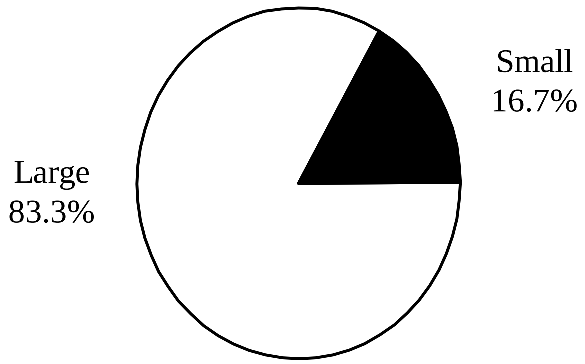

**Figure 2-5. Distribution of Affected U.S. Companies by Size: 1997**

only two coke oven batteries have been rebuilt since 1990—National Steel in Ecorse, Michigan and Bethlehem Steel in Burns Harbor, Indiana (Agarwal et al., 1996). Most recent investments in new cokemaking have been made in non-recovery, rather than by-product recovery, coke batteries. In fact, LTV Steel Corporation and the U.S. Steelworkers Union are reportedly exploring the possibility of locating a non-recovery coke facility on the site of LTV's current coke plant in Pittsburgh (*American Metal Market,* 1998). LTV closed this coke plant at the end of 1997 because its operating and environmental performance deteriorated to the point that it was unable to meet CAA requirements without prohibitive investments of between $400 and $500 million (*New Steel*, 1997a).

Faced with the prospect of spending hundreds of millions of dollars to rebuild aging coke batteries, many integrated steelmakers have totally abandoned their captive cokemaking operations and now rely on outside suppliers. As of 1997, five integrated steel companies did not produce their own coke and had to purchase this input from merchant plants, foreign sources, or other integrated producers with coke surpluses. These integrated steel companies—Inland Steel, Rouge Steel, USS/Kobe Steel, WCI Steel, and Weirton Steel—had an estimated aggregate coke demand of 5.8 million short tons (Hogan and Koelble, 1996). In addition, four other integrated producers currently have coke deficits. However, there are few integrated producers with coke surpluses to take up the slack. Hogan and Koelble (1996) reported that only four integrated steelmakers had coke surpluses as of 1995. This number is now down to three with the March 1998 closing of Bethlehem Steel's coke operations in Bethlehem, Pennsylvania (*New Steel*, 1998b). These recent closures by LTV and Bethlehem removed 2.4 million short tons, or 10.5 percent, of U.S. coke capacity (*New Steel*, 1998b).

Furthermore, several integrated firms have sold some or all of their coke batteries to merchant companies, which then sell the majority of the coke they produce to the steel company at which the battery is located. Some of these are existing coke batteries, and others are newly rebuilt batteries, including some that use the non-recovery cokemaking process. An example is the Indiana Harbor Coke Company's coke batteries located at Inland Steel's Indiana Harbor Works in East Chicago, Indiana. Both National Steel and Bethlehem Steel have recently sold coke batteries to DTE Energy Company (*New Steel*, 1998a; *New Steel*, 1997b). Both steel companies will continue to operate the batteries and will buy the majority of the coke produced by the batteries from DTE at market value (National Steel, 1998).

These recent trends should have the following future impacts on the U.S. coke industry:

- Reduce the share of furnace coke produced by integrated producers, thereby increasing reliance on merchant producers and foreign sources.
- Increase the furnace coke share of merchant production as these producers respond to expected increases in market prices for furnace coke, which also has lower production cost than foundry coke.
- Increase the volume of foreign imports of furnace and foundry coke as domestic demand continues to exceed domestic supply.

### *2.2.4 Markets*

The U.S. coke industry has two primary product markets (i.e., furnace and foundry coke) that are supplied by two producing sectors—integrated producers and merchant producers. Integrated producers are part of integrated iron and steel mills and only produce furnace coke for captive use in blast furnaces. Therefore, much of the furnace coke is produced and consumed by the same integrated producer and never passes through a market. However, some integrated steel producers have closed their coke batteries over the past decade and must purchase their coke supply from merchant producers or foreign sources. In addition, a small number of integrated steelmakers produce more furnace coke than they need and sell their surplus to other integrated steelmakers. As of 1997, integrated producers accounted for roughly 76 percent of U.S. coke capacity with merchant producers accounting for the remaining 23 percent. These merchant producers sell furnace and foundry coke on the open market to integrated steel producers (i.e., furnace coke) and iron foundries (i.e., foundry coke). Some merchant producers sell both furnace and foundry coke, while others specialize in only one.

Although captive consumption currently dominates the U.S. furnace coke market, open market sales of furnace coke are increasing (USITC, 1994). Because of higher production costs, U.S. integrated steel producers have been increasing their consumption of furnace coke from merchant coke producers, foreign imports, and other integrated steel producers with coke surpluses. In 1997, seven companies produced furnace coke in the United States. Although concentration ratios indicate that the U.S. furnace market is slightly concentrated, it is expected to be competitive at the national level after factoring in competition from foreign imports and integrated producers with coke surpluses.

Merchant coke producers account for a small share of U.S. furnace coke production (about 12 percent in 1997); however, they account for 100 percent of U.S. foundry coke production. In 1997, six companies produced foundry coke in the United States. The U.S. foundry market appears to be fairly concentrated with two companies currently accounting for almost 68 percent of U.S. production—Drummond Company Incorporated with 45 percent and Citizens Gas and Coke with 22.6 percent. The remaining four merchant producers each account for between 7.5 and 8.8 percent of the market. However, these producers do not produce a differentiated product and are limited to selling only to iron foundries, and these factors limit their ability to influence prices. In addition, the strategic location of these manufacturers would appear to promote competition within the southeastern and north-central United States and, perhaps, across regions given access to water transportation. Thus, the U.S. market for foundry coke is also expected to be competitive at the national level.

## 2.3 Historical Industry Data

This section presents historical and projected market data for coke products. Table 2-5 provides the historical volumes of U.S. production, foreign trade, changes in inventories, and apparent consumption of coke. Historical domestic data for 1980 through 1997 were obtained from the U.S. Department of Energy’s Energy Information

## Table 2-5. U.S. Production, Foreign Trade, and Apparent Consumption of Coke: 1980-1997 ($10^3$ short tons)

| Year | U.S. Production | Exports | Imports | Changes in Inventories | Apparent Consumption[a] |
|---|---|---|---|---|---|
| 1980 | 46,132 | 2,071 | 659 | 3,442 | 41,278 |
| 1981 | 42,786 | 1,170 | 527 | –1,903 | 44,046 |
| 1982 | 28,115 | 993 | 120 | 1,466 | 25,776 |
| 1983 | 25,808 | 665 | 35 | –4,672 | 29,850 |
| 1984 | 30,561 | 1,045 | 582 | 198 | 29,900 |
| 1985 | 28,651 | 1,122 | 578 | –1,163 | 29,270 |
| 1986 | 25,540 | 1,004 | 329 | –487 | 25,352 |
| 1987 | 26,304 | 574 | 922 | –1,012 | 27,664 |
| 1988 | 28,945 | 1,093 | 2,688 | 529 | 30,011 |
| 1989 | 28,045 | 1,085 | 2,311 | 336 | 28,935 |
| 1990 | 27,617 | 572 | 1,078 | –1 | 28,124 |
| 1991 | 24,046 | 740 | 1,185 | 189 | 24,302 |
| 1992 | 23,410 | 642 | 2,098 | –224 | 25,090 |
| 1993 | 23,182 | 835 | 2,155 | –422 | 24,924 |
| 1994 | 22,686 | 660 | 3,338 | –525 | 25,889 |
| 1995 | 23,749 | 750 | 3,820 | 366 | 26,453 |
| 1996 | 23,075 | 1,121 | 2,543 | 21 | 24,476 |
| 1997 | 22,115 | 832 | 3,185 | 3 | 24,465 |
| **Average Annual Growth Rates** | | | | | |
| 1980–1997 | –3.1% | –3.5% | 22.5% | –5.9% | –4.7% |
| 1980–1989 | –4.4% | –5.3% | 27.9% | –10.0% | –1.7% |
| 1989–1997 | –2.6% | –2.9% | 4.7% | –12.4% | –2.4% |

[a] Apparent consumption is equal to U.S. production minus exports plus imports minus changes in inventories.

Sources: U.S. Department of Energy. "AER Database: Coke Overview, 1949-1997." <http://tonto.eia.doe.gov/aer/aer-toc-d.cfm>. Washington, DC: Energy Information Administration. As obtained on September 14, 1998a.
Hogan, William T., and Frank T. Koelble. 1996. "Steel's Coke Deficit: 5.6 Million Tons and Growing." *New Steel* 12(12):50-59.
U.S. International Trade Commission. Trade Database: Version 1.7.1. <http://205.197.120.17/scripts/user_set.asp> As obtained in September 1998.

Administration (EIA) and supplemented by USITC (1994) and Hogan and Koelble (1996). Historical data for U.S. exports and imports of coke were obtained from the U.S. International Trade Commission's Trade Database (USITC, 1998).

### *2.3.1 Domestic Production*

As shown in Table 2-5, U.S. coke production has declined by 52 percent from 46.1 million short tons in 1980 to 22.1 million short tons in 1997. During this period, coke production declined at an average annual rate of 3.1 percent, with growth from year to year varying slightly throughout the period. The largest decline occurred between 1981 and 1982 as U.S. coke production fell from 42.8 to 28.1 million short tons. This reduction was caused by the large-scale restructuring of the U.S. steel industry during which a large number of integrated mills and their associated cokemaking plants were shut down. As shown in Table 2-5, the production volume of coke remained relatively stable during the remainder of the 1980s. U.S. coke production was almost unchanged from 28.1 million short tons in 1982 to 28 million short tons in 1989. However, during the 1990s, it has steadily declined by an average of 2.6 percent per year. This steady reduction is associated with the closings of aging cokemaking operations by several integrated U.S. steel producers.

Available sources do not provide a breakdown of merchant production by type of coke. Thus, to provide U.S. production by type of coke, the Agency generated historical estimates of the furnace coke share of merchant production. Based on limited time-series data from Hogan and Koelble (1996) on the furnace coke share of merchant coke production, regression analysis was employed to estimate an equation to project this share from 1980 through 1997.[1] The following time trend equation was estimated using ordinary least squares (with t-statistics shown in parentheses below coefficients):

$$\text{Furnace Coke Share} = \underset{(-39.0)}{-47.04} + \underset{(-39.3)}{.0238}\ \text{Year} \tag{2.1}$$

This equation appears to be highly predictive with an adjusted R-square value of 0.9987. The Agency estimated U.S. furnace coke production from merchant producers by multiplying the projected shares from Equation 1 by total merchant coke production for each year from 1980 through 1997. U.S. foundry coke production was then derived as the residual volume.

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[1] The time-series data consisted of only three annual observations for 1979 (19 percent), 1988 (39.6 percent), and 1996 (59.6 percent).

Table 2-6 provides historical data on U.S. furnace coke production by producer type. As shown, U.S. production of furnace coke has declined by 51 percent from 42.8 million short tons in 1980 to 21 million short tons in 1997—an average annual reduction of 3 percent. Integrated producers have been predominant and accounted for 98 percent of U.S. furnace coke production in 1980. This share has declined by 6.5 percent over time to 91.5 percent as of 1997. This decline is attributable to reductions in U.S. cokemaking capacity due to plant closings at integrated producers. As a result, merchant producer's share has increased by four-fold from 2.1 percent in 1980 to 8.5 percent in 1997. This increase is not only due to declines at integrated producers but also steady increases in production by merchant producers. As shown in Table 2-6, merchant production of furnace coke has doubled over this period from an estimated 0.9 million short tons in 1980 to 1.8 million short tons in 1997—an average increase of almost 6 percent per year.

Table 2-7 provides historical data on U.S. foundry coke production at merchant plants. Although merchant production of furnace coke has increased over time, merchant production of foundry coke has steadily declined. As shown, U.S. production of foundry coke has declined by two-thirds from an estimated 3.34 million short tons in 1980 to 1.11 million short tons in 1997—an average annual reduction of 3 percent. These reductions are attributable to two factors: (1) declining demand by iron foundries, and (2) increasing incentive to shift production toward furnace coke. During the 1980s, the demand for iron castings declined because of the poor performance of the U.S. economy and changes in the automotive industry (i.e., reduced demand and material substitution). As a result, one-third of the U.S. foundries shut down operations (USITC, 1994). Reductions in demand have continued throughout the 1990s as foundries have made technological improvements, similar to those at blast furnaces, to reduce the amount of coke required to produce castings. In addition, merchant producers now face increasing incentives of expected higher prices and lower costs of producing furnace coke to meet the increasing domestic demand by integrated steelmakers.

### *2.3.2 Foreign Trade*

International trade has historically comprised a small portion of the U.S. coke industry because of limitations associated with transport costs and breakage during transport. However, trade has become increasingly important during the 1990s. Table 2-5 provides the volume of U.S. exports and imports for coke from 1980 through 1997. As shown, the United States has become a net importer of coke. In 1980, the volume of coke exports was

## Table 2-6. U.S. Production of Furnace Coke by Producer Type: 1980-1997 ($10^3$ short tons)

| | Integrated Producers | | Merchant Producers | | |
|---|---|---|---|---|---|
| **Year** | **Volume** | **Share** | **Volume** | **Share** | **Total Production** |
| 1980 | 41,899 | 97.9% | 893 | 2.1% | 42,792 |
| 1981 | 38,903 | 97.7% | 912 | 2.3% | 39,815 |
| 1982 | 25,374 | 97.3% | 709 | 2.7% | 26,083 |
| 1983 | 22,556 | 96.1% | 919 | 3.9% | 23,475 |
| 1984 | 26,791 | 95.9% | 1,156 | 4.1% | 27,947 |
| 1985 | 25,175 | 95.6% | 1,148 | 4.4% | 26,323 |
| 1986 | 22,251 | 95.0% | 1,165 | 5.0% | 23,416 |
| 1987 | 22,973 | 94.8% | 1,259 | 5.2% | 24,232 |
| 1988 | 25,490 | 94.8% | 1,389 | 5.2% | 26,879 |
| 1989 | 24,808 | 94.7% | 1,378 | 5.3% | 26,186 |
| 1990 | 23,892 | 93.7% | 1,675 | 6.3% | 25,567 |
| 1991 | 20,796 | 93.1% | 1,540 | 6.9% | 22,336 |
| 1992 | 20,162 | 92.6% | 1,616 | 7.4% | 21,778 |
| 1993 | 19,973 | 92.3% | 1,673 | 7.7% | 21,646 |
| 1994 | 19,444 | 91.7% | 1,768 | 8.3% | 21,212 |
| 1995 | 20,510 | 91.8% | 1,844 | 8.2% | 22,354 |
| 1996 | 19,969 | 91.6% | 1,841 | 8.4% | 21,810 |
| 1997 | 19,213 | 91.5% | 1,790 | 8.5% | 21,003 |
| **Average Annual Growth Rates** | | | | | |
| 1980–1997 | –3.2% | –0.4% | 5.9% | 18.1% | –3.0% |
| 1980–1989 | –4.5% | –0.4% | 6.0% | 16.9% | –4.3% |
| 1989–1997 | –2.8% | –0.4% | 3.7% | 7.7% | –2.5% |

Source: EPA estimates.

## Table 2-7. U.S. Production of Foundry Coke by Producer Type: 1980–1997[a] ($10^3$ short tons)

| | Integrated Producers | | Merchant Producers | | |
|---|---|---|---|---|---|
| Year | Volume | Share | Volume | Share | Total Production |
| 1980 | 0 | 0.0% | 3,340 | 100.0% | 3,340 |
| 1981 | 0 | 0.0% | 2,972 | 100.0% | 2,972 |
| 1982 | 0 | 0.0% | 2,032 | 100.0% | 2,032 |
| 1983 | 0 | 0.0% | 2,334 | 100.0% | 2,334 |
| 1984 | 0 | 0.0% | 2,614 | 100.0% | 2,614 |
| 1985 | 0 | 0.0% | 2,328 | 100.0% | 2,328 |
| 1986 | 0 | 0.0% | 2,124 | 100.0% | 2,124 |
| 1987 | 0 | 0.0% | 2,072 | 100.0% | 2,072 |
| 1988 | 0 | 0.0% | 2,066 | 100.0% | 2,066 |
| 1989 | 0 | 0.0% | 1,859 | 100.0% | 1,859 |
| 1990 | 0 | 0.0% | 2,049 | 100.0% | 2,049 |
| 1991 | 0 | 0.0% | 1,712 | 100.0% | 1,712 |
| 1992 | 0 | 0.0% | 1,632 | 100.0% | 1,632 |
| 1993 | 0 | 0.0% | 1,536 | 100.0% | 1,536 |
| 1994 | 0 | 0.0% | 1,476 | 100.0% | 1,476 |
| 1995 | 0 | 0.0% | 1,396 | 100.0% | 1,396 |
| 1996 | 0 | 0.0% | 1,264 | 100.0% | 1,264 |
| 1997 | 0 | 0.0% | 1,113 | 100.0% | 1,113 |
| **Average Annual Growth Rates** | | | | | |
| 1980–1997 | 0.0% | 0.0% | –3.9% | 0.0% | –3.9% |
| 1980–1989 | 0.0% | 0.0% | –4.9% | 0.0% | –4.9% |
| 1989–1997 | 0.0% | 0.0% | –5.9% | 0.0% | –5.9% |

[a] May include some coke screenings or industrial coke.

Source: EPA estimates.

2.1 million short tons, while the volume of coke imports was only 0.7 million short tons. By 1997, coke exports had declined by almost 60 percent from 1980 to 0.8 million short tons, and coke imports had increased by almost 400 percent to 3.2 million short tons. The decline in coke exports resulted from reductions in coke production associated with the declining U.S. steel industry during the 1980s. Despite the U.S. steel industry's turnaround during the 1990s, coke exports have continued to decline as they are crowded out by increasing domestic demand. The dramatic increase in imports has resulted from the improved U.S. economy and increasing demand for U.S. steel products since the late 1980s. These factors combined with previous and continued closings of U.S. coke plants have caused an aggregate coke deficit at integrated iron and steel mills during the 1990s as domestic supply is not able to keep pace with demand for coke.

### *2.3.3 Market Prices*

Historical data on market prices for coke are not directly available from public sources nor can they be derived from the sources providing market volumes. Based on discussions with DOE's EIA, the USITC (1994) is the only known source of recent market prices for coke. These market prices are reported as net f.o.b. at plant and are based on industry responses to the USITC questionnaire. According to the USITC (1994), a vast majority of coke is sold under long-term contracts ranging from 1 to 6 years. These contracts typically provide for semiannual or annual renegotiation so that contract prices are closely related to open market prices. Thus, because a large share of coke is purchased through contracts, the USITC provides prices for both contract sales and spot market sales.

Table 2-8 provides market prices by type of coke product for 1990 through 1993. As shown, the spot market price is generally higher than the contract sales price and both seem positively correlated over time. The table also provides a weighted average price based on the volume sold through contracts and the spot market for each year. As shown, the weighted average market price for furnace coke was roughly $100 per short ton in 1993 and has declined since 1990. The market price for foundry coke is typically 50 percent higher than for furnace coke. In 1993, the weighted average market price for foundry coke was $154 per short ton and has slightly increased since 1990. Table 2-8 also provides the market prices for other industrial coke and coke breeze. Industrial coke had a weighted average market price of $113 per short ton in 1993, while coke breeze was priced at $44 per short ton.

## Table 2-8. Market Prices of Coke by Type: 1990–1993[a] ($ per short ton)

| Product/Year | Contract Sales Price | Spot Market Sales Price | Weighted Average Price |
|---|---|---|---|
| Furnace coke | | | |
| 1990 | $106.62 | $113.87 | $107.06 |
| 1991 | $103.99 | $111.26 | $105.00 |
| 1992 | $103.05 | $81.55 | $102.50 |
| 1993[b] | $101.18 | $71.12 | $100.69 |
| Foundry coke | | | |
| 1990 | $149.06 | $151.86 | $149.82 |
| 1991 | $153.55 | $147.60 | $151.83 |
| 1992 | $152.26 | $153.60 | $152.58 |
| 1993[b] | $152.90 | $156.35 | $153.75 |
| Other industrial coke | | | |
| 1990 | $119.98 | $117.53 | $119.21 |
| 1991 | $117.07 | $118.06 | $117.41 |
| 1992 | $115.13 | $117.46 | $115.25 |
| 1993[b] | $112.08 | $115.89 | $112.29 |
| Coke breeze | | | |
| 1990 | $42.83 | $69.01 | $43.31 |
| 1991 | $44.42 | $70.67 | $44.94 |
| 1992 | $45.42 | $59.78 | $45.88 |
| 1993[b] | $43.35 | $70.38 | $43.91 |

[a] Market prices are reported as net f.o.b. at plant.
[b] Reflects prices observed for January through June 1993.

Source: U.S. International Trade Commission. 1994. *Metallurgical Coke: Baseline Analysis of the U.S. Industry and Imports.* Publication No. 2745. Washington, DC: USITC.

### *2.3.4 Future Projections*

Future projections for the U.S. coke industry depend on several uncertain and interdependent factors including trends in integrated steelmaking and iron casting, compliance with environmental regulation, investments in or closures of domestic coke capacity, quality and availability of imports, and economic performance of domestic producers. For furnace coke, most analysts agree that U.S. capacity and production will decline faster than consumption and result in continued coke shortfalls to be met by foreign imports. Based on a survey of studies, the USITC (1994) reports that U.S. furnace coke capacity is expected to decline by between 10 to 37 percent from 1990 through 2000, while U.S. consumption is expected to decline by between 10 to 23 percent. During the 1990s, furnace coke capacity at U.S. integrated producers has already declined by 27 percent from 24.2 million short tons in 1990 to 17.6 million short tons per year in 1997 (USITC, 1994; EPA, 1998). This decline in capacity at integrated producers has been partially offset by increases in furnace coke capacity at merchant producers from 2.7 million short tons in 1990 to roughly 4 million short tons in 1997 (USITC, 1994; EPA, 1998).

Assuming current rates of investment in existing coke batteries at integrated producers, furnace coke production in the United States is not expected to exceed 16 million short tons per year through 2000 (Agarwal et al., 1996). Alternatively, assuming integrated steelmakers demand between 52 to 59 million tons per year of molten iron, furnace coke consumption is estimated at between 18 to 22 million tons per year in 2000 (Agarwal et al., 1996). This projected consumption level also assumes that injection of natural gas and coal will continue to increase, thereby reducing coke rates and decreasing demand for coke by an additional 1.2 to 2 million short tons per year. If steel demand is low (i.e., 52 to 54 million tons per year), then coke demand will be satisfied at the current import level of 3 million tons per year. However, if this demand is high (i.e., 56 to 59 million tons per year), then coke imports would likely increase to 6 million tons per year. Agarwal et al. (1996) predict that this increase in foreign imports may lead to future increases in coke prices and trigger a scramble for coke.

For foundry coke, most analysts agree that U.S. capacity will be stable and sufficient to meet future demands by iron foundries. The American Foundryman’s Society has projected the demand for iron castings to be between 9 and 10.5 million short tons through 2004 (Stark, 1995). Based on casting yields of 55 percent, metal to coke ratios of 8 to 1, and a cupola-melting share at 64 percent of total, Stark (1995) projects foundry coke demand to range from 1.3 to 1.5 million short tons per year through 2004. As of 1997, total merchant plant capacity was 5.6 million short tons per year with roughly 2.1 million tons for foundry coke. Therefore, existing foundry coke capacity will exceed the projected demand and likely cause merchant producers to increasingly rely on furnace coke to fill this excess capacity (Stark, 1995).

# SECTION 3

# ENGINEERING COST ANALYSIS

Control measures implemented to comply with the MACT standard will impose regulatory costs on coke batteries. This section presents compliance costs for typical "model" batteries and the national estimate of compliance costs associated with the proposed rule. These engineering costs are defined as the annual capital and operating and maintenance costs assuming no behavioral market adjustment by producers or consumers. For input to the EIA, engineering costs are expressed per unit of coke production and used to shift the coke supply functions in the market model.

The proposed MACT will cover the Coke Ovens: Pushing, Quenching, and Battery Stacks source category. It will affect all 58 by-product coke oven batteries at 23 coke plants. The processes covered by the proposed regulation include pushing the coke from the coke oven, quenching the incandescent coke with water in a quench tower, and maintaining the battery stack that is the discharge point for the underfiring system. Capital, operating and maintenance, and monitoring costs were estimated for 10 representative model batteries. Model battery costs were linked to the existing population of coke batteries to estimate the national costs of the regulation.

## 3.1 Overview of Emissions from Coke Batteries

The listed HAPs of concern in coke oven emissions include hundreds of organic compounds formed when volatiles are thermally distilled from the coal during the coking process. Traditionally, benzene-soluble organics and methylene chloride-soluble organics have been used as surrogate measures of coke oven emissions. The primary constituents of concern are polynuclear aromatic hydrocarbons (PAHs). Other constituents include benzene, toluene, and xylene.

Coke oven emissions from pushing and quenching occur when the coal has not been fully coked, which is called a "green" push. A green push produces a dense cloud of coke oven emissions that is not captured and controlled by the emission control systems used for particulate matter. Coke oven emissions from battery stacks occur when raw coke oven gas leaks through the oven walls, enters the flues of the underfiring system, and is discharged through the stack. Coke oven emissions from these sources are controlled by pollution prevention activities, diagnostic procedures, and corrective actions. One component of the control technology is the operating and maintenance of the general battery to prevent green pushes and stack emissions.

Based on limited test data and best engineering judgment, the proposed standards are expected to reduce coke oven emissions from pushing, quenching, and battery stacks by about 50 percent. There is significant uncertainty in attempts to estimate emissions and emission reductions because the emissions are fugitive in nature. For example, the emissions from green coke during pushing and quenching are not enclosed or captured in a conveyance, which makes accurate measurement of concentrations and flow rates very difficult.

## 3.2 Approach for Estimating Compliance Costs

The costs for individual batteries to achieve the MACT level of control will vary depending on the battery condition and control equipment in place. There is uncertainty in determining exactly what costs will be incurred by each battery. Consequently, several model batteries were developed to represent the range of battery types and conditions to place bounds on the probable costs. The emission control programs and equipment in place at the best controlled batteries were investigated, and the associated costs were obtained. The costs were then applied to the model batteries to estimate the cost necessary to comply with the MACT level. A model battery was assigned to each actual battery based on available emissions data, knowledge of battery condition, and engineering judgment. Errors in underestimating and overestimating costs for individual batteries will tend to cancel when summing these costs to estimate total nationwide costs.

## 3.3 Costs for MACT Performance

The MACT standard involves a routine program of systematic operating and maintenance and oven repairs to control emissions from battery stacks and pushing. An important element of this routine program for battery stacks is the use of continuous opacity monitors (COMs). In addition, control of quenching emissions will require the installation of baffles in three quench towers that do not have them.

Several plants were surveyed to obtain cost information on the technologies that comprise the MACT standard. Basic oven repairs include spray patching, ceramic welding, mobile gunning, silica dusting, end flue repairs, and through-wall brickwork. An annual baseline program of oven repairs was developed from the frequency of oven repairs at USS Clairton Works and includes spray patching, end flue repairs, and through-wall repairs. Annual estimated costs for oven repairs range from \$31,000 to \$564,000 per battery.

Another element of the cost of the MACT is monitoring, which involves observing four pushes per battery per day and bag leak detection systems for batteries that control pushing emissions with baghouses. The average time to observe four pushes is estimated to be about 1 hour, allowing for some delays and time for the observer to get into position. (For batteries operated as three in a battery unit, the time may be as short as 15 to 20 minutes, and for some foundry batteries, the observation time may be 1.5 hours or more.) Two hours per plant are allowed for observer travel time and data reduction. For a typical inspection labor charge of \$30/hour, the inspection cost per plant per year would be

$$\$/\text{yr} = 365\ \text{days/yr} * \$30/\text{hr} * [1\ \text{hr/battery} * \text{number of batteries} + 2\ \text{hr/plant} * 1\ \text{plant}] =$$

$$\$11{,}000 * \text{number of batteries} + \$22{,}000.$$

The installed capital cost for bag leak detectors provided by vendors is \$9,000 per baghouse. Annual operating and maintenance costs are estimated to be \$500/yr per detector.

## 3.4 Costs for Model Batteries

The model batteries are described in Table 3-1. Two groups are defined: one to represent foundry coke by-product batteries and one to represent furnace coke by-product batteries. These groups are further subdivided into models that represent different battery conditions that affect emissions and the cost to improve emission control. For example, Group A represents batteries that already achieve the MACT level of control and will not incur significant additional expenses. Group B represents batteries that must implement a baseline program similar to that at the MACT batteries, but they will not incur significant capital investment. Group C represents batteries that will incur capital expenses to repair and upgrade oven walls and end flues and, in addition, must implement a baseline program of continuing diagnostics and repair. Group D batteries in the furnace coke group represent the newer 6-meter batteries that are generally in a state of good repair.

**Table 3-1. Model Batteries**

| | **Foundry By-Product Recovery Batteries (12 batteries at 6 plants)** | | | **Furnace By-Product Recovery Batteries (46 batteries at 17 plants)** | | | |
|---|---|---|---|---|---|---|---|
| | **1A** | **1B** | **1C** | **2A** | **2B** | **2C** | **2D** |
| Battery condition | No significant costs for pushing or stacks | Will require baseline repair program | Will require baseline repair program plus 2 through-walls, 10 end flues, and spray patching on 50 percent of ovens | No significant costs for pushing or stacks | Will require baseline repair program | Will require baseline repair program plus 2 through-walls, 10 end flues, and spray patching on 50 percent of ovens | No additional costs for pushing or stacks |
| No. of ovens | 41 | | | 63 | | | 77 |
| Height (m) | 4 | | | 4 | | | 6 |
| Coking time (hrs) | 27 | | | 19 | | | 18 |
| Coke production (tpy) | 89,000 | | | 320,000 | | | 830,000 |

The cost elements associated with the model batteries are given below:

1. Model Battery Groups A and D—MACT batteries: no significant additional repair costs.
2. Model Battery Group B—Must implement a baseline program like the one at USS Clairton.
3. Model Battery Group C—Must implement a baseline program like the one at USS Clairton plus additional one-time repairs and rebuilds to put them on par with the Group B batteries: assume spray patching of 50 percent of the ovens, two through-wall repairs, and 10 end flue repairs per battery. These repairs will be treated as a capital cost.
4. Monitoring—all groups: Cost of COM for those batteries that do not have one and cost of observing four pushes per day for those not already doing it, as well as bag leak detection system for plants with baghouses. These costs will be assigned on a battery-specific basis.
5. Quenching—Apply the cost of baffles to those plants that do not have them. These costs will also be assigned on a battery-specific basis.

Model battery costs are summarized in Table 3-2. For the Model A batteries (batteries that can already achieve the MACT level of control), the lower end of the range (no additional costs) represents those batteries that already have COMs and pushing emission observers, and the upper end of the range represents batteries that must install COMs and hire pushing emission observers. The Model B batteries' costs include the cost of monitoring plus the implementation of a baseline program. The Model C batteries' costs are based on a capital expenditure to rebuild or upgrade ovens, plus the costs of monitoring and the baseline program. The Model D furnace coke batteries have the same cost elements for monitoring as the Model A group.

**Table 3-2. MACT Compliance Cost Estimates by Model Coke Battery ($1998)**

| | Total Costs ($$10^3$) | | | |
|---|---|---|---|---|
| | Capital | Annual Capital[a] | Annual Operating | Total Annual |
| **Foundry Coke Model Battery** | | | | |
| A[b] | 0 to 46 | 0 to 6 | 0 to 42 | 0 to 48 |
| B | 46 | 6 | 317 | 323 |
| C | 2,550 | 241 | 317 | 558 |
| **Furnace Coke Model Battery** | | | | |
| A[b] | 0 to 46 | 0 to 6 | 0 to 42 | 0 to 48 |
| B | 46 | 6 | 442 | 448 |
| C | 2,550 | 241 | 442 | 683 |
| D[b] | 0 to 46 | 0 to 6 | 0 to 42 | 0 to 48 |

[a] Reflects capital recovery based on a 20-year life and 7 percent interest for pushing controls and baffles and a 10-year life and 7 percent interest for monitoring equipment.

[b] The range includes those batteries already performing monitoring and those that do not.

## 3.5 Estimates of National Engineering Costs

National engineering costs were estimated by assigning model batteries to each actual battery and then applying the model battery costs (adjusted for the number of ovens in each actual battery). For example, batteries that have already achieved the MACT control level are in Groups A and D, and these batteries will incur no additional control costs. However, some of these batteries will incur monitoring costs if they do not already have a COM or if they are not observing four pushes per day. The Group B batteries will incur costs to implement the baseline program (at $6,100/oven per year). Group C batteries will incur the capital cost of through-wall repairs, end flue repairs, and spray patching (at $2,500,000 +

$525 * [50% of the ovens]) plus the cost of the baseline program. All batteries without baffles in their quench tower are assumed to install new baffles.

The costs of COMs are applied to each stack that currently does not have one. In addition, bag leak detectors are assumed to be installed for each baghouse. In cases where a single baghouse serves multiple batteries, the cost of the bag leak detection system ($9,000) is distributed among the batteries.

Table 3-3 presents the cost elements of the MACT and the number of batteries for each model battery type that will incur costs for that element. Individual battery annualized compliance costs range from $0 to $679,000, with a mean of $243,000 and a median of $209,000.

The aggregate capital, operating, and total national annual costs are given in Table 3-4. Total annualized engineering costs are estimated to be approximately $14.1 million per year (1998 dollars).[1] Oven repair accounts for approximately 86 percent of total annualized costs, and monitoring accounts for the remaining 14 percent.

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[1] Annualized costs were converted to 1997 dollars for the EIA to match the latest market data available. Total annualized costs in 1997 dollars are $14.2 million.

Table 3-3. Number of Coke Batteries Incurring MACT Compliance Costs: 1998

| Model Battery Description | Number of Batteries Represented | Number of Batteries Requiring | | | | | |
|---|---|---|---|---|---|---|---|
| | | Oven Rebuilds | Baseline Repair Program | Baffles in Quench Tower | Continuous Opacity Monitor | Visible Emission Observer | Bag Leak Detector |
| 1A: Foundry coke battery in good condition | 3 | 0 | 0 | 0 | 3 | 3 | 3 |
| 1B: Foundry coke battery; needs baseline repair program | 10 | 0 | 10 | 2 | 7 | 10 | 8 |
| 1C: Foundry coke battery; needs extensive oven rebuild and baseline repair program | 3 | 3 | 10 | 1 | 3 | 3 | 0 |
| 2A: Furnace coke battery in good condition | 14 | 0 | 0 | 0 | 4 | 14 | 11 |
| 2B: Furnace coke battery; needs baseline repair program | 17 | 0 | 17 | 0 | 10 | 17 | 15 |
| 2C: Furnace coke battery; needs extensive oven rebuild and baseline repair program | 3 | 2 | 3 | 0 | 3 | 3 | 0 |
| 2D: Furnace coke battery; newer 6-meter; in good condition | 8 | 0 | 0 | 0 | 1 | 6 | 5 |
| Totals | 58 | 5 | 40 | 3 | 31 | 56 | 42 |

## Table 3-4. National MACT Compliance Costs by Model Coke Battery: 1998

| Model Battery Description | Number of Batteries | Annual Capital Cost ($10$^3$) | | Operating Cost ($10$^3$/yr) | | Total Annual Cost ($10$^3$/yr) | |
|---|---|---|---|---|---|---|---|
| | | Oven Repair, Baffles | Monitoring | Oven Repair, Baffles | Monitoring | Oven Repair, Baffles | Monitoring |
| 1A: Foundry coke battery in good condition | 3 | $0 | $92 | $0 | $61 | $0 | $74 |
| 1B: Foundry coke battery; needs baseline repair program | 10 | $140 | $212 | $2,043 | $262 | $2,416 | $292 |
| 1C: Foundry coke battery; needs extensive oven rebuild and baseline repair program | 3 | $5,312 | $74 | $732 | $82 | $1,231 | $93 |
| 2A: Furnace coke battery in good condition | 14 | $0 | $193 | $0 | $463 | $0 | $491 |
| 2B: Furnace coke battery; needs baseline repair program | 17 | $0 | $433 | $6,789 | $644 | $6,789 | $706 |
| 2C: Furnace coke battery; needs extensive oven rebuild and baseline repair program | 3 | $5,034 | $111 | $1,220 | $123 | $1,693 | $139 |
| 2D: Furnace coke battery; newer 6-meter; in good condition | 8 | 0 | 82 | 0 | 209 | 0 | 220 |
| Totals | 58 | 10,486 | 1,197 | 10,784 | 1,844 | 12,129 | 2,015 |

# SECTION 4

# ECONOMIC IMPACT ANALYSIS

The proposed rule to control the release of HAPs from coke pushing and quenching operations will directly (through imposition of compliance costs) or indirectly (through changes in market prices) affect the entire U.S. iron and steel industry. Implementation of the proposed rule will increase the costs of producing furnace and foundry coke at affected facilities. As described in Section 3, these costs will vary across facilities and their coke batteries depending upon their physical characteristics and baseline controls. The response by these producers to these additional costs will determine the economic impacts of the regulation. Specifically, the impacts will be distributed across producers and consumers of coke, steel mill products, and iron castings through changes in prices and quantities in the affected markets. This section presents estimates of the economic impacts of the coke MACT using an economic model that captures the linkages between the furnace coke and steel mill products, and foundry coke and iron castings markets.

This section describes the data and approach used to estimate the economic impacts of this proposed rule for the baseline year of 1997. Section 4.1 presents the inputs for the economic analysis, including characterization of producers, markets, and the costs of compliance. Section 4.2 summarizes the conceptual approach to estimating the economic impacts on the affected industries. A fully detailed description of the economic impact methodology is provided in Appendix A. Lastly, Section 4.3 provides the results of the economic impact analysis.

## 4.1 EIA Data Inputs

Inputs to the economic analysis are a baseline characterization of directly and indirectly affected producers, their markets, and the estimated costs of complying with the proposed rule.

### *4.1.1 Producer Characterization*

As detailed in Section 2, the baseline characterization of integrated and merchant manufacturing plants is based on the facility responses to EPA’s industry survey and industry data sources.  These plant-specific data on existing sources were supplemented with secondary information from the *1998 Directory of Iron and Steel Plants* published by the Association of Iron and Steel Engineers and *World Cokemaking Capacity* published by the International Iron and Steel Institute, as well as coke-specific cost equations as developed for the 1993 Coke Ovens MACT (as described fully in Appendix B).

### *4.1.2 Market Characterization*

Figure 4-1 summarizes the market interactions included in the Agency's EIA modeling approach.  Changes in the equilibrium price and quantity due to control costs on coke batteries were estimated simultaneously in four linked markets:

- market for furnace coke,
- market for foundry coke,
- market for steel mill products, and
- market for iron castings.

As described in Section 2, many captive coke plants supply their excess coke to the furnace coke market.  Merchant coke plants and foreign imports account for the remaining supply to the furnace coke market.  Furnace coke produced at captive coke plants and shipped directly to integrated iron and steel mills owned by their parent companies does not directly enter the market for furnace coke.  However, compliance costs incurred by captive, or "in-house", furnace coke batteries indirectly affect the furnace coke market through price and output changes in the steel mill products market.

The market demand for furnace coke is derived from integrated mills producing steel mill products.  Integrated iron and steel mills that need more coke than their captive batteries can produce purchase furnace coke from the market.  Integrated mills' market (and captive) demand for furnace coke depends on their production levels as influenced by the market for steel mill products.  Steel mill products are supplied by three general groups:  integrated iron and steel mills, nonintegrated steel mills (primarily mini-mills), and imports.  Domestic consumers of steel mill products and exports account for the market demand.

As described in Section 2, merchant plants are the sole suppliers of foundry coke to the market.  Based on U.S. industry production and consumption data, foreign imports of

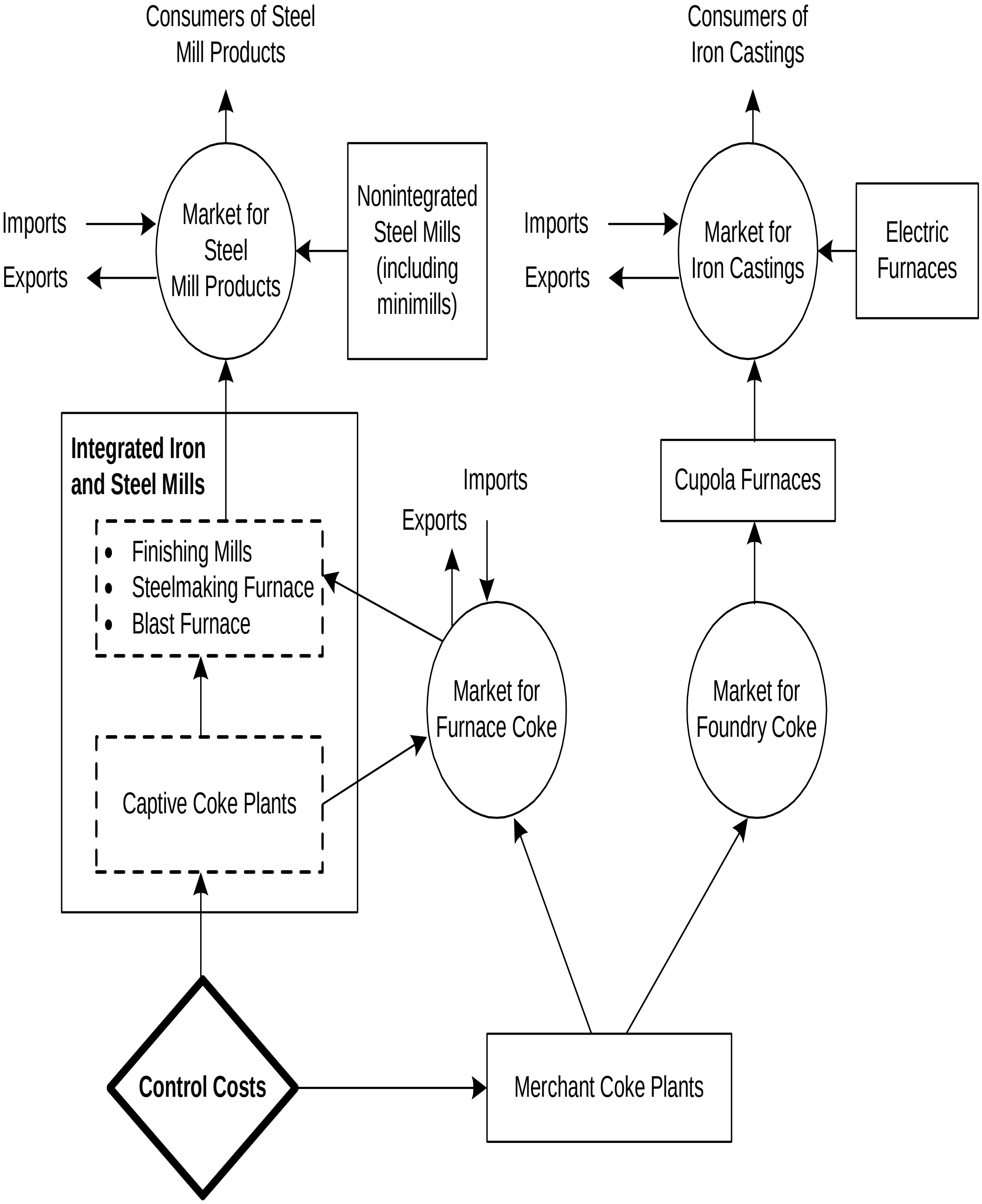

Figure 4-1. Market Linkages Modeled in the Economic Impact Analysis

foundry coke in 1997 were negligible.[1] Consumers of foundry coke include foundries with cupolas that produce iron castings, and they are modeled using aggregate market demand curves.[2]

Table 4-1 provides the 1997 data on the U.S. furnace and foundry coke, steel mill products, and iron castings markets for use in this analysis. The market price for steel mill products was obtained from Current Industrial Reports (CIR), (U.S. DOC, 1997) and reflects the production-weighted average across all product types. The market price for iron castings was also obtained from CIR and reflects the production-weighted average across iron castings (ductile, gray, and malleable). Market prices for each coke product were determined, consistent with economic theory, by the highest-cost merchant producer. Domestic production from affected facilities reflects the aggregate of the plant-specific data presented in Section 2, while unaffected domestic production is derived either directly from secondary sources or as the difference between observed total U.S. production and the aggregate production from affected facilities. Foreign trade data were obtained from industry and government statistical publications supplemented by survey data. Market volumes for each product are then computed as the sum of U.S. production and foreign imports.

### *4.1.3 Regulatory Control Costs*

As shown in Section 3, the Agency developed compliance cost estimates for model plants that may be mapped to each of the coke manufacturing facilities affected by the proposed rule. These estimates reflect the "most-reasonable" scenario for this industry. To be consistent with the 1997 baseline industry characterization of the economic model, the Agency adjusted the compliance cost estimates from 1998 dollars to 1997 dollars using the producer price index[3]. These cost estimates serve as inputs to the economic

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[1] Recent studies have indicated an increasing trend of foreign imports of foundry coke, primarily from China (USITC, 2000). Including foreign suppliers of foundry coke in the economic model would lead to smaller price changes as imports replace some domestic production. However, the U.S. ITC report indicated that lower quality of imported foundry coke and future environmental regulations being proposed in China may limit the market penetration of foreign foundry coke in the United States.

[2] Other coke, frequently grouped with foundry coke, is purchased as a fuel input by cement plants, chemical plants, and nonferrous smelters. However, other coke represents only 2 percent of U.S. coke production in 1997. For simplicity, supply and demand for other coke are assumed to be unaffected by the proposed coke regulation and are not included in the market model.

[3] Finished Goods 1982 = 100. $\left|\frac{131.8}{130.7}\right| = 1.008$

## Table 4-1. Baseline Characterization of U.S. Iron and Steel Markets: 1997

| | Baseline |
|---|---|
| **Furnace Coke** | |
| Market price ($/short ton) | $107.36 |
| Market output ($10^3$ tpy) | 11,710 |
| Domestic production | 7,944 |
| Imports | 3,765 |
| **Foundry Coke** | |
| Market price ($/short ton) | $145.02 |
| Market output ($10^3$ tpy) | 1,669 |
| Domestic production | 1,669 |
| Imports | NA |
| **Steel Mill Products** | |
| Market price ($/short ton) | $639.74 |
| Market output ($10^3$ tpy) | 137,015 |
| Domestic production | 105,858 |
| Integrated producers | 62,083 |
| Nonintegrated steel mills[a] | 43,775 |
| Imports | 31,157 |
| **Iron Castings** | |
| Market price ($/short ton) | $845.55 |
| Market output ($10^3$ tpy) | 12,314 |
| Domestic production | 11,483 |
| Cupola furnaces | 6,695 |
| Electric furnaces[b] | 4,789 |
| Imports | 831 |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

analysis and affect the operating decisions for each affected facility and thereby the markets that are served by these facilities.

## 4.2 EIA Methodology Summary

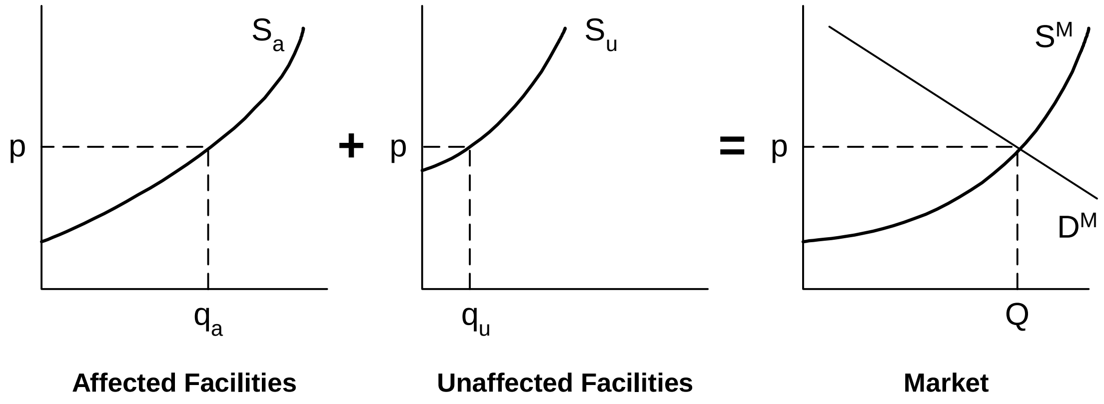
In general, the EIA methodology needs to allow EPA to consider the effect of the different regulatory alternatives. Several types of economic impact modeling approaches have been developed to support regulatory development. These approaches can be viewed as varying along two modeling dimensions:

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

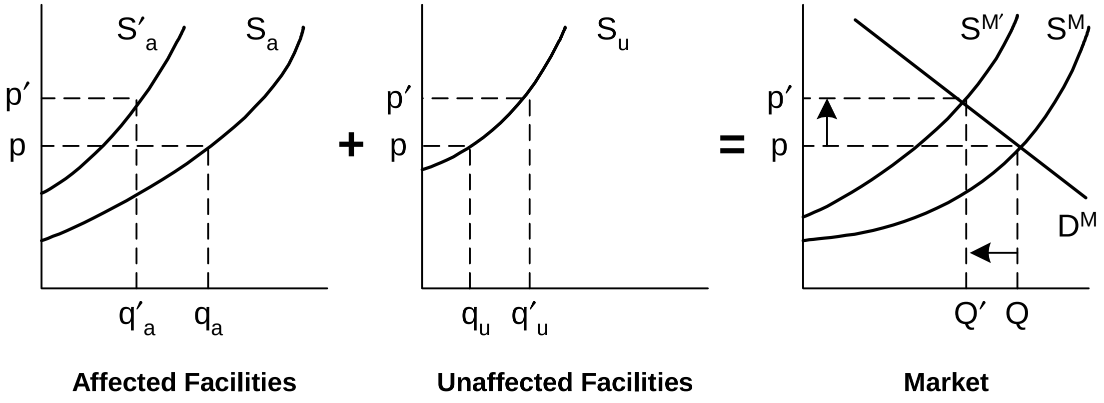
Each of these dimensions was considered in selecting the approach used to model the economic impact of the proposed coke regulation.

To conduct the analysis for the proposed coke regulation, the Agency used a market modeling approach that incorporates behavioral responses in a multiple-market partial equilibrium model. Multiple-market partial equilibrium analysis provides a manageable approach to incorporate interactions between coke, steel mill product, and iron castings markets into the EIA to better estimate the proposed regulation’s impact. The multiple-market partial equilibrium approach represents an intermediate step between a simple, single-market partial equilibrium approach and a full general equilibrium approach. The modeling technique is to link a series of standard partial equilibrium models by specifying the interactions between the supply and demand for products and then solving for changes in prices and quantities across all markets simultaneously. The EIA methodology is fully detailed in Appendix A.

The Agency’s methodology is soundly based on standard microeconomic theory relying heavily on previous economic analyses, employs a comparative static approach, and assumes certainty in relevant markets. For this analysis, prices and quantities are determined in perfectly competitive markets for furnace coke, foundry coke, finished steel mill products, and iron castings. The competitive model of price formation, as shown in Figure 4-2 (a), posits that market prices and quantities are determined by the intersection of market supply and demand curves. Under the baseline scenario, a market price and quantity (P, Q) are determined by the downward-sloping market demand curve ($D^M$) and the upward-sloping



a) Baseline Equilibrium



b) With-Regulation Equilibrium

**Figure 4-2. Market Equilibrium without and with Regulation**

market supply curve ($S^M$) that reflects the horizontal summation of the individual supply curves of directly affected and indirectly affected facilities that produce a given product.

With the regulation, the cost of production increases for directly affected producers. The imposition of the compliance costs is represented as an upward shift in the supply curve for each affected facility from $S_a$ to $S_a'$. As a result, the market supply curve to shift upward to $S^{M\prime}$ as shown in Figure 4-2(b) reflecting the increased costs of production at these facilities. In the baseline scenario without the proposed standards, the industry would produce total output, Q, at the price, P, with affected facilities producing the amount $q_a$ and unaffected facilities accounting for Q minus $q_a$, or $q_u$. At the new equilibrium with the regulation, the market price increases from P to P′ and market output (as determined from the market demand curve, $D^M$) declines from Q to Q′. This reduction in market output is the net result from reductions at affected facilities and increases at unaffected facilities.

## 4.3 Economic Impact Results

Based on the simple analytics presented above, when faced with higher costs of coke production, producers will attempt to mitigate the impacts by making adjustments to shift as much of the burden on other economic agents as market conditions allow. The adjustments available to facility operators include changing production processes, changing inputs, changing output rates, or even closing the facility. This analysis focuses on the last two options because they appear to be the most viable for coke manufacturing facilities, at least in the near-term. A large segment of the furnace and foundry coke market is affected by the regulation so we would expect upward pressure on prices as producers reduce output rates in response to higher costs. Higher prices reduce quantity demanded and output for each market product, leading to changes in profitability of batteries, facilities, and firms. These market and industry adjustments will also determine the social costs of the regulation and its distribution across stakeholders (producers and consumers).

To estimate these impacts, the economic modeling approach described in Appendix A was operationalized in a multiple spreadsheet model. This model characterizes those producers and consumers identified in Figure 4-1 and their behavioral responses to the imposition of the regulatory compliance costs. These costs are expressed per ton of furnace or foundry coke and serve as the input to the economic model, or “cost-shifters” of the baseline supply curves at affected facilities. Given these costs, the model determines a new equilibrium solution in a comparative static approach. The following sections provide the Agency’s estimates of the resulting economic impacts for the proposed rule.

### *4.3.1 Market-Level Impacts*

The increased cost of coke production due to the regulation is expected to increase the price of coke, steel mill products, and iron castings and reduce their production and consumption from 1997 baseline levels. As shown in Table 4-2, the regulation is projected to increase the price of furnace coke by 1.5 percent, or $1.56 per short ton, and the price of foundry coke by nearly 3 percent, or $4.17 per short ton. The increased captive production costs and higher market price associated with furnace coke are projected to increase steel mill product prices by less than 0.1 percent, or $0.12 per ton. Similarly, the higher market price of foundry coke are projected to increase iron castings prices by less than 0.1 percent, or $0.35 per ton. As expected, directly affected output declines across all producers, while supply from domestic and foreign producers not subject to the regulation increases. Although the resulting net declines are slight across all products (i.e., roughly 0.1 percent decline in market output) the change in domestic production is typically higher than 0.1 percent. This is especially true for furnace coke where domestic production declines by 2.25 percent.

### *4.3.2 Industry-Level Impacts*

Industry revenue, costs, and profitability change as prices and production levels adjust to increased production costs. As shown in Table 4-3, the economic model projects that profits for directly affected integrated iron and steel producers will decrease by $10.8 million, or 0.8 percent. In addition, the Agency projects profit losses of $4.6 million for foundries that produce iron casting with cupola furnaces. However, because integrated steel mills reduce their captive production of furnace coke and purchase more through the market, industry-level profits for U.S. merchant coke producers are expected to increase by $2.7 million, or 5.6 percent, for furnace coke. Similarly, because foundries with cupola furnaces must continue to buy foundry coke to produce iron castings (i.e., inelastic demand), industry-level profits for U.S. merchant coke producers are expected to increase by $3.9 million, or 5.0 percent, for foundry coke. Those domestic suppliers not subject to the regulation experience windfall gains with non-integrated steel mills (i.e., mini-mills) increasing profits by $5.4 million and foundries with electric furnaces increasing profits by $1.7 million.

## Table 4-2. Market-Level Impacts of the Proposed Coke MACT: 1997

| | | Changes From Baseline | |
|---|---|---|---|
| | **Baseline** | **Absolute** | **Percent** |
| **Furnace Coke** | | | |
| Market price ($/short ton) | $107.36 | $1.56 | 1.46% |
| Market output ($10^3$ tpy) | 11,710 | –11.8 | –0.10% |
| Domestic production | 7,944 | –178.7 | –2.25% |
| Imports | 3,765 | 166.9 | 4.43% |
| **Foundry Coke** | | | |
| Market price ($/short ton) | $145.02 | $4.17 | 2.87% |
| Market output ($10^3$ tpy) | 1,669 | –1.4 | –0.08% |
| Domestic production | 1,669 | –1.4 | –0.08% |
| Imports | NA | NA | NA |
| **Steel Mill Products** | | | |
| Market price ($/short ton) | $639.74 | $0.12 | 0.02% |
| Market output ($10^3$ tpy) | 137,015 | –16.0 | –0.01% |
| Domestic production | 105,858 | –21.9 | –0.02% |
| Integrated producers | 62,083 | –30.3 | –0.05% |
| Nonintegrated steel mills[a] | 43,775 | 8.4 | 0.02% |
| Imports | 31,157 | 6.0 | 0.02% |
| **Iron Castings** | | | |
| Market price ($/short ton) | $845.55 | $0.35 | 0.04% |
| Market output ($10^3$ tpy) | 12,314 | –3.1 | –0.03% |
| Domestic production | 11,483 | –3.4 | –0.03% |
| Cupola furnaces | 6,695 | –5.4 | –0.08% |
| Electric furnaces[b] | 4,789 | 2.0 | 0.04% |
| Imports | 831 | 0.3 | 0.04 |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

## Table 4-3. National-Level Industry Impacts of the Proposed Coke MACT: 1997

| | | Changes From Baseline | |
|---|---|---|---|
| | Baseline | Absolute | Percent |
| **Integrated Iron and Steel Mills** | | | |
| Total revenues ($\$10^6$/yr) | $40,223.9 | –$10.50 | –0.03% |
| Steel mill products | $39,716.9 | –$11.80 | –0.03% |
| Market coke operations | $507.0 | $1.29 | 0.26% |
| Total costs ($\$10^6$/yr) | $38,837.5 | $0.25 | –0.01% |
| Control costs | $0.0 | $8.43 | NA |
| Steel production | $0.0 | $0.00 | NA |
| Captive coke production | $0.0 | $6.29 | NA |
| Market coke production | $0.0 | $2.14 | NA |
| Production costs | $38,837.5 | –$8.17 | –0.02% |
| Steel production | $36,292.9 | –$18.25 | –0.05% |
| Captive coke production | $942.5 | –$0.30 | –0.03% |
| Market coke consumption | $1,167.8 | $16.11 | 1.38% |
| Market coke production | $434.3 | –$5.74 | –1.32% |
| Operating profits ($\$10^6$/yr) | $1,386.4 | –$10.76 | –0.78% |
| Iron and steel facilities (#) | 20 | 0 | 0.00% |
| Coke batteries (#) | 37 | 0 | 0.00% |
| Employment (FTEs) | 67,198 | –39 | –0.06% |
| **Coke Producers (Merchant Only)** | | | |
| *Furnace* | | | |
| Revenues ($\$10^6$/yr) | $366.5 | –$10.01 | –2.73% |
| Costs ($\$10^6$/yr) | $318.5 | –$12.69 | –3.98% |
| Control costs | $0.0 | $2.16 | NA |
| Production costs | $318.5 | –$14.85 | –4.66% |
| Operating profits ($\$10^6$/yr) | $48.0 | $2.68 | 5.59% |
| Coke batteries (#) | 13 | –1 | –7.69% |
| Employment (FTEs) | 840 | –126 | –15.00% |
| *Foundry* | | | |
| Revenues ($\$10^6$/yr) | $273.3 | $7.03 | 2.57% |
| Costs ($\$10^6$/yr) | $194.2 | $3.10 | 1.60% |
| Control costs | $0.0 | $3.30 | NA |
| Production costs | $194.2 | –$0.20 | –0.10% |
| Operating profits ($\$10^6$/yr) | $79.1 | $3.93 | 4.96% |
| Coke batteries (#) | 12 | 0 | 0.00% |
| Employment (FTEs) | 2,420 | 0 | 0.00% |
| **Nonintegrated Steel Mills**[a] | | | |
| Operating profits ($\$10^6$/yr) | NA | $5.4 | NA |
| **Cupola Furnaces** | | | |
| Operating profits ($\$10^6$/yr) | NA | –$4.6 | NA |
| **Electric Furnaces**[b] | | | |
| Operating profits ($\$10^6$/yr) | NA | $1.7 | NA |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

[c] Includes iron foundries that use electric arc or electric induction furnaces.

### *4.3.2.1 Changes in Profitability*

For integrated steel mills, operating profits decline by $10.8 million. This is the net result of three effects:

- Net decrease in revenue ($10.5 million): Steel mill product revenue decreases as a result of reductions in output. However, these losses were mitigated by increased revenues from furnace coke supplied to the market as a result of higher prices.
- Net decrease in production costs ($8.2 million): Reduction in steel mill and market coke production costs occur as output declines. However, producers also experience increases in costs associated with the higher price of inputs (i.e., furnace coke).
- Increase in control costs ($8.4 million): The costs of captive production of furnace coke increase as a result of regulatory controls.

Industry-wide profits for merchant furnace coke producers increase by $2.7 million as a result of the following:

- Decreases in revenue ($10 million): Reductions in output outweigh revenue increases as a result of higher market prices.
- Reduction in production costs ($14.9 million): Reduction in coke production costs occurs as output declines.
- Increased control costs ($2.2 million): The cost of producing furnace coke increases as a result of regulatory controls.

Industry-wide profits for merchant foundry coke producers increase by $3.9 million under the regulation:

- Increase in revenue ($7.0 million): Revenue increases as a result of higher market prices with only slight reductions in output.
- Reduction in production costs ($0.2 million): Reduction in coke production costs occur as output declines.
- Increased control costs ($3.3 million): The cost of producing foundry coke increases as a result of regulatory controls.

Industry-wide profits for domestic cupola furnaces are projected to decrease by $4.6 million as the result of higher price for foundry coke–their primary input.

Lastly, domestic producers that are not subject to the regulation benefit from higher prices without additional control costs. As mentioned above, profits increase are projected for nonintegrated steel mills and foundries producing iron castings with electric furnaces.

Additional distributional impacts of the rule within each producer segment are not necessarily apparent from the reported decline or increase in their aggregate operating profits. The regulation creates both gainers and losers within each industry segment based on the distribution of compliance costs across facilities. As shown in Table 4-4, a substantial subset of the merchant coke facilities are projected to experience profit increases under both alternatives (i.e., 11 furnace coke batteries, or 85 percent, and 10 foundry coke batteries, or 83 percent). However, one merchant battery is projected to cease market operations as it was the highest-cost coke battery with the additional regulatory costs.

A majority of directly affected integrated iron and steel facilities (i.e., 15 plants, or 75 percent) are projected to become less profitable with the regulation with a total loss of $15.9 million. However, five integrated mills are projected to benefit from higher coke prices and experience a total profit gain of $5.2 million. These integrated plants sell a significant share of furnace coke in the market as compared to negatively affected facilities.

#### *4.3.2.2 Facility Closures*

EPA estimates one merchant battery supplying furnace coke is likely to prematurely close as a result of the regulation. In addition, one captive battery ceases to supply the market and only produces coke sufficient for its internal requirements for production of steel mill products. In both cases, these batteries are the highest-cost producers of furnace coke with the regulation.

#### *4.3.2.3 Changes in Employment*

As a result of decreased output levels, industry employment is projected to decrease by less than 1 percent, or 165 full-time equivalents (FTEs), with the regulation. This is the net result of employment losses for integrated iron and steel mills totaling 39 FTEs and merchant coke plants of 126 FTEs. Although EPA projects increases in output for producers not subject to the rule, which would likely lead to increases in employment, the Agency did not develop quantitative estimates for this analysis.

**Table 4-4. Distribution Impacts of the Proposed Coke MACT Across Directly Affected Producers: 1997**

| | With Regulation | | | |
|---|---|---|---|---|
| | Increased Profits | Decreased Profits | Closure | Total |
| **Integrated Iron and Steel Mills** | | | | |
| Facilities (#) | 5 | 15 | 0 | 20 |
| Coke production | | | | |
| Total ($10^3$ tpy) | 8,409 | 6,473 | 0 | 14,882 |
| Average (tons/facility) | 1,682 | 432 | 0 | 744 |
| Coke compliance costs | | | | |
| Total ($\$10^6$/yr) | $2.72 | $5.87 | $0 | $8.59 |
| Average ($/ton) | $0.32 | $0.91 | $0.00 | $0.58 |
| Change in operating profit ($\$10^6$) | $5.15 | –$15.91 | $0.00 | –$10.76 |
| **Coke Plants (Merchant Only)** | | | | |
| *Furnace* | | | | |
| Batteries (#) | 11 | 1 | 1 | 13 |
| Production ($10^3$ tpy) | | | | |
| Total ($10^3$ tpy) | 3,046 | 160 | 127 | 3,332 |
| Average (tons/facility) | 277 | 160 | 127 | 256 |
| Compliance costs | | | | |
| Total ($\$10^6$/yr) | $1.95 | $0.21 | $0.21 | $2.37 |
| Average ($/ton) | $0.64 | $1.31 | $1.66 | $0.71 |
| Change in operating profit ($\$10^6$) | $2.70 | –$0.01 | $0.00 | $2.68 |
| *Foundry* | | | | |
| Batteries (#) | 10 | 2 | 0 | 12 |
| Production | | | | |
| Total ($10^3$ tpy) | 1,702 | 246 | 0 | 1,948 |
| Average (tons/facility) | 170 | 123 | 0 | 162 |
| Compliance costs | | | | |
| Total ($\$10^6$/yr) | $2.17 | $1.14 | $0.00 | $3.30 |
| Average | $1.27 | $4.63 | $0.00 | $1.70 |
| Change in operating profit ($\$10^6$) | $4.10 | –$0.17 | $0.00 | $3.93 |

### *4.3.3 Social Cost*

The social impact of a regulatory action is traditionally measured by the change in economic welfare that it generates. The social costs of the proposed rule will be distributed across consumers and producers alike. Consumers experience welfare impacts due to changes in market prices and consumption levels associated with the rule. Producers experience welfare impacts resulting from changes in profits corresponding with the changes in production levels and market prices. However, it is important to emphasize that this measure does not include benefits that occur outside the market, that is, the value of reduced levels of air pollution with the regulation.

The national compliance cost estimates are often used as an approximation of the social cost of the rule. The engineering analysis estimated annual costs of \$14.3 million. In this case, the burden of the regulation falls solely on the affected facilities that experience a profit loss exactly equal to these cost estimates. Thus, the entire loss is a change in producer surplus with no change (by assumption) in consumer surplus. This is typically referred to as a “full-cost absorption” scenario in which all factors of production are assumed to be fixed and firms are unable to adjust their output levels when faced with additional costs.

In contrast, the economic analysis accounts for behavioral responses by producers and consumers to the regulation (i.e., shifting costs to other economic agents). This approach results in a social cost estimate that differs from the engineering estimate and also provides insights on how the regulatory burden is distributed across stakeholders. As shown in Table 4-5, the economic model estimates the total social cost of the rule to be \$14.0 million. This small difference occurs because society reallocates resources as a result of the increased cost of coke production.

In the final product markets, higher market prices lead to consumers of steel mill products experiencing losses of \$16.8 million and consumers of iron castings experiencing losses of \$4.3 million. Although integrated iron and steel producers are able to pass on a limited amount of cost increases to their final consumers, e.g., automotive manufactures and construction industry, the increased costs result in a net decline in profits at integrated mills of \$10.8 million and foundries with cupola furnaces of \$4.6 million.

In the coke industry, low-cost merchant producers of furnace and foundry coke benefit at the expense of consumers and higher-cost merchant and captive coke batteries resulting in an industry-wide increase in profits. Furnace coke profits at merchant plants

**Table 4-5. Distribution of the Social Costs of the Proposed Coke MACT: 1997**

| | |
|---|---|
| **Change in Consumer Surplus ($\$10^6$/yr)** | **–$21.14** |
| Steel mill product consumers | –$16.81 |
| Domestic | –$16.07 |
| Foreign | –$0.74 |
| Iron casting consumers | –$4.33 |
| Domestic | –$4.07 |
| Foreign | –$0.26 |
| **Change in Producer Surplus ($\$10^6$/yr)** | **$7.14** |
| Domestic producers | –$1.69 |
| Integrated iron and steel mills | –$10.76 |
| Nonintegrated steel mills[a] | $5.37 |
| Cupola furnaces | –$4.60 |
| Electric furnaces[b] | $1.69 |
| Furnace coke (merchant only) | $2.68 |
| Foundry coke (merchant only) | $3.93 |
| Foreign producers | $8.83 |
| Iron and steel | $2.52 |
| Castings | $0.29 |
| Furnace coke | $6.02 |
| **Social Costs of the Regulation ($\$10^6$/yr)** | **–$14.00** |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

increase in aggregate by $2.7 million, and foundry coke profits at merchant plants increase in aggregate by $3.9 million.

Lastly, domestic producers not subject to the regulation (i.e., nonintegrated steel mills and electric furnaces) as well as foreign producers experience unambiguous gains because they benefit from increases in market price under both alternatives.

# SECTION 5

# SMALL BUSINESS IMPACTS

This regulatory action will potentially affect the economic welfare of owners of coke batteries. These individuals may be owners/operators who directly conduct the business of the firm or, more commonly, investors or stockholders who employ others to conduct the business of the firm on their behalf through privately held or publicly traded corporations. The legal and financial responsibility for compliance with a regulatory action ultimately rests with plant managers, but the owners must bear the financial consequences of the decisions. Although environmental regulations can affect all businesses, small businesses may have special problems complying with such regulations.

The Regulatory Flexibility Act (RFA) of 1980 requires that special consideration be given to small entities affected by federal regulations. The RFA was amended in 1996 by the Small Business Regulatory Enforcement Fairness Act (SBREFA) to strengthen its analytical and procedural requirements. Under SBREFA, the Agency must perform a regulatory flexibility analysis for rules that will have a significant impact on a substantial number of small entities.

This section focuses on the compliance burden of the small businesses with the coke manufacturing industry and provides a screening analysis to determine whether this proposed rule is likely to impose a significant impact on a substantial number of the small entities (SISNOSE) within this industry. The screening analysis employed here is a “sales test” that computes the annualized compliance costs as a share of sales for each company. In addition, it provides information about the impacts on small businesses after accounting for producer responses to the proposed rule and the resulting changes in market prices and output.

## 5.1 Identifying Small Businesses

The Small Business Administration (SBA) released guidelines effective October 2000 that provide small business thresholds based on NAICS codes that replace the previous thresholds based on SIC codes. Under these new guidelines, SBA establishes 1,000 or fewer employees as the small business threshold for Iron and Steel Mills (i.e., NAICS 331111), while coke ovens not integrated with steel mills are classified under All Other Petroleum and Coal Products Manufacturing (i.e., NAICS 324199) with a threshold of 500. Based on these SBA size definitions for the affected industries and reported sales and employment data, as described in Section 2, the Agency has identified three of the 18 companies as small businesses (i.e., 17 percent). The following businesses were identified as small for the purpose of this analysis:

- New Boston Coke Corporation,
- Shenango Inc. (owned by Aloe Holding Company), and
- Tonawanda Coke Corporation.

Each of these small companies owned and operated a merchant coke facility with a total of five coke batteries, or roughly 8 percent of all the coke batteries operated in 1997.

## 5.2 Screening-Level Analysis

To assess the potential impact of this rule on small businesses, the Agency calculated the share of annual compliance costs relative to baseline sales for each company. When a company owns more than one affected facility, EPA combined the costs for each facility for the numerator of the test ratio. Annual compliance costs include annualized capital costs and operating and maintenance costs imposed on these companies.[1] They do not include changes in production or market adjustments.

Although small businesses represent 17 percent of the companies within the source category, they are expected to incur only 11 percent of the total industry compliance costs of $14.3 million (see Table 5-1). The average total annual compliance cost is projected to be $533,000 per small company, while the average for large companies is projected to be $840,000 per company. The mean (median) cost-to-sales ratio for small businesses is 1.3 percent (1.4 percent), with a range of 0.04 to 2.4 percent. EPA estimates that two of the three small businesses may experience an impact greater than 1 percent of sales, but no small

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[1] Annualized capital costs include purchased equipment costs (PEC), direct costs for installation (DCI), and indirect costs for installation (ICI) related to engineering and start up. Operating and maintenance costs include direct annual costs (DAC), such as catalysis replacement, increased utilities, and increased labor, and indirect annual costs (IAC), such as costs due to tax, overhead, insurance, and administrative burdens.

**Table 5-1. Summary Statistics for SBREFA Screening Analysis: 1997**

| | **Small** | | **Large** | | **All Companies** | |
|---|---|---|---|---|---|---|
| Total Number of Companies | 3 | | 15 | | 18 | |
| Total Annual Compliance Costs (TACC) (\$$10^6$/yr) | \$1.6 | | \$12.6 | | \$14.3 | |
| Average TACC per company (\$$10^6$/yr) | \$0.53 | | \$0.84 | | \$0.79 | |
| Compliance Cost-to-Sales Ratios | | | | | | |
| Average | 1.27% | | 0.09% | | 0.28% | |
| Median | 1.36% | | 0.04% | | 0.05% | |
| Minimum | 0.04% | | 0.00% | | 0.00% | |
| Maximum | 2.40% | | 0.26% | | 2.40% | |
| | Number | Share | Number | Share | Number | Share |
| Compliance costs are <1% of sales | 1 | 33% | 15 | 100% | 16 | 89% |
| Compliance costs are ≥1 to 3% of sales | 2 | 67% | 0 | 0% | 2 | 11% |
| Compliance costs are ≥3% of sales | 0 | 0% | 0 | 0% | 0 | 0% |

Note: Assumes no market responses (i.e., price and output adjustments) by regulated entities.

businesses will experience an impact greater than 3 percent of sales. In contrast, all of the large companies are affected at less than 1 percent of sales.

## 5.3 Economic Analysis

The Agency also analyzed the economic impacts on small businesses under with-regulation conditions expected to result from implementing the MACT. Unlike the screening analysis, this approach examines small business impacts in light of the behavioral responses of producers and consumers to the regulation. As shown in Table 5-2, the economic model projects operating profits increase by $0.5 million for the furnace coke plants operated by small businesses. For these plants, furnace coke price increases outweigh the additional costs associated with the MACT. In contrast, the model projects operating profits decrease by $0.1 million for foundry coke plants operated by a small firm. In this case, increased foundry coke prices mitigate the losses associated with additional control costs. No batteries (furnace or foundry) are projected to prematurely close as a result of the additional control costs associated with the regulation.

## 5.4 Assessment

Based on the *Quarterly Financial Report* (*QFR*) from the U.S. Bureau of the Census, the average return to sales for all reporting companies within the iron and steel industry ranged from 3.2 to 4.6 percent (U.S. Bureau of the Census, 1998).[2] In addition, Dun & Bradstreet reports the median return on sales as 3.7 percent for SIC 3312—Steel Works, Blast Furnaces (including Coke Ovens), and Rolling Mills (Dun & Bradstreet, 1997). Although this industry is typically characterized by average profit margins, the Agency's analysis indicated that none of the coke manufacturing facilities owned by small businesses are at risk of closure because of the proposed rule. In fact, the two facilities manufacturing furnace coke are projected to experience a slight increase in profits because of market feedbacks related to higher costs incurred by competitors, while the one facility manufacturing foundry coke is projected to experience a decline in profits of slightly less than 1 percent. In summary, this analysis supports certification under the Regulatory Flexibility Act because, while a few small firms may experience initial impacts greater than 1 percent of sales, the Agency's economic analysis indicates no significant impacts on their viability to continue operations and remain profitable.

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[2] Furthermore, the *QFR* reports that companies within the iron and steel industry of less than $25 million in assets reported an average return to sales ranging from 6.8 to 9.8 percent.

## Table 5-2. Small Business Impacts of the Proposed Coke MACT: 1997

| | | Changes From Baseline | |
|---|---|---|---|
| | **Baseline** | **Absolute** | **Percent** |
| **Coke Plants (Merchant Only)** | | | |
| *Furnace* | | | |
| Revenues ($\$10^6$/yr) | $73.0 | $1.1 | 1.4% |
| Costs ($\$10^6$/yr) | $72.8 | $0.5 | 0.7% |
| Control costs | $0.0 | $0.5 | NA |
| Production costs | $72.8 | $0.0 | 0.0% |
| Operating profits ($\$10^6$/yr) | $0.2 | $0.5 | 331.5% |
| Coke batteries (#) | 2 | 0 | 0.0% |
| Employment (FTEs) | 414 | 0 | 0.0% |
| *Foundry* | | | |
| Revenues ($\$10^6$/yr) | $38.8 | $1.1 | 2.8% |
| Costs ($\$10^6$/yr) | $27.3 | $1.1 | 4.1% |
| Control costs | $0.0 | $1.1 | NA |
| Production costs | $27.3 | $0.0 | 0.0% |
| Operating profits ($\$10^6$/yr) | $11.5 | –$0.1 | –0.5% |
| Coke batteries (#) | 3 | 0 | 0.0% |
| Employment (FTEs) | 260 | 0 | 0.0% |
| *Total* | | | |
| Revenues ($\$10^6$/yr) | $111.8 | $2.1 | 1.9% |
| Costs ($\$10^6$/yr) | $100.2 | $1.6 | 1.6% |
| Control costs | $0.0 | $1.6 | NA |
| Production costs | $100.2 | $0.0 | 0.0% |
| Operating profits ($\$10^6$/yr) | $11.7 | $0.5 | 4.2% |
| Coke batteries (#) | 5 | 0 | 0.0% |
| Employment (FTEs) | 674 | 0 | 0.0% |

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# APPENDIX A

# ECONOMIC IMPACT ANALYSIS METHODOLOGY

This appendix provides the methodology for analyzing the economic impacts of the proposed MACT standard for coke ovens. Implementation of this methodology provided the economic data and supporting information that EPA requires to support its regulatory determination. This approach is firmly rooted in microeconomic theory and the methods developed for earlier EPA studies to operationalize this theory. The Agency employed a computerized market model of the coke, steel mill products, and iron castings industries to estimate the behavioral responses to the imposition of regulatory costs and, thus, the economic impacts of the proposed standard. The market model captures the linkages between these industries through changes in equilibrium prices and quantities. The same model is used to evaluate the economic impact of the proposed integrated iron and steel facilities MACT and iron foundries MACT to ensure consistency across the EIAs for these MACT standards.

This methodology section describes the conceptual approach selected for this EIA. For each product market included in the analysis, EPA derived facility-level supply and demand functions that are able to account for the behavioral response and market implications of the regulation’s costs. Finally, this appendix presents an overview of the specific functional forms that constitute the Agency’s computerized market model.

## A.1 Overview of Economic Modeling Approach

In general, the EIA methodology needs to allow EPA to consider the effect 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 decision making accounted for in the model, and
- the scope of interaction between different segments of the economy.

Each of these dimensions was considered in selecting the approach used to model the economic impact of the proposed coke regulation. Bingham and Fox (1999) provide a useful summary of these dimensions as they relate to modeling the outcomes of environmental regulations.

For this analysis, prices and quantities are determined in perfectly competitive markets for furnace coke, foundry coke, finished steel mill products, and iron castings. The Agency analyzed the impact of the proposed regulation using a market modeling approach that incorporates behavioral responses in a multiple-market partial equilibrium model. Multiple-market partial equilibrium analysis accounts for the interactions between coke, steel mill product, and iron castings markets into the EIA to better estimate the proposed regulation's impact. The modeling technique is to link a series of standard partial equilibrium models by specifying the interactions between the supply and demand for products and then solving for changes in prices and quantities across all markets simultaneously.

Figure A-1 summarizes the market interactions included in the Agency's EIA modeling approach. Changes in the equilibrium price and quantity due to control costs on coke batteries were estimated simultaneously in four linked markets:

- market for furnace coke,
- market for foundry coke,
- market for steel mill products, and
- market for iron castings.

As described in Section 2 of this EIA report, many captive coke plants supply their excess furnace coke to the market. Merchant coke plants and foreign imports account for the remaining supply to the furnace coke market. Furnace coke produced at captive coke plants and shipped directly to integrated iron and steel mills owned by their parent companies does not directly enter the market for furnace coke. However, compliance costs incurred by these captive, or "in-house," furnace coke batteries indirectly affect the furnace coke market through price and output changes in the steel mill products market.

The market demand for furnace coke is derived from integrated mills producing steel mill products. Integrated iron and steel mills that need more coke than their captive batteries can produce will purchase furnace coke from the market. Integrated mills' market demand

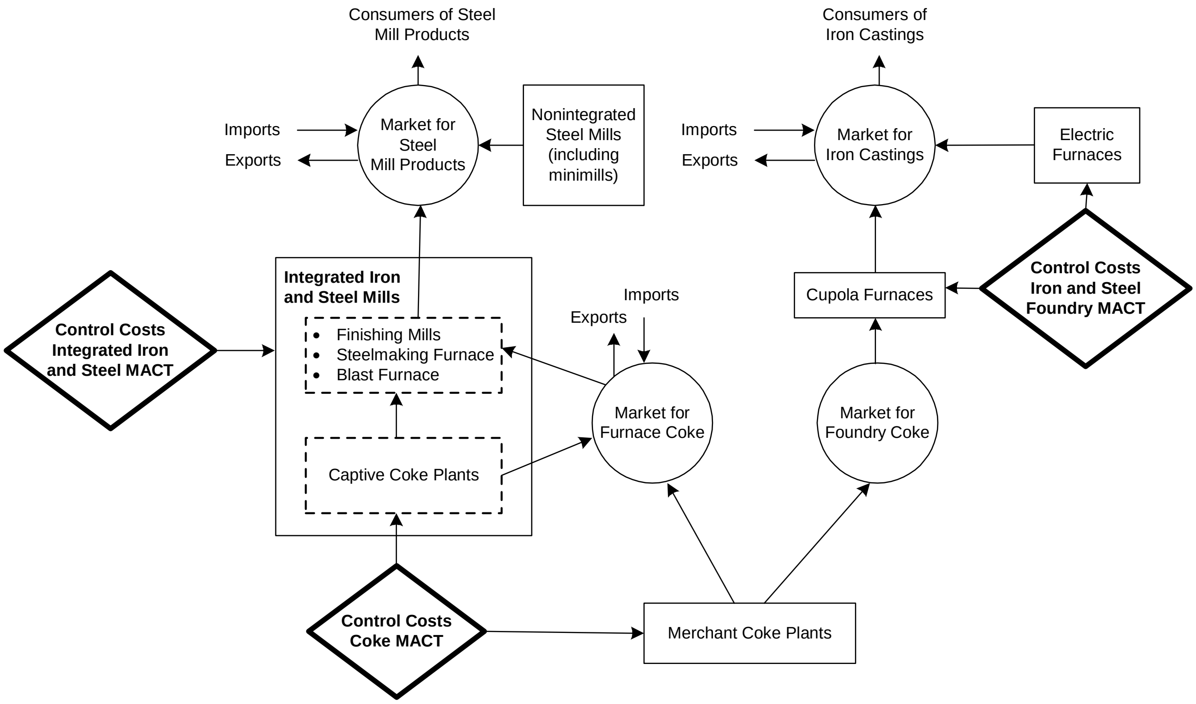


**Figure A-1. Market Linkages Modeled in the Economic Impact Analysis**

for furnace coke depends on their production levels as influenced by the market for steel mill products. Steel mill products are supplied by three sources: integrated iron and steel mills, nonintegrated steel mills (primarily mini-mills), and imports. Domestic consumers of steel mill products and exports account for the market demand.

As described in Section 2 of this EIA report, in the analysis baseline of 1997, merchant plants are the sole suppliers of foundry coke to the market. The U.S. International Trade Commission (2000) has documented an increasing trend in foreign imports of foundry coke from China; however, these Chinese imports represented less than 1 percent of U.S. foundry coke consumption in 1997. Moreover, the USITC report indicates that the inferior quality of imported foundry coke and future environmental regulations being proposed in China may limit the market penetration in the United States. Consumers of foundry coke include foundries with cupolas that produce iron castings that are modeled using a single, representative demand curve.

In addition to furnace and foundry coke, merchant and captive coke plants sell a by-product referred to as “other coke” that is purchased as a fuel input by cement plants, chemical plants, and nonferrous smelters.  Because “other coke” is a by-product and represented only 2 percent of U.S. coke production in 1997 it is not formally characterized by supply and demand in the market model.  Revenues from this product are accounted for by assuming its volume is a constant proportion of the total amount of coke produced by a battery and sold at a constant price.

## A.2 Conceptual Market Modeling Approach

This section examines the impact of the regulations on the production costs of coke for affected facilities, both merchant and captive.  It provides an overview of the basic economic theory of the effect of regulations on facility production decisions and the concomitant effect on market outcomes.  Following the *OAQPS Economic Analysis Resource Document* (EPA, 1999), we employed standard concepts in microeconomics to model the supply of affected products and the impacts of the regulations on production costs and the operating decisions.  The approach relies heavily on previous economic analyses, employs a comparative static approach, and assumes certainty in relevant markets.  The three main elements of the analysis are regulatory effects on the manufacturing facility, market responses, and facility–market interactions.  The remainder of this section describes each of these main elements.

### *A.2.1 Facility-level Responses to Control Costs*

Individual plant-level production decisions were modeled to develop the market supply and demand for key industry segments in the analysis.  Production decisions were modeled as intermediate-run decisions, assuming that the plant size, equipment, and technologies are fixed.  For example, the production decision typically involves (1) whether a firm with plant and equipment already in place purchases inputs to produce output and (2) at what capacity utilization the plant should operate.  A profit-maximizing firm will operate existing capital as long as the market price for its output exceeds its per-unit variable production costs, since the facility will cover not only the cost of its variable inputs but also part of its capital costs.  Thus, in the short run, a profit-maximizing firm will not pass up an opportunity to recover even part of its fixed investment in plant and equipment.

The existence of fixed production factors gives rise to diminishing returns to those fixed factors and, along with the terms under which variable inputs are purchased, defines the upward-sloping form of the marginal cost (supply) curve employed for this analysis. Figure A-2 illustrates this derivation of the supply function at an individual mill based on the classical U-shaped cost structure. The MC curve is the marginal cost of production, which intersects the facility's average variable (avoidable) cost curve (AVC) and its average total cost curve (ATC) at their respective minimum points. The supply function is that portion of the marginal cost curve bounded by the minimum economically feasible production rate ($q^m$) and the technical capacity ($q^M$). A profit-maximizing producer will select the output rate where marginal revenue equals price, that is, at [P*, q*]. If market price falls below ATC, then the firm's best response is to cease production because total revenue does not cover total costs of production.

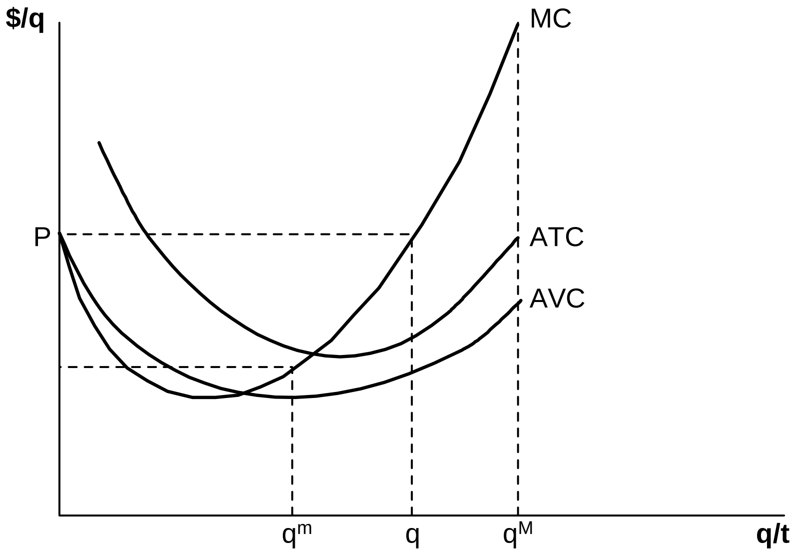


**Figure A-2. Product Supply Function at Facility**

Now consider the effect of the proposed regulation and the associated compliance costs. These fall into one of two categories: avoidable variable and avoidable nonvariable. These proposed costs are characterized as avoidable because a firm can choose to cease operation of the facility and, thus, avoid incurring the costs of compliance. The variable control costs include the operating and maintenance costs of the controls, while the nonvariable costs include compliance capital equipment. Figure A-3 illustrates the effect of

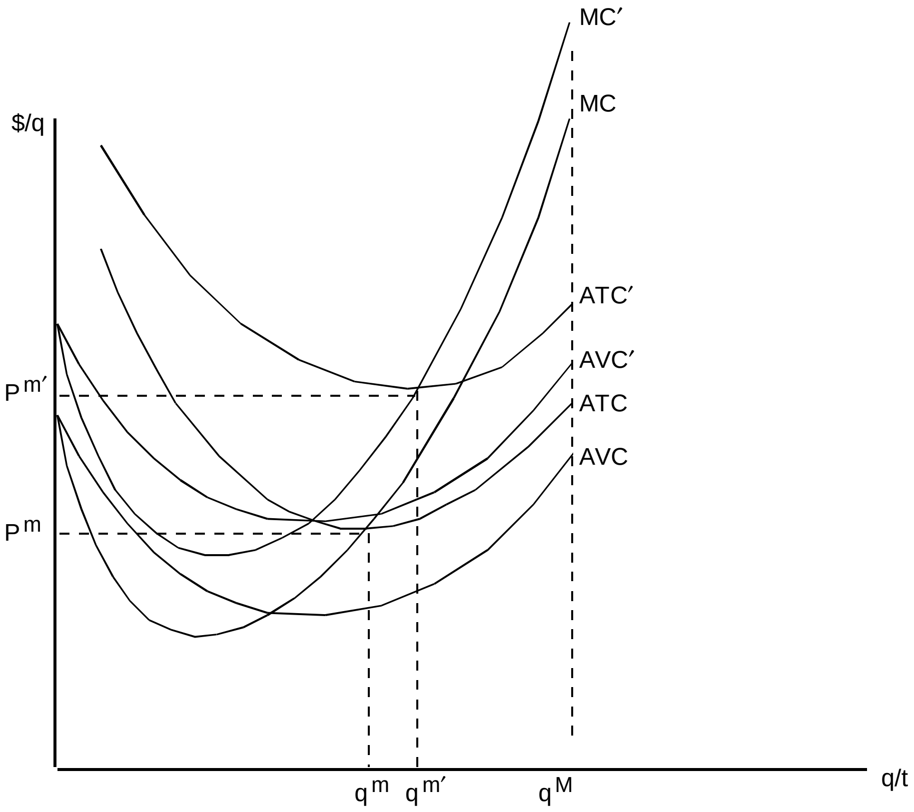


**Figure A-3. Effect of Compliance Costs on Product Supply Function at Facility**

these additional costs on the facility supply function. The facility's AVC and MC curves shift upward (to AVC′ and MC′) by the per-unit variable compliance costs. In addition, the nonvariable compliance costs increase total avoidable costs and, thus, the vertical distance between ATC′ and AVC′. The facility's supply curve shifts upward with marginal costs and the new (higher) minimum operating level (q) is determined by a new (higher) ps.

Next consider the effect of compliance costs on the derived demand for inputs at the regulated facility. Integrated iron and steel mills are market demanders of furnace coke, while foundries with cupola furnaces are market demanders of foundry coke. We employ similar neoclassical analysis to that above to demonstrate the effect of the regulation on the demand for market coke inputs, both furnace and foundry. Figure A-4 illustrates the derived demand curve for coke inputs. Each point on the derived demand curve equals the

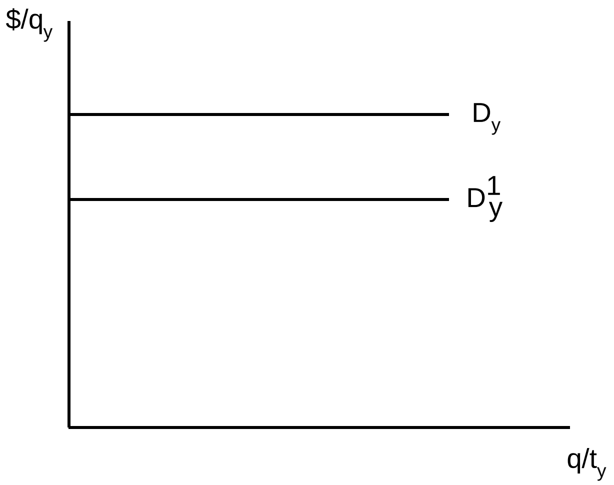
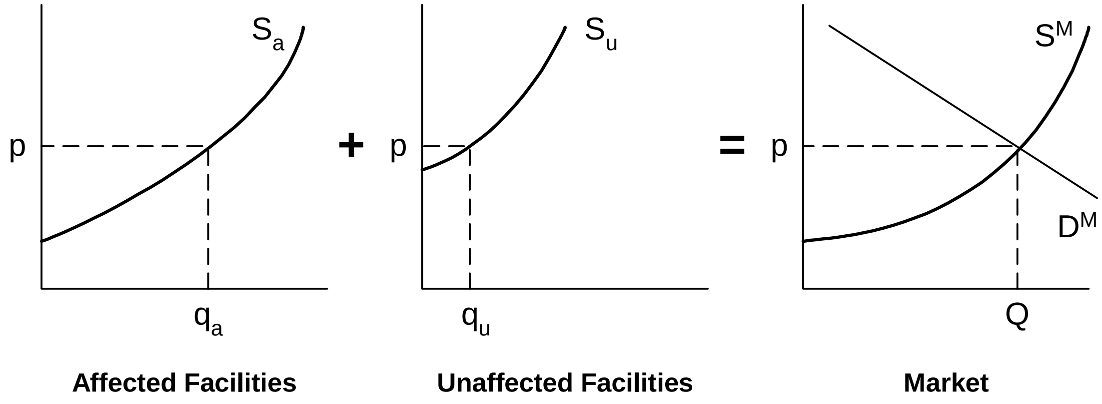


**Figure A-4. Derived Demand Curve for Coke Inputs**

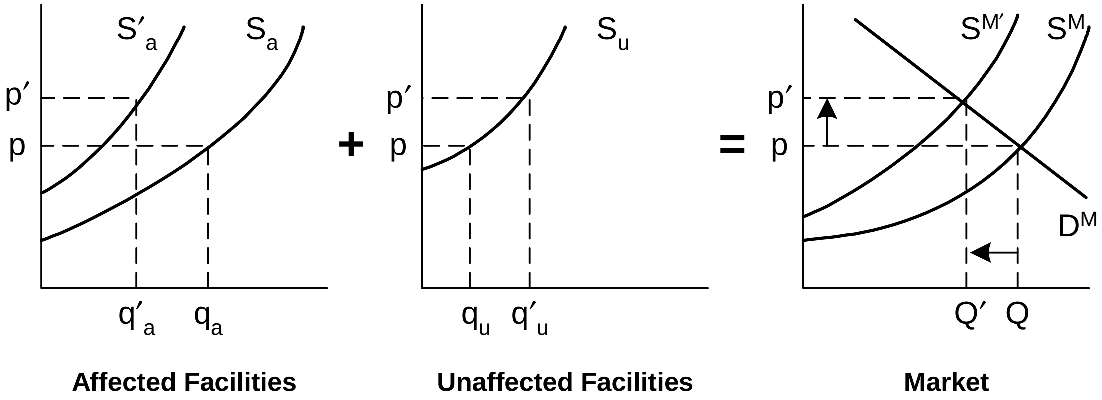
willingness to pay for the corresponding marginal input. This is typically referred to as the input's value of marginal product (VMP), which is equal to the price of the output (P) less the per-unit compliance cost (c) times the input's "marginal physical product" (MPP), which is the incremental output attributable to the incremental inputs. If, as assumed in this analysis, the input-output relationship between the market coke input and the final product (steel mill products or iron castings) is strictly fixed, then the VMP of the market coke is constant and the derived demand curve is horizontal with the constant VMP as the vertical intercept, as shown in Figure A-4. Ignoring any effect on the output price for now, an increase in regulatory costs will lower the VMP of all inputs leading to a downward shift in the derived demand in Figure A-4 from $D_y$ to $D^1_y$.

### *A.2.2 Market Effects*

To evaluate the market impacts, the economic analysis assumes that prices and quantities are determined in a competitive market (i.e., individual facilities have negligible power over the market price and thus take the price as "given" by the market). As shown in Figure A-5(a), under perfect competition, market prices and quantities are determined by the intersection of market supply and demand curves. The initial baseline scenario consists of a market price and quantity (P, Q) that is determined by the downward-sloping market demand



a) Baseline Equilibrium



b) With-Regulation Equilibrium

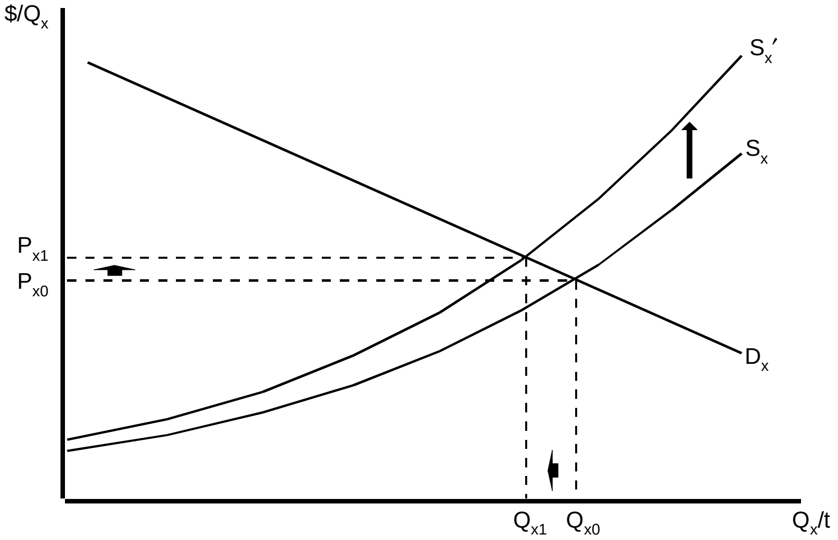
**Figure A-5. Market Equilibrium without and with Regulation**

curve ($D^M$) and the upward-sloping market supply curve ($S^M$) that reflects the horizontal summation of the individual producers' supply curves.

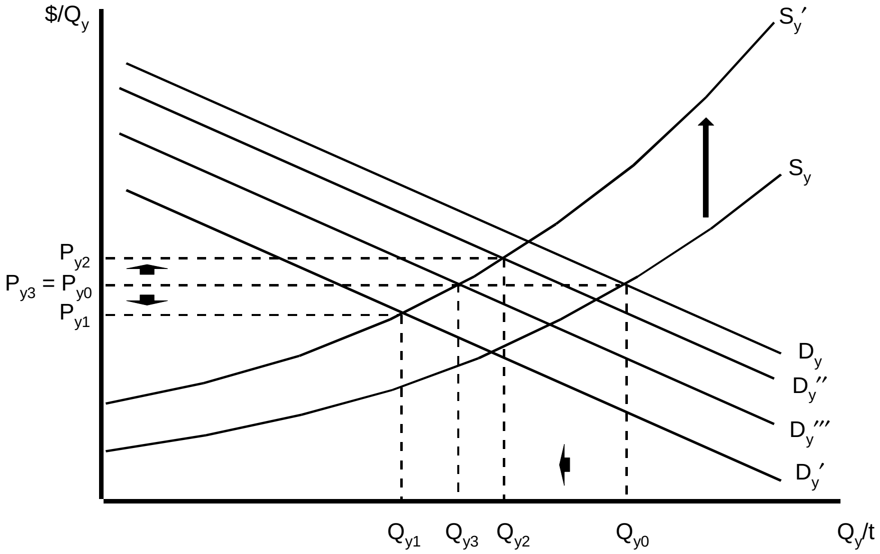
Now consider the effect of the regulation on the baseline scenario as shown in Figure A-5(b). In the baseline scenario without the proposed standards, at the projected price, P, the industry would produce total output, Q, with affected facilities producing the amount $q_a$ and unaffected facilities accounting for Q minus $q_a$, or $q_u$. The regulation raises the production costs at affected facilities, causing their supply curves to shift upward from $S_a$ to $S_a'$ and the market supply curve to shift upward to $S^{M\prime}$. At the new with-regulation equilibrium with the regulation, the market price increases from P to P′ and market output (as determined from the market demand curve, $D^M$) declines from Q to Q′. This reduction in market output is the net result from reductions at affected facilities and increases at unaffected facilities. Unaffected facilities do not incur the increased costs due to regulation so their response to higher product prices is to increase production. Foreign suppliers (i.e., imports), which also do not face higher costs, will respond in the same manner as these unaffected producers.

The above description is typical of the expected market effects for final product markets. The proposed regulation will affect the costs of producing steel mill products by increasing the market price of furnace coke and the cost of producing captive furnace coke. The increase in the market price and captive production costs for furnace coke result in an upward shift in the supply functions of integrated iron and steel mills, while nonintegrated and foreign supplier are unaffected. Additionally, the proposed regulation will affect the costs of producing iron castings by increasing the market price of foundry coke. The increase in market price results in an upward shift in supply functions of foundries operating cupola furnaces, while foundries operating electric furnaces are unaffected.

However, there are additional impacts on the furnace and foundry coke markets related to their derived demand as inputs to either the production of steel mill products or iron castings. Figure A-6 illustrates, under perfect competition, the baseline scenario where the market quantity and price of the final steel mill product or iron casting, $Q_x(Q_{x0}, P_{x0})$, are determined by the intersection of the market demand curve ($D_x$) and the market supply curve ($S_x$), and the market quantity and price of furnace or foundry coke, $Q_y(Q_{y0}, P_{y0})$, are determined by the intersection of the market demand curve ($D_y$) and market supply curve ($S_y$). Given the derived demand for coke, the demanders of coke, $Q_y$, are the individual facilities that purchase coke for producing their final products (i.e., integrated steel mills in the case of furnace coke or foundries with cupola furnaces in the case of foundry coke).



**(a) Market for single steel mill product or iron casting, $Q_x$**



**(b) Market for coke input, $Q_y$**

Figure A-6. Market Equilibria With and Without Compliance Costs

Imposing the regulations increases the costs of producing coke and, thus, the final product, shifting the market supply functions for both commodities upward to $S_x'$ and $S_y'$, respectively. The supply shift in the final product market causes the market quantity to fall to $Q_{x1}$ and the market price to rise to $P_{x1}$ in the new equilibrium. In the market for coke, the reduced production of the final product causes a downward shift in the demand curve ($D_y$) with an unambiguous reduction in coke production, but the direction of the change in market price is determined by the relative magnitude of the demand and supply shift. If the downward demand effect dominates, the price will fall (e.g., $P_{y1}$); however, if the upward supply effect dominates, the price will rise (e.g., $P_{y2}$). Otherwise, if the effects just offset each other, the price remains unchanged (e.g., $P_{y3} = P_{y0}$).

### *A.2.3 Facility-Level Responses to Compliance Costs and New Market Prices*

In evaluating the market effects, we must distinguish between the initial effect of the regulations and the net effect after all markets have adjusted. The profit-maximizing behavior of firms, as described above, may lead to changes in output that, when aggregated across all producers, lead to changes in the market-clearing price and feedback on the firms to alter their decisions. These adjustments are characterized as a simultaneous interaction of producers, consumers, and markets. Thus, to evaluate the facility-market outcomes, the analysis must go beyond the initial effect of the regulation and estimate the net effect after markets have fully adjusted.

Given changes in the market prices and costs, each facility will elect to either

- continue to operate, adjusting production and input use based on new revenues and costs, or
- cease production at the facility if total revenues do not exceed total costs.

This decision can be extended to those facilities with multiple product lines or operations (e.g., coke batteries, blast furnaces, cupolas). If product revenues are less than product-specific costs, then these product-lines or operations may be closed.

Therefore, after accounting for the facility-market interaction, the operating decisions at each individual facility can be derived. These operating decisions include whether to continue to operate the facility (i.e., closure) and, if so, the optimal production level based on compliance costs and new market prices. The approach to modeling the facility closure decision is based on conventional microeconomic theory. This approach compares the ATC—which includes all cost components that fall to zero when production discontinues—to the expected post-regulatory price. Figure A-3 illustrates this comparison. If price falls below the ATC, total revenue would be less than the total costs. In this situation, the owner's cost-minimizing response is to close the facility. Therefore, as long as there is some return to the fixed factors of production— that is, some positive level of profits— the firm is expected to continue to operate the facility.

If the firm decides to continue operations, then the facility's decision turns to the optimal output rate. Facility and product-line closures, of course, directly translate into reductions in output. However, the output of facilities that continue to operate will also change depending on the relative impact of compliance costs and higher market prices. Increases in costs will tend to reduce producers' output rates; however, some of this effect is mitigated when prices are increased. If the market price increase more than offsets the increase in unit costs, then even some affected facilities could respond by increasing their production. Similarly, supply from unaffected domestic producers and foreign sources will respond positively to changes in market prices.

## A.3 Operational Economic Model

Implementation of the proposed MACT standard on coke plants will affect the costs of coke production for captive and merchant plants across the United States. Responses at the facility-level to these additional costs will collectively determine the market impacts of the rule. Specifically, the cost of the regulation may induce some facilities to alter their current level of production or to cease operations. These choices affect and, in turn are affected by, the market price of each product. As described above, the Agency has employed standard microeconomic concepts to model the supply and demand of each product and the impacts of the regulation on production costs and the output decisions of facilities. The main elements of the analysis are to

- characterize production of each product at the individual supplier and market levels,
- characterize the demand for each product, and
- develop the solution algorithm to determine the new with-regulation equilibrium.

The following sections provide the supply and demand specifications for each product market as implemented in the EIA model and summarize the model's solution algorithm. Demand elasticities are presented in Table A-1.

**Table A-1. Supply and Demand Elasticities Used in Analysis**

| Market | Supply Elasticity | Demand Elasticity |
|---|---|---|
| *Furnace Coke* | | |
| Domestic | Calculated | Derived |
| Foreign | 3.0[a] | –0.3[a] |
| *Foundry Coke* | | |
| Domestic | Calculated | Derived |
| *Steel Mill Products* | | |
| Domestic | 1.0[b] | –0.59[c] |
| Foreign | 1.0[b] | –1.0[b] |
| *Iron Castings* | | |
| Domestic | 1.0[b] | –0.58[c] |
| Foreign | 1.0[b] | –1.0[b] |

[a] Graham, Thorpe, and Hogan (1999).

[b] Assumed value.

[c] Weighted average of product demand elasticities estimated in econometric analysis.

## *A.3.1 Furnace Coke Market*

The market for furnace coke consists of supply from domestic coke plants, both merchant and captive, and foreign imports and of demand from integrated steel mills and foreign exports. The domestic supply for furnace coke is modeled as a stepwise supply function developed from the marginal cost of production at individual furnace coke batteries. The domestic demand is derived from iron and steel production at integrated mills as determined through the market for steel mill products and coking rates for individual batteries. The following section details the market supply and demand components for this analysis.

### *A.3.1.1 Market Supply of Furnace Coke*

The market supply for furnace coke, $Q^{Sc}$, is the sum of coke production from merchant facilities, excess production from captive facilities (coke produced at captive batteries less coke consumed for internal production on steel mill products), and foreign imports, i.e.,

$$Q^{Sc} = q_M^{Sc} + q_I^{Sc} + q_F^{Sc} \tag{A.1}$$

where

$q_M^{Sc}$ = furnace coke supply from merchant plants,

$q_I^{Sc}$ = furnace coke supply from integrated steel mills, and

$q_F^{Sc}$ = furnace coke supply from foreign sources (imports).

*Supply from Merchant and Captive Coke Plants*. The domestic supply of furnace coke is composed of the supply from merchant and captive coke plants reflecting plant-level production decisions for individual coke batteries. For merchant coke plants the supply is characterized as

$$q_M^{Sc} = \sum_l \sum_j q_{M(l,j)}^{Sc} \tag{A.2}$$

where

$q_M^{Sc}$ = supply of foundry coke from coke battery (j) at merchant plant (l).

Alternatively, for captive coke plants the supply is characterized as the furnace coke production remaining after internal coke requirements are satisfied for production of final steel mill products, i.e,

$$q_I^{SE} = \mathrm{MAX}\left[\sum_l \left( \sum_j q_{I(l,j)}^{Sc} - r_{I(l)}^{S}\ q_{I(l)}^{Ss}\right),\ 0\right] \tag{A.3}$$

where

$q_{I(l,j)}^{Sc}$ = the furnace coke production from captive battery (j) at integrated steel mill (l);

$r^{S}_{I(l)}$ = the coke rate for integrated steel mill (l), which specifies the amount of furnace coke input per unit of final steel mill product;[1] and

$q^{Ss}_{I(l)}$ = supply of steel mill product from integrated mill (l).

The MAX function in Eq. (A.3) indicates that if the total captive production of furnace coke at an integrated mill is greater than the amount of furnace coke consumption required to produce steel mill products, then supply to the furnace coke market will equal the difference; otherwise, the mill's supply to the furnace coke market will be zero (i.e., it only satisfies internal requirements from its captive operations).

As stated above, the domestic supply of furnace coke is developed from plant-level production decisions for individual coke batteries. For an individual coke battery the marginal cost was assumed to be constant. Thus, merchant batteries supply 100 percent of a battery's capacity to the market if the battery's marginal cost (MC) is below the market price for furnace coke ($p_c$), or zero if MC exceeds $p_c$. Captive batteries first supply the furnace coke demanded by their internal steelmaking requirements. Any excess capacity will then supply the furnace coke market if the remaining captive battery's MC is below the market price.

Marginal cost curves were developed for all furnace coke batteries at merchant and captive plants in the United States as detailed in Appendix B. Production costs for a single battery are characterized by constant marginal cost throughout the capacity range of the battery. This yields the inverted L-shaped supply function shown in Figure A-7(a). In this case, marginal cost (MC) equals average variable cost (AVC) and is constant up to the production capacity given by q. The supply function becomes vertical at q because increasing production beyond this point is not possible. The minimum economically achievable price level is equal to p*. Below this price level, p* is less than AVC, and the supplier would choose to shut down rather than to continue to produce coke.

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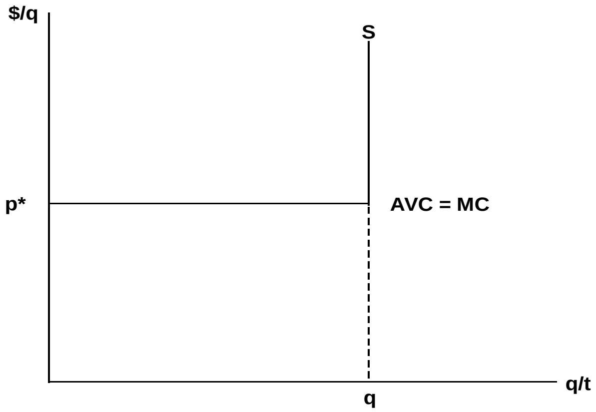
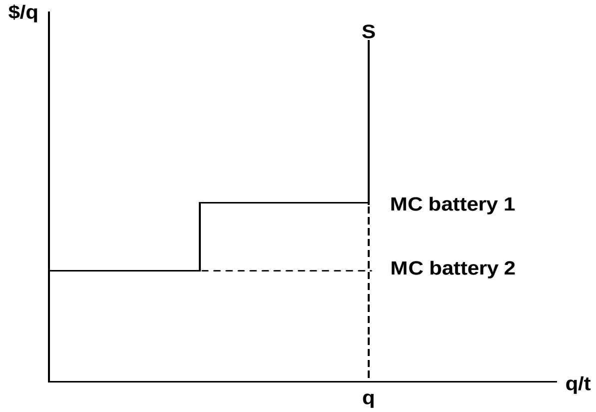
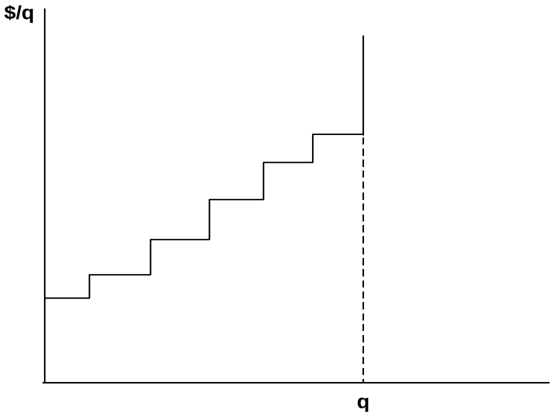
[1] The furnace coke rate for each integrated steel mill is taken from Hogan and Koelble (1996). The coke rate is assumed to be constant with respect to the quantity of finished steel products produced at a given mill. A constant coke rate at each integrated mill implies a constant efficiency of use at all output levels and substitution possibilities do not exist given the technology in place at integrated mills. Furthermore, the initial captive share of each integrated mill's coke requirement is based on the baseline data from the EPA survey.



(a) Inverted L-Shaped Supply Function at Single-Battery Plant



(b) Inverted L-Shaped Supply Functions at Multibattery Plant



(c) Stepwise Market Supply Curve

**Figure A-7. Facility-Level Supply Functions for Coke**

A stepwise supply function can be created for each facility with multiple batteries by ordering production from least to highest MC batteries (see Figure A-7[b]). For captive coke plants, the lowest cost batteries are assumed to supply internal demand, leaving the higher cost battery(ies) to supply the market if MC<P for the appropriate battery(ies). Similarly, a stepwise aggregate domestic supply function can be created by ordering production from least to highest MC batteries (see Figure A-7(c)). Based on this characterization of domestic supply, a decrease in demand for furnace coke would then sequentially close batteries beginning with the highest MC battery.

*Foreign Supply of Furnace Coke*. Foreign supply of furnace coke ($q_F^{Sc}$) is expressed as

$$q_F^{Sc} = A_F^c \, (p^c)^{\xi_F^c} \tag{A.4}$$

where

$A_F^c$ = multiplicative parameter for the foreign furnace coke supply equation, and

$\xi_F^c$ = foreign supply elasticity for furnace coke (assumed value = 1).

The multiplicative parameter ($A_F^c$) calibrates the foreign coke supply equation to replicate the observed 1997 level of furnace coke imports based on the market price and the foreign supply elasticity.

### *A.3.1.2 Market Demand for Furnace Coke*

Market demand for furnace coke ($Q^{Dc}$) is the sum of domestic demand from integrated steel mills and foreign demand (exports), i.e.,

$$Q^{Dc} = q_I^{Dc} + q_F^{Dc} \tag{A.5}$$

where

$q_I^{Dc}$ = derived demand of furnace coke from integrated steel mills, and

$q_F^{Dc}$ = foreign demand of furnace coke (exports).

*Domestic Demand for Furnace Coke*. Integrated steel mills use furnace coke as an input to the production of finished steel products. Furnace coke demand is derived from the final product supply decisions at the integrated steel mills. Once these final production decisions of integrated producers have been made, the mill-specific coke input rate will determine their individual coke requirements. Integrated steel mills satisfy their internal requirements first through captive operations and second through market purchases. Thus, the derived demand for furnace coke is the difference between total furnace coke required and the captive capacity at integrated plants, i.e.,

$$q_I^{Dc} = \mathrm{MAX}\left[\sum_l \left(r_{I(l)}^s \, q_{I(l)}^{Ss} - \sum_j q_{I(l,j)}^{Sc}\right),\ 0\right] \qquad \text{(A.6)}$$

$r_{I(l)}^s$ = the coke rate for integrated steel mill (l), which specifies the amount of furnace coke input per unit of final steel mill product;

$q_{I(l)}^{Ss}$ = supply of steel mill product from integrated mill (l); and

$q_{I(l,j)}^{Sc}$ = the furnace coke production from captive battery (j) at integrated steel mill (l).

The MAX function in Eq. (A.3) indicates that if the amount of furnace coke consumption required by an integrated mill to produce steel mill products is greater than its total captive production, then demand from the furnace coke market will equal the difference; otherwise, the mill’s demand from the furnace coke market will be zero (i.e., it fully satisfies internal requirements from its captive operations).

Increases in the price for furnace coke will increase the per-unit costs of final steel products and thereby shift upward the integrated mill’s supply curve for steel mill products. The shift in the supply curve decreases the market quantity of finished steel products produced, which subsequently reduces the quantity of furnace coke consumed at integrated mills and shifts their demand curve downward in the furnace coke market.

*Foreign Demand for Furnace Coke (Exports)*. Foreign demand for furnace coke is expressed as

$$q_F^{Dc} = B_F^c \, (p^c)^{\eta_F^c} \tag{A.7}$$

where

$B_F^c$ = multiplicative demand parameter for the foreign furnace coke demand equation, and

$\eta_F^c$ = foreign demand elasticity for furnace coke (literature estimate = –0.3).

The multiplicative demand parameter, $B_F^c$, calibrates the foreign coke demand equation to replicate the observed 1997 level of foreign exports based on the market price and the foreign demand elasticity.

### *A.3.2 Market for Steel Mill Products*

The market for steel mill products consists of supply from domestic mills and foreign imports and of demand from domestic and foreign consumers. Steel mill products are modeled as a single commodity market. The domestic supply for steel mill products includes production from integrated mills operating blast furnaces that require furnace coke and from nonintegrated mills that operate electric arc furnaces that do not. The proposed rule is expected to increase the price of furnace coke that will increase the cost of production at integrated mills and thereby shift their supply curves upward and increase the price of steel mill products.

#### *A.3.2.1 Market Supply of Steel Mill Products*

The market supply for steel mill products ($Q^{Ss}$) is defined as the sum of the supply from integrated iron and steel mills, nonintegrated mills, and foreign imports, i.e.,

$$Q^{Ss} = q_I^{Ss} + q_{NI}^{Ss} + q_F^{Ss} \tag{A.8}$$

where

$q_I^{Ss}$ = supply of steel mill products from integrated mills;

$q_{NI}^{Ss}$ = supply of steel mill products from the nonintegrated steel mills; and

$q_F^{Ss}$ = supply of steel mill products from foreign suppliers (imports).

*Supply from Integrated Mills*. Supply of steel mill products from integrated iron and steel mills is the sum of individual mill production, i.e.,

$$q_I^{Ss} = \sum_{l} q_{I(1)}^{Ss} \qquad \text{(A.9)}$$

where

$q_{I(l)}^{Ss}$ = quantity of steel mill products produced at an individual integrated mill (l).

Integrated producers of steel mill products vary output as production costs change. As described above, upward-sloping supply curves were used to model integrated mills' responses. For this analysis, the generalized Leontief technology is assumed to characterize the production of steel mill products at each facility. This technology is appropriate, given the fixed-proportion material input of coke and the variable-proportion inputs of labor, energy, and raw materials. The generalized Leontief supply function is

$$q_{I(1)}^{Ss} = \gamma_1 + \frac{B}{2}\left(\frac{1}{p_s}\right)^{\frac{1}{2}} \qquad \text{(A.10)}$$

where $p_s$ is the market price for the steel product, $\gamma_l$ and $\beta$ are model parameters, and l indexes affected integrated mills. The theoretical restrictions on the model parameters that ensure upward-sloping supply curves are $\gamma_l > 0$ and $\beta < 0$.

Figure A-8 illustrates the theoretical supply function of Eq. (A.6). As shown, the upward-sloping supply curve is specified over a productive range with a lower bound of zero that corresponds with a shutdown price equal to $\frac{\beta^2}{4\gamma_l^2}$ and an upper bound given by the productive capacity of $q_l^M$ that is approximated by the supply parameter $\gamma_l$. The curvature of the supply function is determined by the $\beta$ parameter.

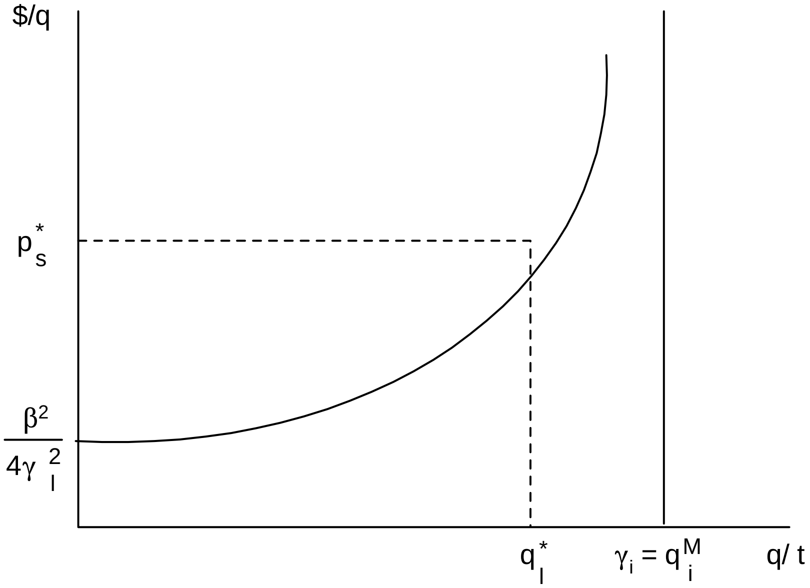


**Figure A-8. Theoretical Supply Function for Integrated Facilities and Foundries**

To specify the supply function of Eq. (A.6) for this analysis, the β parameter was computed by substituting an assumed market supply elasticity for the product (ξ), the market price of the product (p), and the production-weighted average annual production level across mills (q) into the following equation:

$$\beta = -\xi 4q\left[\frac{1}{p_s}\right]^{-\frac{1}{2}} \tag{A.11}$$

The β parameter was calculated by incorporating market price and elasticity of supply values into Eq. (A.11). Absent empirical or literature-based estimates, the Agency assumed the market-level supply elasticity is equal to one (i.e., a 1 percent change in price leads to a 1 percent change in output).

The intercept of the supply function, $\gamma_l$, approximates the productive capacity and varies across products at each facility. This parameter does not influence the facility's production responsiveness to price changes as does the β parameter. Thus, the parameter $\gamma_l$ is used to calibrate the economic model so that each individual facility's supply equation matches its baseline production data from 1997.

*Modeling the Impact of Compliance Costs*. The effect of the regulation is to increase the MC of producing furnace coke by the compliance costs. These costs include the variable component consisting of the operating and maintenance costs and the nonvariable component consisting of the control equipment required for the regulatory option. Regulatory control costs will shift the supply curve upward for each affected facility by the annualized compliance cost (operating and maintenance plus annualized capital) expressed per unit of coke production. Computing the supply shift in this way treats compliance costs as the conceptual equivalent of a unit tax on output. For coke facilities, the horizontal portion of its supply curve will rise by the per-unit total compliance costs. In this case, the MC curve will shift by this amount to allow the new higher reservation price for the coke battery to appropriately reflect the fixed costs of compliance in the operating decision. At a multiple-battery facility, the change in each battery's MC may cause a reordering of the steps because the compliance costs vary due to the technology, age, and existing controls of individual batteries.

Compliance costs on captive furnace coke batteries will directly affect production decisions at integrated mills, while compliance costs on merchant furnace coke batteries will indirectly affect these decisions through the change in the market price of furnace coke. Both of these impacts were modeled as reducing the net price integrated mills receive for finished steel products. Returning to the integrated mill's supply function presented in Eq. (A.10), the mill's production quantity with compliance costs is expressed as

$$q^{Ss}_{I(l)} = \gamma_l + \frac{\beta}{2}\left[\frac{1}{p_s - r^{S}_{I(l)}\,[\alpha_l \Delta c_l + (1-\alpha_l)\,\Delta p_c]}\right] \tag{A.12}$$

where

$r^{s}_{I(l)}$ = the coke rate for integrated steel mill (l), which specifies the amount of furnace coke input per unit of steel mill product;

$\alpha_l$ = the share of integrated steel mill l's furnace coke provided by captive batteries;

$\Delta c_l$ = change in per-unit cost of captive coke production at integrated steel mill l;

$(1–\alpha_l)$ = share of integrated steel mill l's furnace coke provided by the market; and

$\Delta p_c$ = change in the market price for furnace coke.

The bracketed term in the denominator represents the increased costs due to the regulation, i.e., both the direct and indirect effects. These costs, $\Delta c_l$ and $\Delta p_c$, are expressed per ton of furnace coke and weighted to reflect each integrated mill's reliance on captive versus market furnace coke.[2] The change in the cost per ton of furnace coke due to the regulation is then multiplied by the mill's coke rate to obtain the change in the cost per ton of finished steel product. The change in the cost per ton of finished steel product corresponds to the shift in the affected facility supply curve shown in Figure A-5b.

*Supply from Nonintegrated Mills*. The supply of steel mill products from domestic nonintegrated mills is specified as

$$q_{NI}^{Ss} = A_{NI}^{s} (p^{s})^{\xi_{NI}^{s}} \tag{A.13}$$

where

$A_{NI}^{s}$ = multiplicative parameter for nonintegrated mill supply equation, and

$\xi_{NI}^{s}$ = the nonintegrated mill supply elasticity for finished steel products (assumed value = 1).

Absent literature or econometric estimates of the supply elasticity, this analysis employed an assumed value of one, which was then varied in conducting a sensitivity analysis for this parameter. The multiplicative supply parameter is determined by backsolving Eq. (A.8), given baseline values of the market price, supply elasticities, and quantities supplied by nonintegrated mills and foreign mills.

*Foreign Supply (Imports)*. The supply of steel mill products from foreign suppliers (imports) is specified as

$$q_{F}^{Ss} = A_{F}^{s} (p^{s})^{\xi_{F}^{s}} \tag{A.14}$$

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[2] The captive versus market furnace coke weights are endogenous in the model because integrated mills exhaust their captive supply of coke first; hence, changes in coke consumption typically come from changes in market purchases, while captive consumption remains relatively constant.

where

$A_F^s$ = multiplicative parameter for foreign supply equation, and

$\xi_F^s$ = the foreign supply elasticity for finished steel products (assumed value = 1).

Absent literature or econometric estimates (new or existing) of the supply elasticity, this analysis employed an assumed value of one, which was then varied in conducting a sensitivity analysis for this parameter. The multiplicative supply parameters are determined by backsolving Eq. (A.8), given baseline values of the market price, supply elasticity, and level of imports.

### *A.3.2.2 Market Demand for Steel Mill Products*

The market demand for finished steel mill products, $Q^{Ds}$, is the sum of domestic and foreign demand, i.e.,

$$Q^{Ds} = q_D^{Ds} + q_F^{Ds} \tag{A.15}$$

where

$q_D^{Ds}$ = domestic demand for finished steel mill products, and

$q_F^{Ds}$ = foreign demand for steel mill products (exports).

*Domestic Demand for Steel Mill Products*. The domestic demand for finished steel products is expressed as

$$q_D^{Ds} = B_D^s \, (p^s)^{\eta_D^s} \tag{A.16}$$

where

$B_D^s$ = multiplicative parameter for domestic steel mill products demand equation, and

$\eta_D^s$ = domestic demand elasticity for steel mill products (estimate = –0.59).

The multiplicative demand parameter calibrates the domestic demand equation given baseline data on price and demand elasticity to replicate the observed 1997 level of domestic consumption.

*Foreign Demand for Steel Mill Products (Exports).* Foreign demand (exports) for finished steel products is expressed as

$$q_F^{Ds} = B_F^s \, (p^s)^{\eta_F^s} \tag{A.17}$$

where

$B_F^s$ = multiplicative demand parameter for foreign steel mill products' demand equation, and

$\eta_F^s$ = foreign (export) demand elasticity for steel mill products (assumed value = –1).

The multiplicative demand parameter calibrates the foreign demand equation given data on price and demand elasticities to replicate the observed 1997 level of foreign exports.

### *A.3.3 Market for Foundry Coke*

The market for furnace coke consists of supply from merchant coke plants and demand from foundries operating cupola furnaces. The domestic supply for foundry coke is modeled as a stepwise supply function developed from the marginal cost of production at individual foundry coke batteries. The domestic demand is derived from iron castings production at foundries operating cupola furnaces as determined through the market for iron castings and coking rates for individual batteries. As described previously, the level of imports and exports of foundry coke were negligible in 1997 and, thus, were not included in the market model. The following section details the market supply and demand components for this analysis.

#### *A.3.3.1 Market Supply of Foundry Coke*

The market supply of foundry coke, $Q^{Sk}$, is composed solely of the supply from domestic merchant plants reflecting plant-level production decisions for individual merchant coke batteries, i.e.,

$$Q^{Sk} = \underset{\text{Merchant}}{q_M^{Sk}} = \sum_l \sum_j q_{M(l,j)}^{Sk} \tag{A.18}$$

where

l = plants

j = batteries

$q_{M(l,j)}^{Sk}$ = supply of foundry coke from coke battery (j) at merchant plant (l).

As was the case for furnace coke batteries, the marginal cost for an individual foundry coke battery is assumed to be constant reflecting a fixed-coefficient technology. Marginal cost curves were developed for all foundry coke batteries at merchant plants in the United States as detailed in Appendix B.

Foundry coke production decisions are based on the same approach used to model furnace coke production decisions. Thus, as illustrated previously in Figure A-7, the production decision is determined by an inverted L-shaped supply curve that is perfectly elastic to the capacity level of production and perfectly inelastic thereafter. Foundry coke batteries will supply 100 percent of capacity if its marginal cost is less than market price; otherwise, it will cease production. The regulatory costs shift each affected battery’s marginal cost upward, affecting facilities’ decision to operate or shut down individual batteries.

### *A.3.3.2 Market Demand for Foundry Coke*

The market demand for foundry coke, $Q^{Dk}$, is composed solely of the domestic demand by foundries operating cupola furnaces. Therefore, the foundry coke demand is derived from the production of iron castings from cupola furnaces. Increases in the price of foundry coke due to the regulation will lead to decreases in production of iron castings at foundries operating cupola furnaces. Foundries operating cupola furnaces are modeled as a single representative supplier. Thus, the demand function for foundry coke is expressed as follows:

$$Q^{Dk} = q_{CF}^{Dk} = r_{CF}^{i} \, q_{CF}^{Si} \tag{A.19}$$

where

$q_{CF}^{Dk}$ = derived demand for foundry coke from domestic cupola foundries;

$r_{CF}^{i}$ = the coke rate for cupola foundries, which specifies the amount of foundry coke input per unit output; and

$q_{CF}^{Si}$ = quantity of iron castings produced at domestic cupola foundries;

Changes in production at foundries using electric arc and electric induction furnaces to produce iron castings do not affect the demand for foundry coke.

### *A.3.4 Market for Iron Castings*

The market for iron castings consists of supply from domestic foundries and foreign imports and of demand from domestic and foreign consumers. Iron castings are modeled as a single commodity market. The domestic supply for iron castings includes production from foundries operating cupola furnaces that require foundry coke and from foundries that operate electric furnaces that do not. The proposed rule is expected to increase the price of foundry coke that will increase the cost of production at foundries with cupola furnaces and thereby shift their supply curves upward and increase the price of iron castings.

#### *A.3.4.1 Market Supply of Iron Castings*

The market supply for iron castings, $Q^{Si}$, is defined as the sum of the supply from domestic and foreign foundries. Domestic foundries are further segmented into operations using foundry coke (referred to as cupola foundries) and operations using electric furnaces (referred to as electric foundries). Supply is expressed as a function of the market price for castings:

$$Q^{Si} = q_{CF}^{Si} + q_{EF}^{Si} + q_{F}^{Si} \tag{A.20}$$

where

$q_{CF}^{Si}$ = quantity of iron castings produced at domestic cupola foundries,

$q_{EF}^{Si}$ = supply from domestic electric foundries, and

$q_{F}^{Si}$ = supply from foreign foundries.

*Domestic Cupola Foundries*. The Agency used a simple supply function (Cobb Douglas) to characterize the production of iron castings. Compliance costs on captive foundry coke batteries will directly affect cupola foundries' production decisions through the change in the market price of foundry coke. This impact is modeled as reducing the net revenue cupola foundries receive for the sales of iron castings. The aggregate cupola foundry's supply function is expressed as

$$q_{CF}^{Si} = A_{CF}^{i} \left(p^{i} - r_{CF}^{i} \, \Delta p^{k}\right)^{\xi_{CF}^{i}} \tag{A.21}$$

where

$A_{CF}^{i}$ = multiplicative supply parameter for cupola foundry's supply equation,

$r_{CF}^{i}$ = the coke rate for cupola foundries, which specifies the amount of foundry coke input per unit output,

$\Delta p^{k}$ = change in the market price for foundry coke, and

$\xi_{CF}^{i}$ = supply elasticity for iron castings (assumed value = 1).

The multiplicative supply parameter, $A_{CF}^{i}$, is determined by backsolving Eq. (A.21), given baseline values of the market price, supply elasticity, and quantity supplied.

*Domestic Electric Furnace Foundries*. The functional form of the supply curve for domestic foundries with electric arc or induction furnaces is specified as

$$q_{EF}^{Si} = A_{EF}^{i} \left(p^{i}\right)^{\xi_{EF}^{i}} \tag{A.22}$$

where

$A_{EF}^{i}$ = multiplicative parameter for electric foundries supply equation, and

$\xi^{i}_{EF}$ = electric foundries supply elasticity for iron castings (assumed value = 1).

The multiplicative supply parameter, $A^{i}_{EF}$, is determined by backsolving Eq. (A.22), given baseline values of the market price, supply elasticity, and quantity supplied from electric foundries.

*Foreign Supply (Imports).* The functional form of the foreign supply curve for iron castings is specified as

$$q^{Si}_{F} = A^{i}_{F} \, (p^{i})^{\xi^{i}_{F}} \tag{A.23}$$

where

$A^{i}_{F}$ = multiplicative parameter for foreign iron castings supply equation, and

$\xi^{i}_{F}$ = foreign supply elasticity for iron castings (assumed value = 1).

The multiplicative supply parameter, $A^{i}_{F}$, is determined by backsolving Eq. (A.23), given baseline values of the market price, supply elasticities, and level of imports.

### *A.3.4.2 Market Demand for Iron Castings*

The market demand for iron castings ($Q^{Di}$) is the sum of domestic and foreign demand, and it is expressed as a function of the price of iron castings:

$$Q^{Di} = q^{Di}_{D} + q^{Di}_{F} \tag{A.24}$$

where

$q^{Di}_{D}$ = domestic demand for iron castings, and

$q^{Di}_{F}$ = foreign demand (exports) for iron castings.

*Domestic Demand for Iron Castings.* The domestic demand for iron castings is expressed as

$$q_D^{Di} = B_D^i \, (p^i)^{\eta_D^i} \tag{A.25}$$

where

$B_D^i$ = multiplicative parameter for domestic iron castings’ demand equation, and

$\eta_D^i$ = domestic demand elasticity for steel mill products (estimate = –0.58).

The domestic demand elasticity for iron casting products is expected to be inelastic and assumed to be –0.58. The multiplicative demand parameter calibrates the domestic demand equation given baseline data on price and demand elasticity to replicate the observed 1997 level of domestic consumption.

*Foreign Demand for Iron Castings*. Foreign demand (exports) for iron castings is expressed as

$$q_F^{Di} = B_F^i \, (p^i)^{\eta_F^i} \tag{A.26}$$

where

$B_F^i$ = multiplicative demand parameter for foreign steel mill products’ demand equation, and

$\eta_F^i$ = foreign (export) demand elasticity for steel mill products (assumed value = –1).

The foreign demand elasticity for iron casting products is assumed to be –1.0, which is more elastic than the domestic demand elasticity of –0.58. The multiplicative demand parameter calibrates the foreign demand equation given data on price and demand elasticities to replicate the observed 1997 level of foreign exports.

### *A.3.5 Post-regulatory Market Equilibrium Determination*

Integrated steel mills and iron foundries with cupola furnaces must determine output given the market prices for their finished products, which in turn determines their furnace and foundry coke requirements.  The optimal output of finished steel products at integrated mills also depends on the cost of producing captive furnace coke and the market price of furnace coke; whereas iron foundries with cupolas depend on only the market price of foundry coke because they have no captive operations.  Excess production of captive furnace coke at integrated mills will spill over into the furnace coke market; whereas an excess demand will cause the mill to demand furnace coke from the market.  For merchant coke plants, the optimal market supply of furnace and/or foundry coke will be determined by the market price of each coke product.

Facility responses and market adjustments can be conceptualized as an interactive feedback process.  Facilities face increased costs from the regulation, which initially reduce output. The cumulative effect of these individual changes leads to an increase in the market price that all producers (affected and unaffected) and consumers face, which leads to further responses by producers (affected and unaffected) as well as consumers and thus new market prices, and so on.  The new equilibrium after imposing the regulation is the result of a series of iterations between producer and consumer responses and market adjustments until a stable market price arises where market supply equals market demand for each product, i.e., $Q_S = Q_D$.

The Agency employed a Walrasian auctioneer process to determine equilibrium price (and output) associated with the increased production costs of coke.  The auctioneer calls out a market price for each product and evaluates the reactions by all participants (producers and consumers), comparing total quantities supplied and demanded to determine the next price that will guide the market closer to equilibrium (i.e., where market supply equals market demand).  Decision rules are established to ensure that the process will converge to an equilibrium, in addition to specifying the conditions for equilibrium.  The result of this approach is a vector of prices with the proposed regulation that equilibrates supply and demand for each product.

The algorithm for deriving the with-regulation equilibria in all markets can be generalized to five recursive steps:

1. Impose the control costs for each affected facility, thereby affecting their supply decisions.

2. Recalculate the production decisions for coke products and both final steel mill products and iron castings across all affected facilities.  The adjusted production of steel mill products from integrated steel mills and iron castings from foundries

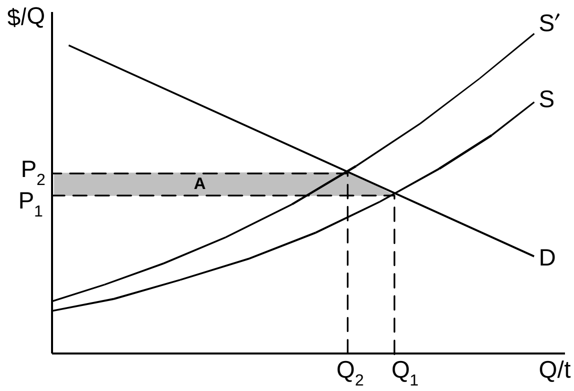
with cupola furnaces determines the derived demand for furnace and foundry coke through the input ratios.  Therefore, the domestic demand for furnace and foundry coke is simultaneously determined with the domestic supply of final steel mill products and iron castings from these suppliers.  After accounting for these adjustments, recalculate the market supply of all products by aggregating across all producers, affected and unaffected.

3. Determine the new prices via a price revision rule for all product markets.
4. Recalculate the supply functions of all facilities with the new prices, resulting in a new market supply of each product, in addition to derived (domestic) demand for furnace and foundry coke.  Evaluate domestic demand for final steel mill products and iron castings, as well as import supply and export demand for appropriate products given the new prices.
5. Go to Step #3, resulting in new prices for each product.  Repeat until equilibrium conditions are satisfied in all markets (i.e., the ratio of supply to demand is approximately one for each and every product).

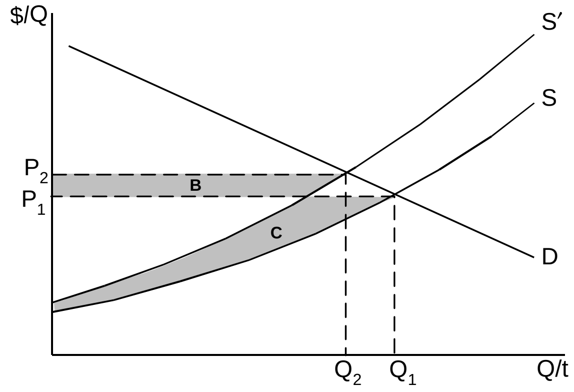
### *A.3.6 Economic Welfare Impacts*

The economic welfare implications of the market price and output changes with the regulation can be examined using two slightly different tactics, each giving a somewhat different insight but the same implications:  changes in the net benefits of consumers and producers based on the price changes and changes in the total benefits and costs of these products based on the quantity changes.  This analysis focuses on the first measure—the changes in the net benefits of consumers and producers.  Figure A-9 depicts the change in economic welfare by first measuring the change in consumer surplus and then the change in producer surplus.  In essence, the demand and supply curves previously used as predictive devices are now being used as a valuation tool.

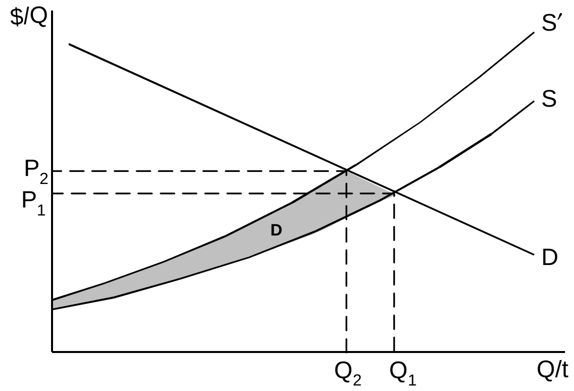
This method of estimating the change in economic welfare with the regulation divides society into consumers and producers.  In a market environment, consumers and producers of the good or service derive welfare from a market transaction.  The difference between the maximum price consumers are willing to pay for a good and the price they actually pay is referred to as “consumer surplus.”  Consumer surplus is measured as the area under the demand curve and above the price of the product.  Similarly, the difference between the minimum price producers are willing to accept for a good and the price they actually receive is referred to as “producer surplus” or profits.  Producer surplus is measured as the area above the supply curve and below the price of the product.  These areas can be thought of as



**(a) Change in Consumer Surplus with Regulation**



**(b) Change in Producer Surplus with Regulation**



**(c) Net Change in Economic Welfare with Regulation**

**Figure A-9. Economic Welfare Changes with Regulation: Consumer and Producer Surplus**

consumers' net benefits of consumption and producers' net benefits of production, respectively.

In Figure A-9, baseline equilibrium occurs at the intersection of the demand curve, D, and supply curve, S. Price is $P_l$ with quantity $Q_l$. The increased cost of production with the regulation will cause the market supply curve to shift upward to $S'$. The new equilibrium price of the product is $P_2$. With a higher price for the product, there is less consumer welfare, all else being unchanged as real incomes are reduced. In Figure A-9(a), area A represents the dollar value of the annual net loss in consumers' benefits with the increased price. The rectangular portion represents the loss in consumer surplus on the quantity still consumed, $Q_2$, while the triangular area represents the foregone surplus resulting from the reduced quantity consumed, $Q_l – Q_2$.

In addition to the changes in consumer welfare, producer welfare also changes with the regulation. With the increase in market price, producers receive higher revenues on the quantity still purchased, $Q_2$. In Figure A-9(b), area B represents the increase in revenues due to this increase in price. The difference in the area under the supply curve up to the original market price, area C, measures the loss in producer surplus, which includes the loss associated with the quantity no longer produced. The net change in producer welfare is represented by area B–C.

The change in economic welfare attributable to the compliance costs of the regulation is the sum of consumer and producer surplus changes, that is, – (A) + (B–C). Figure A-9(c) shows the net (negative) change in economic welfare associated with the regulation as area D. However, this analysis does not include the benefits that occur outside the market (i.e., the value of the reduced levels of air pollution with the regulation). Including this benefit may reduce the net cost of the regulation or even make it positive.

# APPENDIX B

# DEVELOPMENT OF COKE BATTERY COST FUNCTIONS

This appendix outlines EPA's method for estimating 1997 baseline production costs for coke batteries. The Agency used a coke production cost model developed in support of the 1993 MACT on coke ovens. EPA's *Technical Approach for a Coke Production Cost Model* (EPA, 1979) provides a more detailed description of this model. For this analysis, the model was updated with reported technical characteristics of coke batteries from the Information Collection Request (ICR) survey responses and available price data. In addition, the Agency incorporated estimates of MACT pollution abatement costs developed for the 1993 MACT on coke ovens (EPA, 1991).

## B.1 Variable Costs

Coke batteries use four variable inputs during the manufacturing process—metallurgical coal, labor, energy, and other materials/supplies. Metallurgical coal is essentially the only raw material used in the production of coke. Labor transports and delivers the raw materials as well as final products. Coke ovens and auxiliary equipment consume energy and supplies during the production process and periodic maintenance and repair of the coke batteries.

Coke production requires a fixed amount of each variable input per ton of coke, and these inputs are not substitutable. Accordingly, the total variable cost function is linear in the output and input prices, or, in other words, the average variable cost function is independent of output. Therefore, the average variable cost function (expressed in dollars per short ton of coke) can be written as

$$AVC = AV\_CI \bullet P_c + AV\_LI \bullet w + AV\_EI \bullet P_e + AV\_OI \bullet P_o \qquad (B.1)$$

where AV_CI, AV_LI, AV_EI, and AV_OI are the fixed requirements per ton of coke of metallurgical coal, labor, energy, and other material and supplies. $P_c$, w, $P_e$, and $P_o$ are the prices of each variable input, respectively. As shown above, the contribution of each variable input to the per-unit coke cost is equal to the average variable input (fixed requirement of the input per ton of coke) times the price of the input. For example, the contribution of labor to the cost per ton of coke (AV_LI) is equal to the labor requirement per ton of coke times the price of labor (w).

The variable costs above include those costs associated with by- and co-product recovery operations associated with the coke battery. To more accurately reflect the costs specific to coke production, the Agency subtracted by- and co-product revenues/credits from Eq. (B.1). By-products include tar and coke oven gas among others, while co-products include coke breeze and other industrial coke. Following the same fixed coefficient approach, these revenues or credits (expressed per ton of coke) are derived for each recovered product at the coke battery by multiplying the appropriate yield (recovered product per ton of coke) by its price or value. The variable cost components and by-/co-product credits are identified below.

### B.1.1 Metallurgical Coal (AVCI, $P_c$)

The ICR survey responses provided the fixed input requirement for metallurgical coal at each battery. Based on the responses from the survey, U.S. coke producers require an average of 1.36 tons of coal per ton of coke produced. This fixed input varies by type of producer. Integrated, or captive, producers require an average of 1.38 tons of coal per ton of coke produced, while merchant producers require an average of 1.31 tons of coal per ton of coke produced. The U.S. Department of Energy (1998b) provides state-level coal price data for metallurgical coal. For each coke battery, EPA computed the cost of coal per short ton of coke by multiplying its input ratio times the appropriate state or regional price. As shown in Table B-1, the average cost of metallurgical coal per ton of coke in 1997 was $66.27 for captive producers and $63.77 for merchant producers.

### B.1.2 Labor (AVLI, w)

The cost model provides an estimate of the fixed labor requirement for operation, maintenance, and supervision labor at each battery. The Agency used these estimates to derive the average variable labor cost for each individual battery given its technical characteristics and the appropriate state-level wage rates obtained from the U.S. Bureau of Labor Statistics (1998). As shown in Table B-2, average labor costs per ton of coke are significantly lower for captive producers (e.g., $15.74 per ton of coke) relative to merchant producers (e.g., $27.21 per ton of coke). Captive batteries are typically larger capacity batteries and therefore require fewer person-hours per ton of coke.

**Table B-1. Metallurgical Coal Costs by Producter Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average | $66.27 | $63.77 | $65.49 |
| Minimum | $59.25 | $56.18 | $56.18 |
| Maximum | $77.56 | $70.34 | $77.56 |

**Table B-2. Labor Costs by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average | $15.74 | $27.21 | $19.30 |
| Minimum | $8.62 | $10.48 | $8.62 |
| Maximum | $31.04 | $42.04 | $42.04 |

### *B.1.3 Energy (AVEI, $P_e$)*

The cost model estimates the fixed energy requirements (i.e., electricity, steam, and water) for each battery. These estimates are used to derive the energy costs per ton of coke for each battery. Captive producers have a lower electricity requirement (i.e., 47.58 kWh per ton of coke) relative to merchant producers (i.e., 50.96 kWh per ton of coke). As shown in Table B-3, the average energy cost per ton of coke across all coke batteries is $4.36. Average energy costs per ton of coke are lower for captive producers (e.g., $4.19 per ton of coke) relative to merchant producers (e.g., $4.71 per ton of coke). This difference reflects lower state/regional electricity prices in regions where captive batteries produce coke.

**Table B-3. Energy Costs by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average | $4.19 | $4.71 | $4.36 |
| Minimum | $3.00 | $3.13 | $3.00 |
| Maximum | $10.59 | $10.59 | $10.59 |

### B.1.4 Other Materials and Supplies (AVOI, $P_o$)

The fixed requirements for other materials and supplies associated with the production of coke include

- chemicals,
- maintenance materials,
- safety and clothing, and
- laboratory and miscellaneous supplies.

As shown in Table B-4, the cost model estimates the average cost for these items across all coke batteries is $4.02 per short ton of coke, ranging from $2.73 to $6.56 per ton of coke. These costs vary by producer type, with merchant producers averaging $4.82 per ton of coke versus captive producers who average $3.66 per ton of coke.

### B.1.5 By- and Co-product Credits

In addition to the variable cost inputs described above, by- and co-products are associated with the manufacture of coke products. Therefore, the Agency modified Eq. (B.1) by subtracting (1) revenues generated from the sale of by-/co-products and (2) credits associated with using of coke oven gas as an energy input in the production process. The following cost function adjustments were made to the engineering model to incorporate by- and co-products into the cokemaking cost function:

**Table B-4. Other Costs by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average | $3.66 | $4.82 | $4.02 |
| Minimum | $2.73 | $2.79 | $2.73 |
| Maximum | $5.70 | $6.56 | $6.56 |

- Coke breeze—ICR survey responses provided coke breeze output per ton of coke for each battery. The U.S. International Trade Commission (1994) provided data on market prices of coke breeze.

- Other industrial coke—ICR survey responses provided other industrial coke output per ton of coke for each battery. The U.S. International Trade Commission (1994) provided data on market prices of other industrial coke.

- Coke oven gas—Based on secondary sources and discussions with engineers, furnace coke producers were assumed to produce 8,500 $ft^3$ per ton of coal, and foundry producers were assumed to produce 11,700 $ft^3$ per ton of coal (Lankford et al., 1985; EPA, 1988).

As shown in Table B-5, the average by-/co-product credit is $16.55 per ton of coke for captive producers and $21.31 per ton of coke for merchant producers.

## B.2 MACT/LAER Pollution Abatement Costs

The 1990 Clean Air Act Amendments mandated two levels of control for emissions from coke ovens. The first control level, referred to as MACT, specified limits for leaking doors, lids, offtakes, and time of charge. This level of control was to be attained by 1995. The second level of control, Lowest Achievable Emissions Rate (LAER), specified more stringent limits for leaking doors and offtakes. Estimates of the MACT and LAER costs associated with these controls were developed for EPA's *Controlling Emissions from By-Product Coke Oven Charging, Door Leaks, and Topside Leaks: An Economic Impacts*

**Table B-5. By-/Co-Product Credits by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average | $16.55 | $21.31 | $18.03 |
| Minimum | $13.41 | $8.83 | $8.83 |
| Maximum | $30.95 | $48.30 | $48.30 |

*Analysis* (EPA, 1991).[1] Table B-6 provides summary statistics for the projected costs associated with each level of control. However, the Agency determined that industry actions undertaken in the interim period to comply with the MACT limits have enabled them to also meet the LAER limits. Therefore, only the MACT-related pollution abatement costs have been incorporated to determine the appropriate baseline costs for the 1997 economic model. As shown in Table B-6, the average MACT pollution abatement cost across all coke batteries is $1.27 per short ton of coke. The projected costs for captive producers range from zero to $2.54 per ton of coke, while projected costs for merchant producers range from zero to $10.93 per ton of coke.

## B.3 Fixed Costs

Production of coke requires the combination of variable inputs outlined above with fixed capital equipment (e.g., coke ovens and auxiliary equipment). It also includes other overhead and administrative expenses. For each coke battery, the average fixed costs per ton of coke can be obtained by dividing the total fixed costs (TFC) estimated by the coke model by total battery coke production. Therefore, the average fixed cost function (expressed in dollars per ton of coke) can be written as

$$AFC = (PTI + ASE + PYOH + PLOH)/Q \tag{B.2}$$

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[1] The Agency estimated costs for the LAER control level using two scenarios. The first (LAER-MIN) assumed all batteries will require new doors and jambs. The second (LAER-MAX) also assumed all batteries will require new doors and jambs and in addition assumed batteries with the most serious door leak problems would be rebuilt. This analysis reports cost estimates for the LAER-MIN scenario.

**Table B-6. Pollution Abatement Costs by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| MACT | | | |
| Average | $0.82 | $2.29 | $1.27 |
| Minimum | $0.00 | $0.00 | $0.00 |
| Maximum | $2.54 | $10.93 | $10.93 |
| LAER | | | |
| Average | $1.64 | $2.44 | $1.88 |
| Minimum | $0.07 | $0.94 | $0.07 |
| Maximum | $2.63 | $6.07 | $6.07 |

where

- property taxes and insurance (PTI) = (0.02)•($225•Coke Capacity). This category accounts for the fixed costs associated with property taxes and insurance for the battery. The cost model estimates this component as 2 percent of capital cost. Capital costs are estimated to be $225 per annual short ton of capacity based on reported estimates of capital investment cost of a rebuilt by-product coke-making facility (USITC, 1994). As shown in Table B-7, the average PTI cost across all batteries is $4.47 per ton of coke.

- administration and sales expense (ASE) = (0.02)•($225•Coke capacity). This category accounts for the fixed costs associated with administrative and sales expenses for the coke battery. The cost model also calculates this component as 2 percent of capital cost. As shown in Table B-7, the average cost across all coke batteries for ASE is $5.02 per ton of coke.

- payroll overhead (PYOH) = (0.2)•(Total labor costs). Payroll overhead is modified as 20 percent of total labor costs. Payroll overhead is used to capture fringe benefits because wage rates obtained from the Bureau of Labor Statistics exclude fringe benefits. As shown in Table B-7, the average payroll overhead is $3.15 per ton of coke for captive producers and $5.44 per ton of coke for merchant producers, reflecting the different labor requirements by producer type.

**Table B-7. Average Fixed Costs by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Property taxes and insurance | | | |
| Average | $4.41 | $4.58 | $4.47 |
| Minimum | $3.20 | $3.55 | $3.20 |
| Maximum | $6.78 | $6.11 | $6.78 |
| Administrative and sales expense | | | |
| Average | $4.96 | $5.16 | $5.02 |
| Minimum | $3.60 | $4.00 | $3.60 |
| Maximum | $7.63 | $6.87 | $7.63 |
| Payroll overhead | | | |
| Average | $3.15 | $5.44 | $3.86 |
| Minimum | $1.72 | $2.10 | $1.72 |
| Maximum | $6.21 | $8.41 | $8.41 |
| Plant overhead | | | |
| Average | $9.33 | $17.77 | $11.95 |
| Minimum | $5.38 | $7.50 | $5.38 |
| Maximum | $17.67 | $26.95 | $26.95 |

- plant overhead (PLOH) = (0.5)•(Total payroll + Total other expenses). The cost model computes plant overhead as 50 percent of total payroll and total other expenses by producer type. As shown in Table B-7, the average plant overhead cost is $9.33 for captive producers and $17.77 for merchant producers. As with payroll overhead, this difference reflects differences in labor requirements for captive and merchant producers.

## B.5 Summary of Results

Table B-8 summarizes each cost component and aggregates them to estimate the average total costs per ton of coke by producer type. As shown, the average total cost (ATC) across all coke batteries is $101.72 per short ton of coke. The ATC for captive producers is $95.99 per short ton of coke and is significantly lower than the ATC for merchant producers

**Table B-8. Cost Summary by Producer Type: 1997 ($/ton of coke)**

| | Captive | Merchant | All Coke Batteries |
|---|---|---|---|
| Number of batteries | 40 | 18 | 58 |
| Average variable cost[a] | | | |
| Average | $73.32 | $79.21 | $75.15 |
| Minimum | $62.09 | $44.91 | $44.91 |
| Maximum | $82.74 | $95.43 | $95.43 |
| MACT | | | |
| Average | $0.82 | $2.29 | $1.27 |
| Minimum | $0.00 | $0.00 | $0.00 |
| Maximum | $2.54 | $10.93 | $10.93 |
| Average fixed cost | | | |
| Average | $21.85 | $32.96 | $25.30 |
| Minimum | $15.03 | $17.37 | $15.03 |
| Maximum | $38.28 | $46.16 | $46.16 |
| Average total cost | | | |
| Average | $95.99 | $114.47 | $101.72 |
| Minimum | $77.42 | $76.97 | $76.97 |
| Maximum | $119.72 | $145.02 | $145.02 |

[a] Includes by-/co-product credits.

at $114.47. This difference reflects both economies of scale and lower production costs associated with the production of furnace coke. These differences are also consistent with observed market prices for furnace coke $71–$114 (produced mainly by captive producers) and for foundry coke $148–$154 (produced solely by merchant producers with some furnace coke) (USITC, 1994). A correlation analysis of these cost estimates shows that ATC is negatively correlated with coke battery capacity (correlation coefficient of -0.66) and start/rebuild date (correlation coefficient of -0.36). Therefore, average total costs are lower for larger coke batteries and those that are new or recently rebuilt. Tables B-A and B-B, at the end of this appendix, present cost estimates for individual captive and merchant coke batteries, respectively.

## B.6 Nonrecovery Cokemaking

Several substitute technologies for by-product cokemaking have been developed in the United States and abroad. In the United States, the nonrecovery method is the only substitute that has a significant share of the coke market. This technology is relatively new, and, as a result, the original coke production cost model did not include estimates for these types of coke-making batteries. The nonrecovery process is less costly than the by-product process because of the absence of recovery operations and a lower labor input requirement per ton of coke. Therefore, the Agency modified the model to reflect these cost advantages in the following manner:

- No expenses/credits associated with by- and co-product recovery.
- Reduced labor input—labor requirement estimates generated by the model were multiplied by a factor of 0.11, which represents the ratio of employment per ton of coke at merchant batteries to employment per ton of coke at nonrecovery batteries.
- Exceed current standards of pollution abatement (*Engineering and Mining Journal*, 1997)—MACT compliance costs were excluded.

As shown in Table B-9, the ATC for nonrecovery coke-making facilities is $71.28 per ton of coke, which is significantly lower than the average ATC of captive and merchant producers. These costs vary slightly across these batteries ranging from $68.49 to $72.88 per ton of coke. Table B-C, at the end of this appendix, presents cost estimates for individual nonrecovery cokemaking batteries.

**Table B-9. Cost Summary for Nonrecovery Coke Batteries: 1997 ($/ton of coke)**

| | Nonrecovery |
|---|---|
| Number of batteries | 8 |
| Metallurgical coal | |
| Average | $52.03 |
| Minimum | $50.38 |
| Maximum | $53.67 |
| Labor | |
| Average | $1.90 |
| Minimum | $1.31 |
| Maximum | $2.39 |
| Energy | |
| Average | $5.17 |
| Minimum | $5.01 |
| Maximum | $5.38 |
| Other | |
| Average | $1.74 |
| Minimum | $1.63 |
| Maximum | $1.82 |
| Average fixed cost | |
| Average | $10.45 |
| Minimum | $9.90 |
| Maximum | $10.85 |
| Average total cost | |
| Average | $71.28 |
| Minimum | $68.49 |
| Maximum | $72.88 |

## Table B-A. Cost Data Summary for Captive Coke Batteries: 1997

| Facility Name | Location | Producer Type[a] | Coke Type[b] | Capacity (short tons/yr) | Start/ Rebuild Date | AVC[c] ($/short ton) | MACT ($/short ton) | AFC ($/short ton) | ATC ($/short ton) |
|---|---|---|---|---|---|---|---|---|---|
| Acme Steel | Chicago, IL | C | 1 | 250,000 | 1979 | $80.49 | $1.00 | $20.15 | $101.64 |
| Acme Steel | Chicago, IL | C | 1 | 250,000 | 1978 | $80.49 | $1.00 | $20.15 | $101.64 |
| AK Steel | Ashland, KY | C | 1 | 634,000 | 1978 | $71.63 | $1.26 | $18.63 | $91.52 |
| AK Steel | Ashland, KY | C | 1 | 366,000 | 1953 | $73.79 | $1.00 | $20.83 | $95.62 |
| AK Steel | Middletown, OH | C | 1 | 429,901 | 1952 | $75.09 | $1.21 | $22.12 | $98.42 |
| Bethlehem Steel | Burns Harbor, IN | C | 1 | 948,000 | 1972 | $64.93 | $0.71 | $17.57 | $83.22 |
| Bethlehem Steel | Burns Harbor, IN | C | 1 | 929,000 | 1983 | $65.27 | $0.70 | $18.13 | $84.10 |
| Bethlehem Steel | Lackawanna, NY | C | 1 | 375,000 | 1962 | $71.46 | $1.75 | $20.40 | $93.61 |
| Bethlehem Steel | Lackawanna, NY | C | 1 | 375,000 | 1952 | $71.45 | $1.79 | $20.22 | $93.46 |
| Geneva Steel | Provo, UT | C | 1 | 200,000 | 1944 | $77.36 | $0.26 | $24.84 | $102.46 |
| Geneva Steel | Provo, UT | C | 1 | 200,000 | 1944 | $77.97 | $0.26 | $26.85 | $105.08 |
| Geneva Steel | Provo, UT | C | 1 | 200,000 | 1944 | $78.24 | $0.22 | $22.85 | $101.31 |
| Geneva Steel | Provo, UT | C | 1 | 200,000 | 1944 | $81.21 | $0.22 | $38.28 | $119.72 |
| Gulf States Steel | Gadsden, AL | C | 1 | 250,000 | 1942 | $82.74 | $1.68 | $26.63 | $111.05 |
| Gulf States Steel | Gadsden, AL | C | 1 | 250,000 | 1965 | $81.56 | $2.54 | $18.77 | $102.86 |
| LTV Steel | Chicago, IL | C | 1 | 615,000 | 1982 | $69.02 | $0.35 | $17.96 | $87.33 |
| LTV Steel | Warren, OH | C | 1 | 549,000 | 1979 | $69.05 | $0.04 | $20.79 | $89.88 |
| National Steel | Ecorse, MI | C | 1 | 924,839 | 1992 | $80.77 | $0.26 | $16.56 | $97.59 |
| National Steel | Granite City, IL | C | 1 | 300,931 | 1982 | $75.74 | $0.67 | $20.72 | $97.13 |
| National Steel | Granite City, IL | C | 1 | 300,931 | 1980 | $75.74 | $0.67 | $20.72 | $97.13 |

(continued)

## Table B-A. Cost Data Summary for Captive Coke Batteries: 1997 (continued)

| Facility Name | Location | Producer Type[a] | Coke Type[b] | Capacity (short tons/yr) | Start/ Rebuild Date | AVC[c] ($/short ton) | MACT ($/short ton) | AFC ($/short ton) | ATC ($/short ton) |
|---|---|---|---|---|---|---|---|---|---|
| USX | Clairton, PA | C | 1 | 844,610 | 1982 | $64.94 | $0.71 | $15.28 | $80.92 |
| USX | Clairton, PA | C | 1 | 668,680 | 1976 | $65.89 | $0.00 | $19.72 | $85.61 |
| USX | Clairton, PA | C | 1 | 668,680 | 1978 | $65.89 | $0.00 | $19.72 | $85.61 |
| USX | Clairton, PA | C | 1 | 373,395 | 1989 | $68.36 | $0.00 | $20.96 | $89.32 |
| USX | Clairton, PA | C | 1 | 373,395 | 1989 | $68.36 | $0.00 | $20.96 | $89.32 |
| USX | Clairton, PA | C | 1 | 373,395 | 1979 | $68.36 | $1.02 | $20.96 | $90.34 |
| USX | Clairton, PA | C | 1 | 378,505 | 1955 | $70.52 | $1.02 | $21.96 | $93.50 |
| USX | Clairton, PA | C | 1 | 378,505 | 1955 | $70.52 | $1.07 | $21.96 | $93.55 |
| USX | Clairton, PA | C | 1 | 378,505 | 1955 | $70.52 | $1.07 | $21.96 | $93.55 |
| USX | Clairton, PA | C | 1 | 378,505 | 1954 | $71.75 | $1.07 | $21.69 | $94.51 |
| USX | Clairton, PA | C | 1 | 378,505 | 1954 | $71.75 | $1.02 | $21.69 | $94.46 |
| USX | Clairton, PA | C | 1 | 378,505 | 1954 | $71.75 | $0.00 | $21.69 | $93.44 |
| USX | Gary, IN | C | 1 | 827,820 | 1976 | $73.33 | $0.64 | $22.55 | $96.52 |
| USX | Gary, IN | C | 1 | 827,820 | 1975 | $74.13 | $0.64 | $21.93 | $96.70 |
| USX | Gary, IN | C | 1 | 297,110 | 1954 | $79.40 | $1.48 | $23.84 | $104.72 |
| USX | Gary, IN | C | 1 | 297,110 | 1954 | $79.68 | $1.48 | $24.98 | $106.14 |
| Wheeling-Pitt | Follansbee, WV | C | 1 | 782,000 | 1977 | $62.09 | $0.30 | $15.03 | $77.42 |
| Wheeling-Pitt | Follansbee, WV | C | 1 | 163,000 | 1964 | $76.53 | $1.33 | $28.51 | $106.37 |
| Wheeling-Pitt | Follansbee, WV | C | 1 | 151,000 | 1955 | $77.49 | $1.09 | $27.79 | $106.37 |
| Wheeling-Pitt | Follansbee, WV | C | 1 | 151,000 | 1953 | $77.49 | $1.09 | $27.79 | $106.38 |

[a] C = Captive; M = Merchant.

[b] 1 = Furnace; 2 = Foundry; 3 = Both.

## Table B-B. Cost Data Summary for Merchant Coke Batteries: 1997

| Facility Name | Location | Producer Type[a] | Coke Type[b] | Capacity (short tons/yr) | Start/ Rebuild Date | AVC[c] ($/short ton) | MACT ($/short ton) | AFC ($/short ton) | ATC ($/short ton) |
|---|---|---|---|---|---|---|---|---|---|
| ABC Coke | Tarrant, AL | M | 2 | 490,528 | 1968 | $72.41 | $1.20 | $17.37 | $90.99 |
| ABC Coke | Tarrant, AL | M | 3 | 112,477 | 1951 | $86.96 | $2.64 | $31.18 | $117.48 |
| ABC Coke | Tarrant, AL | M | 3 | 96,962 | 1941 | $91.22 | $2.51 | $34.63 | $125.02 |
| Citizens Gas | Indianapolis, IN | M | 3 | 389,116 | 1979 | $58.28 | $1.03 | $20.19 | $76.97 |
| Citizens Gas | Indianapolis, IN | M | 2 | 128,970 | 1946 | $80.97 | $1.98 | $41.91 | $124.85 |
| Citizens Gas | Indianapolis, IN | M | 2 | 116,845 | 1941 | $85.88 | $2.09 | $46.16 | $134.12 |
| Empire Coke | Holt, AL | M | 2 | 108,026 | 1978 | $93.33 | $7.24 | $36.59 | $137.16 |
| Empire Coke | Holt, AL | M | 2 | 54,013 | 1978 | $95.13 | $10.93 | $38.96 | $145.02 |
| Erie Coke | Erie, PA | M | 2 | 130,073 | 1943 | $76.52 | $1.70 | $44.67 | $122.88 |
| Erie Coke | Erie, PA | M | 2 | 84,878 | 1952 | $77.73 | $1.45 | $46.00 | $125.18 |
| Koppers | Monessen, PA | M | 1 | 245,815 | 1981 | $87.77 | $0.12 | $28.92 | $113.16 |
| Koppers | Monessen, PA | M | 1 | 126,766 | 1980 | $99.08 | $0.35 | $37.76 | $133.55 |
| New Boston | Portsmouth, OH | M | 1 | 346,126 | 1964 | $83.67 | $1.32 | $25.86 | $107.02 |
| Shenango | Pittsburgh, PA | M | 1 | 514,779 | 1983 | $84.44 | $0.00 | $27.30 | $108.16 |
| Sloss Industries | Birmingham, AL | M | 3 | 184,086 | 1959 | $62.04 | $1.58 | $24.69 | $84.77 |
| Sloss Industries | Birmingham, AL | M | 1 | 133,931 | 1952 | $90.33 | $1.58 | $29.16 | $117.35 |
| Sloss Industries | Birmingham, AL | M | 1 | 133,931 | 1956 | $90.33 | $1.58 | $29.16 | $117.35 |
| Tonawanda | Buffalo, NY | M | 2 | 268,964 | 1962 | $44.91 | $1.99 | $32.30 | $79.20 |

[a] C = Captive; M = Merchant.

[b] 1 = Furnace; 2 = Foundry; 3 = Both.

## Table B-C. Cost Data Summary for Nonrecovery Coke Batteries: 1997

| Facility Name | Location | Producer Type[a] | Coke Type[b] | Capacity (short tons/yr) | Start/ Rebuild Date | AVC[c] ($/short ton) | MACT ($/short ton) | AFC ($/short ton) | ATC ($/short ton) |
|---|---|---|---|---|---|---|---|---|---|
| Jewell Coke and Coal | Vansant, VA | M | 1 | 197,000 | 1966 | $58.59 | $0.00 | $9.90 | $68.49 |
| Jewell Coke and Coal | Vansant, VA | M | 1 | 164,000 | 1983 | $59.31 | $0.00 | $10.38 | $69.69 |
| Jewell Coke and Coal | Vansant, VA | M | 1 | 124,000 | 1989 | $59.98 | $0.00 | $10.85 | $70.83 |
| Jewell Coke and Coal | Vansant, VA | M | 1 | 164,000 | 1990 | $59.31 | $0.00 | $10.38 | $69.69 |
| Indiana Harbor Coke Co | East Chicago, IN | M | 1 | 325,000 | 1998 | $62.36 | $0.00 | $10.52 | $72.88 |
| Indiana Harbor Coke Co | East Chicago, IN | M | 1 | 325,000 | 1998 | $62.36 | $0.00 | $10.52 | $72.88 |
| Indiana Harbor Coke Co | East Chicago, IN | M | 1 | 325,000 | 1998 | $62.36 | $0.00 | $10.52 | $72.88 |
| Indiana Harbor Coke Co | East Chicago, IN | M | 1 | 325,000 | 1998 | $62.36 | $0.00 | $10.52 | $72.88 |

[a] C = Captive; M = Merchant.

[b] 1 = Furnace; 2 = Foundry; 3 = Both.

[c] Includes by-/co-product credits.

# APPENDIX C

# ECONOMETRIC ESTIMATION OF THE DEMAND ELASTICITY FOR STEEL MILL PRODUCTS

This appendix summarizes EPA's estimation of the demand elasticities for steel mill products. These estimates are based on national-level data from 1987 through 1997 as obtained from the AISI (1990, 1992, 1997), U.S. Bureau of the Census (1988-1998, 1997, 1998), U.S. Bureau of Labor Statistics (1998), and other government sources (U.S. Department of Energy, 1990, 1998 and U.S. Geological Survey 1987-1990, 1995-1997). The following sections summarize the econometric procedure and present the estimates of the demand elasticity for the following nine steel mill products:

- semi-finished products
- structural shapes and plates
- rails and track accessories
- bars
- tool steel
- pipe and tubing
- wire
- tin mill
- sheet and strip

## C.1 Econometric Model

A partial equilibrium market supply/demand model is specified as a system of interdependent equations in which the price and output of a product are simultaneously determined by the interaction of producers and consumers in the market. In simultaneous equation models, where variables in one equation feed back into variables in other equations, the error terms are correlated with the endogenous variables (price and output). In this case, single-equation ordinary least squares (OLS) estimation of individual equations will lead to biased and inconsistent parameter estimates. Thus, simultaneous estimation of this system to obtain elasticity estimates requires that each equation be identified through the inclusion of exogenous variables to control for shifts in the supply and demand curves over time.

Exogenous variables influencing the demand for steel mill products include measures of economic activity such as U.S. gross national and domestic production and the value of construction activity, and the price of substitute products such as aluminum, plastics and other nonferrous materials and building materials like cement/concrete (typically proxied by the appropriate producer price indices). Exogenous variables influencing the level of supply include measures of the change in the costs of iron and steel production caused by changes in prices of key inputs like raw materials, fuel, and labor (typically proxied by the producer price index for iron ore, coke, metallurgical coal, as well as the average hourly earnings for the industry's production workers).

The supply/demand system for a particular steel mill product over time (t) is defined as follows:

$$Q_t^d = f(P_t,Z_t) + u_t \tag{C.1}$$

$$Q_t^s = g(P_t,W_t) + v_t \tag{C.2}$$

$$Q_t^d = Q_t^s \tag{C.3}$$

Eq. (C.1) shows quantity demanded in year t as a function of price, $P_t$, an array of demand factors, $Z_t$ (e.g., measures of economic activity and substitute prices), and an error term, $u_t$. Eq. (C.2) represents quantity supplied in year t as a function of price and other supply factors, $W_t$ (e.g., input prices), and an error term, $v_t$, while Eq. (C.3) specifies the equilibrium condition that quantity supplied equals quantity demanded in year t, creating a system of three equations in three variables. The interaction of the specified market forces solves this system, generating equilibrium values for the variables $P_t^*$ and $Q_t^*=Q_t^{d*}=Q_t^{s*}$.

Since the objective is to generate estimates of the demand elasticities for use in the economic model, EPA employed the two-stage least squares (2SLS) regression procedure to estimate only the parameters of the demand equation. This 2SLS approach is preferred to the three-stage least squares approach because the number of observations limits the degrees of freedom for use in the estimation procedure. EPA specified the logarithm of the quantity demanded as a linear function of the logarithm of the price so that the coefficient on the price variable yields the estimate of the constant elasticity of demand for steel mill product. All prices employed in the estimation process were deflated by the gross domestic product (GDP) implicit price deflator to reflect real rather than nominal prices. The first stage of the 2SLS procedure involves regressing the observed price against the supply and demand "shifter" variables that are exogenous to the system. This first stage produces fitted (or predicted) values for the price variable that are, by definition, highly correlated with the true endogenous variable, the observed price, and uncorrelated with the error term. In the second stage, these fitted values are then employed as observations of the right-hand side price variable in the demand function. This fitted value is uncorrelated with the error term by construction and thus does not incur the endogeneity bias.

## C.2 Econometric Results

Table C-1 provides the results of the econometric estimation for each steel mill product demand equation. The coefficients of the price variables represent the demand elasticity estimates for each of the nine steel mill products. As economic theory predicts, all of these estimates are negative, reflecting reductions in quantity demanded as price increases. The elasticities range from –0.16 for semi-finished products to –2.17 for rails and track accessories, with a shipments weighted average elasticity for all products of –0.59. As shown, three of the nine elasticity estimates are significant at a 90 percent confidence level.

As expected, the estimated coefficients for the demand growth variables (GDP and value of new construction) are all positive with the exception of the equation for steel wire drawn products. However, this estimate is not statistically significant. The regression coefficient results generally show that the price of aluminum, nonferrous metals' producer price index (PPI), and plastics' PPI are substitutes for the majority of the steel mill products. Prices increases for these products result in increases in quantity demand for steel mill products. The coefficient for the primary copper PPI is negative in the wire equation indicating that it is a complement. A price increase for this product decreases wire consumption. Copper and steel are both used in electric appliances; therefore, this is consistent with these results. The regressions also show a negative coefficient for the price of aluminum in the semi-finished products equation, the nonferrous metals' PPI in the tin mill products equation, and the concrete products' PPI in the structural shapes and plates equation suggesting these products are also complement products. Although these products may be

## Table C-1. Two Stage Least Squares Regression Estimation of Steel Mill Products Demand Equations

| | Dependent Variables (ln $Q^d$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Independent Variables** | **Semi-finished Products** | **Structural Shapes and Plates** | **Rails and Track Accessories** | **Bars** | **Tool Steel** | **Pipe and Tubing** | **Wire** | **Tin Mill Products** | **Sheet and Strip** |
| Constant | 3.42 | 11.24 | 1.26 | 6.56 | 2.06 | 14.41 | 22.5 | 3.66 | 6.14 |
| | (1.47) | (1.93) | (0.27) | (1.71) | (0.31) | (1.11) | (1.14) | (0.61) | (0.61) |
| ln(price)[a] | –0.16 | –0.17 | –2.17 | –0.66 | –0.47 | –1.62 | –0.73 | –0.28 | –0.65 |
| | (–1.39) | (–0.71) | (–1.95)* | (–1.17) | (–2.02)* | (–2.14)* | (–2.05) | (–1.61) | (–1.90) |
| ln(gdp) | 1.52 | 1.20 | 2.95 | 1.61 | — | — | –1.13 | 1.41 | 1.92 |
| | (4.64)*** | (4.00)** | (4.96)*** | (6.08)*** | | | (–0.55) | (2.32)* | (2.59)** |
| ln(value_new_construct) | — | — | — | — | 0.98 | 0.13 | — | — | — |
| | | | | | (1.84) | (0.18) | | | |
| ln(alum_price) | –0.20 | — | 0.08 | 0.27 | 0.09 | — | — | — | 0.12 |
| | (–2.75)** | | (0.69) | (2.67)** | (0.52) | | | | (1.18) |
| ln(PPI_nonferrmetals) | — | 0.69 | — | — | — | — | | –0.15 | — |
| | | (1.66) | | | | | | (–1.59) | |
| ln(PPI_plast_parts_mfg) | — | — | — | — | — | — | — | 0.39 | –0.26 |
| | | | | | | | | (1.23) | (–0.29) |
| ln(PPI_plast_sh_rd_tube) | — | — | — | — | — | 2.09 | — | — | — |
| | | | | | | (0.90) | | | |
| ln(PPI_copper_prim) | — | — | — | — | — | — | –0.50 | — | — |
| | | | | | | | (–2.90)** | | |
| ln(PPI_conc_prod) | — | –1.59 | — | — | — | — | — | — | — |
| | | (–1.25) | | | | | | | |
| ln(PPI_plast_prod) | — | — | — | — | — | — | 1.78 | — | — |
| | | | | | | | (2.46)* | | |
| Time trend squared | — | — | — | — | — | — | –0.002 | –0.002 | — |
| | | | | | | | (–0.54) | (–2.37)* | |

(continued)

### Table C-1.  Two Stage Least Squares Regression Estimation of Steel Mill Products Demand Equations (Continued)

| | Dependent Variables ($\ln Q^d$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Independent Variables** | **Semi-finished Products** | **Structural Shapes and Plates** | **Rails and Track Accessories** | **Bars** | **Tool Steel** | **Pipe and Tubing** | **Wire** | **Tin Mill Products** | **Sheet and Strip** |
| R-Squared | 0.90 | 0.81 | 0.82 | 0.84 | 0.44 | 0.51 | 0.98 | 0.57 | 0.93 |
| Adjusted R-Squared | 0.86 | 0.65 | 0.75 | 0.77 | 0.20 | 0.30 | 0.96 | 0.14 | 0.88 |
| F value | 21.44*** | 5.26** | 10.87*** | 12.32*** | 1.85 | 2.41 | 42.23*** | 1.31 | 17.47*** |
| Observations | 11 | 10 | 11 | 11 | 11 | 11 | 10 | 11 | 10 |
| Degrees of Freedom | 7 | 5 | 7 | 7 | 7 | 7 | 4 | 5 | 5 |

Note:  T-statistics of parameter estimates are in parenthesis.  The F test analyzes the usefulness of the model.  Asterisks indicate significance levels for these tests as follows:

* = 90%, ** = 95%, *** = 99%

[a] Price of corresponding steel mill product.

Variable Descriptions:

| | |
|---|---|
| ln(gdp) | real gross domestic product |
| ln(value_new_construct) | real value of construction put in place |
| ln(alum_price) | real price of aluminum |
| ln(PPI_nonferrmetals) | real producer price index for nonferrous metals |
| ln(PPI_plast_parts_mfg) | real producer price index for plastic parts and components for manufacturing |
| ln(PPI_plast_sh_rd_tube) | real producer price index for laminated plastic sheets, rods, and tubes |
| ln(PPI_copper_prim) | real producer price index for primary copper |
| ln(PPI_conc_prod) | real producer price index for concrete products |
| ln(PPI_plast_prod) | real producer price index for plastic products |
| time trend squared | time trend squared |

substitutes in specific applications, they are often complement products in the production of final goods (i.e., building construction).

As a result of these econometric findings, the market model used the weighted average demand elasticity of –0.59.

# APPENDIX D

# JOINT ECONOMIC IMPACT ANALYSIS OF THE INTEGRATED IRON AND STEEL MACT STANDARD WITH THE COKE MACT STANDARD

For this analysis, the Agency also considered the national-level economic impacts of joint implementation of the Integrated Iron and Steel MACT Standard with the Coke MACT standard. The measures of economic impacts presented in this appendix are the result of incorporating the costs of compliance for each affected integrated iron and steel mill under the Integrated Iron and Steel MACT into market models developed by the Agency to analyze the economic impacts of the Coke MACT Standard. The engineering analysis estimates annual costs for existing sources are $5.9 million under the Integrated Iron and Steel MACT and $14.3 million under the Coke MACT. Therefore, the total national estimate for existing sources under joint implementation are $20.2 million.

## D.1 Market-Level Impacts

The increased cost of coke production due to the regulation is expected to increase the price of coke, steel mill products, and iron castings and reduce their production and consumption from 1997 baseline levels. As shown in Table D-1, the regulation is projected to increase the price of furnace coke by 1.5 percent, or $1.56 per short ton, and the price of foundry coke by nearly 3 percent, or $4.17 per short ton. The increased captive production costs and higher market price associated with furnace coke are projected to increase steel mill product prices by less than 0.1 percent, or $0.14 per ton. Similarly, the higher market price of foundry coke are projected to increase iron castings prices by less than 0.1 percent, or $0.35 per ton. As expected, directly affected output declines across all producers, while supply from domestic and foreign producers not subject to the regulation increases. Although the resulting net declines are slight across all products (i.e., roughly 0.1 percent decline in market output) the change in domestic production are typically higher. This is especially true for furnace coke where domestic production declines by 2.25 percent.

## Table D-1. Market-Level Impacts of the Joint Implementation of the Integrated Iron and Steel MACT with the Coke MACT: 1997

| | | Changes From Baseline | |
|---|---|---|---|
| | Baseline | Absolute | Percent |
| **Furnace Coke** | | | |
| Market price ($/short ton) | $107.36 | $1.56 | 1.46% |
| Market output ($10^3$ tpy) | 11,710 | –11.9 | –0.10% |
| Domestic production | 7,944 | –178.8 | –2.25% |
| Imports | 3,765 | 166.9 | 4.43% |
| **Foundry Coke** | | | |
| Market price ($/short ton) | $145.02 | $4.17 | 2.87% |
| Market output ($10^3$ tpy) | 1,669 | –1.4 | –0.08% |
| Domestic production | 1,669 | –1.4 | –0.08% |
| Imports | NA | NA | NA |
| **Steel Mill Products** | | | |
| Market price ($/short ton) | $639.74 | $0.14 | 0.02% |
| Market output ($10^3$ tpy) | 137,015 | –17.6 | –0.01% |
| Domestic production | 105,858 | –24.2 | –0.02% |
| Integrated producers | 62,083 | –33.4 | –0.05% |
| Nonintegrated steel mills[a] | 43,775 | 9.2 | 0.02% |
| Imports | 31,157 | 6.6 | 0.02% |
| **Iron Castings** | | | |
| Market price ($/short ton) | $845.55 | $0.35 | 0.04% |
| Market output ($10^3$ tpy) | 12,314 | –3.1 | –0.03% |
| Domestic production | 11,483 | –3.4 | –0.03% |
| Cupola furnaces | 6,695 | –5.4 | –0.08% |
| Electric furnaces[b] | 4,789 | 2.0 | 0.04% |
| Imports | 831 | 0.3 | 0.04% |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

## D.2 Industry-Level Impacts

Industry revenue, costs, and profitability change as prices and production levels adjust to increased production costs. As shown in Table D-2, the economic model projects that profits for directly affected integrated iron and steel producers will decrease by $15.9 million, or 1.2 percent. In addition, the Agency projects profit losses of $4.6 million for foundries that produce iron casting with cupola furnaces. However, because integrated steel mills reduce their captive production of furnace coke and purchase more through the market, industry-level profits for U.S. merchant coke producers are expected to increase by $2.7 million, or 5.6 percent, for furnace coke. Similarly, because foundries with cupola furnaces must continue to buy foundry coke to produce iron castings (i.e., inelastic demand), industry-level profits for U.S. merchant coke producers are expected to increase by $3.9 million, or 5.0 percent, for foundry coke. Those domestic suppliers not subject to the regulation experience windfall gains with non-integrated steel mills (i.e., mini-mills) increasing profits by $5.9 million and foundries with electric furnaces increasing profits by $1.7 million.

### *D.2.1 Changes in Profitability*

For integrated steel mills, operating profits decline by $15.9 million. This is the net result of three effects:

- Net decrease in revenue ($11.7 million): Steel mill product revenue decreases as a result of reductions in output. However, these losses were mitigated by increased revenues from furnace coke supplied to the market as a result of higher prices.

- Net decrease in production costs ($10.2 million): Reduction in steel mill and market coke production costs occur as output declines. However, producers also experience increases in costs associated with the higher price of inputs (i.e., furnace coke).

- Increase in control costs ($14.4 million): The costs of captive production of furnace coke increase as a result of regulatory controls.

Industry-wide profits for merchant furnace coke producers increase by $2.7 million as a result of the following:

- Decreases in revenue ($10 million): Reductions in output outweigh revenue increases as a result of higher market prices.

## Table D-2. National-Level Industry Impacts of the Joint Implementation of the Integrated Iron and Steel MACT with the Coke MACT: 1997

| | | Changes From Baseline | |
|---|---|---|---|
| | Baseline | Absolute | Percent |
| **Integrated Iron and Steel Mills** | | | |
| Total revenues ($\$10^6$/yr) | $40,223.9 | –$11.71 | –0.03% |
| Steel mill products | $39,716.9 | –$12.99 | –0.03% |
| Market coke operations | $507.0 | $1.29 | 0.25% |
| Total costs ($\$10^6$/yr) | $38,837.6 | $4.21 | 0.01% |
| Control costs | $0.0 | $14.36 | NA |
| Steel production | $0.0 | $5.94 | NA |
| Captive coke production | $0.0 | $6.28 | NA |
| Market coke production | $0.0 | $2.14 | NA |
| Production costs | $38,837.6 | –$10.15 | –0.03% |
| Steel production | $36,292.9 | –$20.09 | –0.06% |
| Captive coke production | $942.5 | –$0.42 | –0.04% |
| Market coke consumption | $1,167.8 | $16.10 | 1.38% |
| Market coke production | $434.3 | –$5.74 | –1.32% |
| Operating profits ($\$10^6$/yr) | $1,386.3 | –$15.92 | –1.15% |
| Iron and steel facilities (#) | 20 | 0 | 0.00% |
| Coke batteries (#) | 37 | 0 | 0.00% |
| Employment (FTEs) | 67,198 | –45 | –0.07% |
| **Coke Producers (Merchant Only)** | | | |
| *Furnace* | | | |
| Revenues ($\$10^6$/yr) | $366.5 | –$10.01 | –2.73% |
| Costs ($\$10^6$/yr) | $318.5 | –$12.69 | –3.98% |
| Control costs | $0.0 | $2.16 | NA |
| Production costs | $318.5 | –$14.85 | –4.66% |
| Operating profits ($\$10^6$/yr) | $48.0 | $2.68 | 5.59% |
| Coke batteries (#) | 13 | –1 | –7.69% |
| Employment (FTEs) | 840 | –126 | –15.00% |
| *Foundry* | | | |
| Revenues ($\$10^6$/yr) | $273.3 | $7.03 | 2.57% |
| Costs ($\$10^6$/yr) | $194.2 | $3.10 | 1.60% |
| Control costs | $0.0 | $3.30 | NA |
| Production costs | $194.2 | –$0.20 | –0.10% |
| Operating profits ($\$10^6$/yr) | $77.9 | $3.93 | 4.96% |
| Coke batteries (#) | 12 | 0 | 0.00% |
| Employment (FTEs) | 2,420 | 0 | 0.00% |
| **Nonintegrated Steel Mills**[a] | | | |
| Operating profits ($\$10^6$/yr) | NA | $5.9 | NA |
| **Cupola Furnaces** | | | |
| Operating profits ($\$10^6$/yr) | NA | –$4.6 | NA |
| **Electric Furnaces**[b] | | | |
| Operating profits ($\$10^6$/yr) | NA | $1.7 | NA |

[a] Includes mini-mills.

[b] Includes electric arc or electric induction furnaces.

[c] Includes iron foundries that use electric arc or electric induction furnaces.

- Reduction in production costs ($14.9 million): Reduction in coke production costs occurs as output declines.

- Increased control costs ($2.2 million): The cost of producing furnace coke increases as a result of regulatory controls.

Industry-wide profits for merchant foundry coke producers increase by $3.9 million under the regulation:

- Increase in revenue ($7.0 million): Revenue increases as a result of higher market prices with only slight reductions in output.

- Reduction in production costs ($0.2 million): Reduction in coke production costs occur as output declines.

- Increased control costs ($3.3 million): The cost of producing foundry coke increases as a result of regulatory controls.

Industry-wide profits for domestic cupola furnaces are projected to decrease by $4.6 million as the result of higher price for foundry coke–their primary input.

Lastly, domestic producers that are not subject to the regulation benefit from higher prices without additional control costs. As mentioned above, profits increase are projected for nonintegrated steel mills and foundries producing iron castings with electric furnaces.

Additional distributional impacts of the rule within each producer segment are not necessarily apparent from the reported decline or increase in their aggregate operating profits. The regulation creates both gainers and losers within each industry segment based on the distribution of compliance costs across facilities. As shown in Table D-3, a substantial subset of the merchant coke facilities are projected to experience profit increases under both alternatives (i.e., 11 furnace coke batteries, or 85 percent, and 10 foundry coke batteries, or 83 percent). However, one merchant battery is projected to cease market operations as it was the highest-cost coke battery with the additional regulatory costs.

A majority of directly affected integrated iron and steel facilities (i.e., 15 plants, or 75 percent) are projected to become less profitable with the regulation with a total loss of $20.9 million. However, five integrated mills are projected to benefit from higher coke prices and experience a total profit gain of $4.9 million. These integrated plants sell a significant share of furnace coke in the market as compared to negatively affected facilities.

### Table D-3. Distributional Impacts of the Joint Implementation of the Integrated Iron and Steel MACT with the Coke MACT: 1997

| | With Regulation | | | |
|---|---|---|---|---|
| | **Increased Profits** | **Decreased Profits** | **Closure** | **Total** |
| **Integrated Iron and Steel Mills** | | | | |
| Facilities (#) | 5 | 15 | 0 | 20 |
| Steel production | | | | |
| Total ($10^3$ tpy) | 12,081 | 50,002 | 0 | 62,083 |
| Average (tons/facility) | 2,416 | 3,333 | 0 | 3,104 |
| Steel compliance costs | | | | |
| Total ($10^3$ tpy) | $0.35 | $5.59 | 0 | $5.94 |
| Average (tons/facility) | $0.03 | $0.11 | $0.00 | $0.10 |
| Coke production | | | | |
| Total ($10^3$ tpy) | 8,409 | 6,473 | 0 | 14,882 |
| Average (tons/facility) | 1,682 | 432 | 0 | 744 |
| Coke compliance costs | | | | |
| Total ($\$10^6$/yr) | $2.72 | $5.87 | $0 | $8.59 |
| Average ($/ton) | $0.32 | $0.91 | $0.00 | $0.58 |
| Change in operating profit ($\$10^6$) | $4.94 | –$20.87 | $0.00 | –$15.92 |
| **Coke Plants (Merchant Only)** | | | | |
| *Furnace* | | | | |
| Batteries (#) | 11 | 1 | 1 | 13 |
| Production ($10^3$ tpy) | | | | |
| Total ($10^3$ tpy) | 3,046 | 160 | 127 | 3,332 |
| Average (tons/facility) | 277 | 160 | 127 | 256 |
| Compliance costs | | | | |
| Total ($\$10^6$/yr) | $1.95 | $0.21 | $0.21 | $2.37 |
| Average ($/ton) | $0.64 | $1.31 | $1.66 | $0.71 |
| Change in operating profit ($\$10^6$) | $2.70 | –$0.01 | $0.00 | $2.68 |
| *Foundry* | | | | |
| Batteries (#) | 10 | 2 | 0 | 12 |
| Production | | | | |
| Total ($10^3$ tpy) | 1,702 | 246 | 0 | 1,948 |
| Average (tons/facility) | 170 | 123 | 0 | 162 |
| Compliance costs | | | | |
| Total ($\$10^6$/yr) | $2.17 | $1.14 | $0.00 | $3.30 |
| Average | $1.27 | $4.63 | $0.00 | $1.70 |
| Change in operating profit ($\$10^6$) | $4.10 | –$0.17 | $0.00 | $3.93 |

### *D.2.2 Facility Closures*

EPA estimates one merchant battery supplying furnace coke is likely to prematurely close as a result of the regulation. In addition, one captive battery ceases to supply the market and only produces coke sufficient for its internal requirements for production of steel mill projects. In both cases, these batteries are the highest-cost producers of furnace coke with the regulation.

### *D.2.3 Changes in Employment*

As a result of decreased output levels, industry employment is projected to decrease by less than 1 percent, or 171 full-time equivalents (FTEs), with the regulation. This is the net result of employment losses for integrated iron and steel mills totaling 45 FTEs and merchant coke plants of 126 FTEs. Although EPA projects increases in output for producers not subject to the rule, which would likely lead to increases in employment, the Agency did not develop quantitative estimates for this analysis.

## D.3 Social Costs

The social impact of a regulatory action is traditionally measured by the change in economic welfare that it generates. The social costs of the proposed rule will be distributed across consumers and producers alike. Consumers experience welfare impacts due to changes in market prices and consumption levels associated with the rule. Producers experience welfare impacts resulting from changes in profits corresponding with the changes in production levels and market prices. However, it is important to emphasize that this measure does not include benefits that occur outside the market, that is, the value of reduced levels of air pollution with the regulation.

The national compliance cost estimates are often used as an approximation of the social cost of the rule. The engineering analysis estimated annual costs of $20.2 million. In this case, the burden of the regulation falls solely on the affected facilities that experience a profit loss exactly equal to these cost estimates. Thus, the entire loss is a change in producer surplus with no change (by assumption) in consumer surplus. This is typically referred to as a “full-cost absorption” scenario in which all factors of production are assumed to be fixed and firms are unable to adjust their output levels when faced with additional costs.

In contrast, the economic analysis accounts for behavioral responses by producers and consumers to the regulation (i.e., shifting costs to other economic agents). This approach results in a social cost estimate that differs from the engineering estimate and also provides insights on how the regulatory burden is distributed across stakeholders. As shown in Table D-4, the economic model estimates the total social cost of the rule to be $19.9 million. This small difference occurs because society allocates resources as a result of the increased cost of coke production.

In the final product markets, higher market prices lead to consumers of steel mill products experiencing losses of $18.5 million and consumers of iron castings experiencing losses of $4.3 million. Although integrated iron and steel producers are able to pass on a limited amount of cost increases to their final consumers, e.g., automotive manufactures and construction industry, the increased costs result in a net decline in profits at integrated mills of $15.9 million and foundries with cupola furnaces of $4.6 million.

In the coke industry, low-cost merchant producers of furnace and foundry coke benefit at the expense of consumers and higher-cost merchant and captive coke batteries resulting in an industry-wide increase in profits. Furnace coke profits at merchant plants increase in aggregate by $2.7 million, and foundry coke profits at merchant plants increase in aggregate by $3.9 million.

Lastly, domestic producers not subject to the regulation (i.e., nonintegrated steel mills and electric furnaces) as well as foreign producers experience unambiguous gains because they benefit from increases in market price under both alternatives.

## Table D-4. Distribution of the Social Costs of the Joint Implementation of the Integrated Iron and Steel MACT with the Coke MACT: 1997

| | |
|---|---:|
| **Change in Consumer Surplus ($$10^6$/yr)** | **–$22.85** |
| Steel mill product consumers | –$18.51 |
| Domestic | –$17.70 |
| Foreign | –$0.82 |
| Iron casting consumers | –$4.33 |
| Domestic | –$4.07 |
| Foreign | –$0.26 |
| **Change in Producer Surplus ($$10^6$/yr)** | **$2.91** |
| Domestic producers | –$6.31 |
| Integrated iron and steel mills | –$15.92 |
| Nonintegrated steel mills[a] | $5.91 |
| Cupola furnaces | –$4.60 |
| Electric furnaces[b] | $1.69 |
| Furnace coke (merchant only) | $2.68 |
| Foundry coke (merchant only) | $3.93 |
| Foreign producers | $9.22 |
| Iron and steel | $2.91 |
| Castings | $0.34 |
| Furnace coke | $6.02 |
| **Social Costs of the Regulation ($$10^6$/yr)** | **–$19.94** |

[a] Includes mini-mills.
[b] Includes electric arc or electric induction furnaces.

# APPENDIX E

# FOREIGN IMPORTS SENSITIVITY ANALYSIS

In 1997, the baseline year of the Coke MACT EIA, Chinese imports represented approximately 2 percent of U.S. foundry coke consumption (USITC, 2000). As a result, the operational model developed to estimate the economic impacts of the rule on the foundry coke market focused on domestic foundry coke production and did not explicitly model foreign trade. However, the USITC has recently documented an increasing trend in foreign imports of foundry coke from China. This report indicated that the ratio of imports to consumption increased to 11.3 percent in 1999. The purpose of this appendix is to describe our methods for modifying the economic model and investigate the sensitivity of economic impact estimates to the inclusion of foreign trade. We find that including foreign imports of approximately 10 percent does not significantly alter conclusions reported in this report.

## E.1 Modifying the Economic Model

Our approach to investigating the influence of foreign imports on the economic impact of the proposed regulation was to begin with the baseline year of 1997 and impose the 1999 levels of foundry coke imports. The first step in modifying the economic model was to calculate a hypothetical quantity (short tons) of imported foundry coke. The USITC reports that in 1999, imports were 133,000 metric tons and domestic production was 1,248,000 metric tons (see Table 2-2 of the report). Thus, the ratio of imports to domestic production was calculated to be 10.7 percent. Multiplying this ratio by domestic production in 1997 (1,669,094 short tons) results in an import estimate of 178,593 short tons. In addition, we adjusted the baseline level of iron castings production to account for the new foundry coke consumption implied by the additional imports. Finally, we used a simple constant elasticity functional form to develop a supply curve for this foreign supplier (see Eq. [A.4] in Appendix A for a description of the similar foreign supply used for furnace coke) using a furnace coke foreign supply elasticity of 3 based on Graham, Thorpe, and Hogan (1999). Additional sensitivity analysis was conducted for the foreign supply elasticity using an even more elastic value of 6.

## E.2 Sensitivity Analysis Results

As shown in Table E-1, the inclusion of the Chinese imports with an import supply elasticity of 3 does not significantly affect the Coke MACT economic impact results presented in Section 4. The market price does not change and the change in domestic market output decreases from –0.08 percent to –1.02 percent, an additional decrease of 15,600 short tons. Because the change in domestic output is so small, all the decrease in output is borne by the marginal battery.[1] With the addition of foreign imports, the capacity utilization for the marginal battery decreased to 64 percent. We assume that at 64 percent capacity utilization, the battery will continue to operate and hence there are no closures.

**Table E-1. Market-Level Impacts of the Proposed Coke MACT: 1997**

| | Exclude Chinese Imports | Include Chinese Imports $\xi = 3.0$ | Include Chinese Imports $\xi = 6.0$ |
|---|---|---|---|
| **Foundry Coke** | | | |
| Market price (percent change) | 2.9% | 2.9% | 3.9% |
| Market output (percent change) | –0.08% | –0.06% | –0.09% |
| Domestic production | –0.08% | –1.02% | –2.8% |
| Imports | 0 | 8.9% | 25.8% |
| Closures (# batteries) | 0 | 0 | 1 |

As a sensitivity test, Table E-1 also shows the impact of including Chinese imports with an import supply elasticity of 6 (twice the empirical estimate presented in the literature). Again, the Coke MACT economic impact results presented in Section 4 do not significantly change. The market price now increases by 3.9 percent, as opposed to a price increase associated with the regulation of 2.9 percent without imports. The percent change in domestic output also decreases to 2.8 percent. The decrease in domestic output decreases the marginal battery’s capacity utilization to 28 percent. At this utilization rate, we project that

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[1] The marginal battery is the unit with the highest marginal cost of production. Because each coke battery is modeled as having a constant marginal cost of production, all domestic changes in output are borne by the highest cost battery until the decrease in market output is great enough to close the battery.

the battery would close and its market supply would be compensated by increased foreign supply.  The results presented Table E-1 for the supply elasticity 6 scenario incorporate the closure of the marginal battery.

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16. ABSTRACT

This report evaluates the economic impacts of the proposed NESHAP for pushing and quenching operations at coke plants. The social costs of the rule are estimated by incorporating the expected costs of compliance to a partial equilibrium model of the U.S. iron and steel industry and projecting the market impacts for furnace and foundry coke. The report also provides the screening analysis for small business impacts.

17. KEY WORDS AND DOCUMENT ANALYSIS

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