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# STATISTICAL METHODOLOGY FOR ASSIGNING EMISSIONS TO INDUSTRIES IN THE UNITED STATES, REVISED ESTIMATES: 1970 TO 1997

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# SUMMARY

This report develops a methodology to assign emissions of criteria air pollutants to the twenty two-digit standard industrial classification (SIC) code industries of the manufacturing sector for the years from 1970 to 1997. The methodology employed to assign process and fuel combustion emissions to specific industries is described and the emission estimates are listed in an appendix and the accompanying spreadsheet (SIC7097.WK3).

This report develops procedures to estimate the emissions of categories of processes and fuel combustion emissions that are not available ("NA") in *National Air Pollutant Emissions Trends Update: 1970-1997*. As a result, there are cases in which the estimates of emissions used in this report are higher than the official estimates in *National Air Pollutant Emissions Trends Update: 1970-1997*. The Office of Air and Radiation of the U.S. Environmental Protection Agency does not endorse the emission estimates for the "NA" categories. Hence, the emission estimates in this report do not supersede the official estimates in *National Air Pollutant Emissions Trends Update: 1970-1997*.

This is a technical report whose intended audience consists of individuals interested in developing environmental accounts.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| BEA | Bureau of Economic Analysis, U.S. Department of Commerce |
| BLS | Bureau of Labor Statistics, U.S. Department of Labor |
| Btu | British thermal unit |
| CO | carbon monoxide |
| cu. ft. | cubic feet |
| DAEMEC | Derived Annual Estimates of Manufacturing Energy Consumption |
| efr | external floating roof |
| EIA | Energy Information Administration, U.S. Department of Energy |
| ex. | excluding |
| ifr | internal floating roof |
| MECS | Manufacturing Energy Consumption Survey |
| NA | not available |
| NAICS | North American Industrial Classification System |
| NAMEA | National Accounting Matrix including Environmental Accounts |
| NAPAP | National Acid Precipitation Assessment Program |
| NEA | National Energy Accounts |
| *1970-1990 Emissions* | *Statistical Methodology for Assigning Emissions to Industries in the United States: 1970 to 1990* |
| *1940-1990 NAPEE* | *National Air Pollutant Emission Estimates, 1940-1990* |
| *1970-1997 NAPET* | *National Air Pollutant Emission Trends Update: 1970-1997* |
| $NO_x$ | oxides of nitrogen |

## ACRONYMS AND ABBREVIATIONS
**(continued)**

| | |
|---|---|
| Pb | lead |
| PM | particulate matter |
| PM-2.5 | particulate matter less than 2.5 microns in diameter |
| PM-10 | particulate matter less than 10 microns in diameter |
| pt. | part |
| Rec. furnace | recovery furnace |
| SCC | source classification code |
| SEDR | *State Energy Data Report* |
| SIC | Standard Industrial Classification (code) |
| SEEA | System for Integrated Environmental and Economic Accounts |
| $SO_2$ | sulfur dioxide |
| $SO_x$ | oxides of sulfur |
| U.S. DOE | U.S. Department of Energy |
| VOC | volatile organic compound(s) |

# 1. INTRODUCTION

This report updates the estimates of emissions developed in *Statistical Methodology for Assigning Emissions to Industries in the United States: 1970 to 1990* (U.S. EPA, 2000). Developing physical data on environmental-economic interactions represents one facet of environmental accounting. The introductory section of *Statistical Methodology for Assigning Emissions to Industries in the United States: 1970 to 1990* (U.S. EPA, 2000) reviews recent work on environmental accounting.

Several applications of emissions from industries have been proposed.[1] Among the proposed applications are indicators of environmental performance that measure changes in emissions to changes in output over time. Emission data can be combined with input-output tables and used to estimate the pollution-intensity of final demand categories. Finally, adjusted measures of productivity, which credit an industry for reducing emissions, can be estimated by linking emission data with data used to estimate traditional measures of productivity.

After *National Air Pollutant Emission Estimates, 1940-1990* (U.S. EPA, 1991) was released, the U.S. EPA changed its methodology for estimating emissions. For its estimates of emissions after 1984, the "top-down" methodology, which was the basis of the EPA's estimates in *National Air Pollutant Emission Estimates, 1940-1990* (U.S. EPA, 1991), was replaced by a modified "bottom-up" methodology. In addition, the U.S. EPA revised its estimates of emissions for 1970 to 1984. *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a) provides a detailed discussion of both methodologies.[2]

## 1.1. *Purpose of the Project*

This report describes the procedures used to assign emissions of air pollutants to the twenty two-digit standard industrial classification (SIC) code industries of the manufacturing sector for 1970 through 1997. The emission estimates in this report are drawn from *National Air Pollutant Emissions Trends Update: 1970-1997* (U.S. EPA, 1998b).[3] The methodology developed in *1970-1990 Emissions* forms the basis of the procedures employed when assigning

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[1] Nestor and Pasurka (1998, pp. 140-141) discuss additional applications of the data developed in this report.

[2] *National Air Pollutant Emissions Trends, Procedures Document 1900-1993* (U.S. EPA, 1994) also discusses the two methodologies.

[3] Throughout this report, *1970-1990 Emissions* refers to *Statistical Methodology for Assigning Emissions to Industries in the United States: 1970 to 1990* (U.S. EPA, 2000). *1940-1990 NAPEE* refers to *National Air Pollutant Emission Estimates, 1940-1990* (U.S. EPA, 1991). *1940-1990 NAPEE* contains the data used in *1970-1990 Emissions*. Finally, *1970-1997 NAPET* refers to *National Air Pollutant Emission Trends Update: 1970-1997* (U.S. EPA, 1998b).

emissions to industries in the industrial sector.[4] As was the case for *1970-1990 Emissions*, this is a technical report whose intended audience consists primarily of those individuals interested in developing environmental accounts.

The *1970-1997 NAPET* provides information on particulate matter (PM-10 and PM-2.5), sulfur dioxide ($SO_2$), nitrogen oxide ($NO_x$), volatile organic compounds (VOCs), carbon monoxide (CO) and lead (Pb) emissions from fuel combustion and processes. Procedures developed in *1970-1990 Emissions* to allocate fuel combustion emissions among the industries of the industrial sector are used in this report to allocate fuel combustion emissions. The procedures developed in *1970-1990 Emissions* to allocate particulate matter (PM) emissions among the industries of the industrial sector are used in this report to allocate PM-10 emissions from processes.[5] The procedures developed in *1970-1990 Emissions* to allocate $SO_x$ emissions among industries are used in this report to allocate $SO_2$ emissions from processes. The remaining pollutants ($NO_x$, VOC, CO, and Pb) are reported by both the *1940-1990 NAPEE* and the *1970-1997 NAPET*. The procedures developed in *1970-1990 Emissions* to allocate these emissions among the industries of the industrial sector are also used in this report.

There are five principal reasons for the differences between this report's estimates of emissions and estimates in *1970-1990 Emissions*. First, revised estimates of national emissions are used in this report. Second, this report assigns emissions from the combustion of wood, coke oven gas, and still gas to industries. Emissions from these fuels are not assigned to industries in *1970-1990 Emissions*. Third, additional sources of VOC emissions are assigned to industries in this report. Fourth, some emissions from processes assigned to the chemical industry in *1970-1990 Emissions* are now assigned to the mining sector (see Section 2.1.3. for the explanation). Finally, in *1970-1990 Emissions* the emissions from natural gas combustion are allocated between emissions from boilers and emissions from gas pipelines and plants. Emissions from boilers are assigned to industries in the industrial sector, and emissions associated with gas pipelines and plants are assigned to the gas utilities (i.e., production and distribution) sector. According to *1970-1990 Emissions*, between 10 and 15 percent of emissions from natural gas combustion are from boilers. The remaining emissions are from gas pipelines and plants. The *1970-1997 NAPET* does not report separate emission estimates from these two source categories. As a result, this report assigns all emissions from natural gas combustion by the industrial sector to industries in the industrial sector. No emissions are assigned to the gas utilities sector.

This report's estimates of emissions differ from those in the *1970-1997 NAPET* (U.S. EPA, 1998b) for several reasons. First, this report only assigns emissions to industries that belong to the industrial sector. Hence, in this report sources such as motor vehicle emissions are not assigned to industries. Second, this report estimates emissions from some process and fuel

[4] The industrial sector consists of industries in the agriculture, mining, construction, and manufacturing sectors.

[5] Since PM-2.5 emissions are not reported until 1990, they are not assigned to industries.

combustion categories whose emissions are not available (i.e., listed as "NA") in the *1970-1997 NAPET*. Third, this report does not assign emissions from the "Miscellaneous Industrial Processes" (Tier II) category to industries. Finally, this report excludes emissions from the combustion of several types of fuel because there is insufficient information about which industries consume these fuels.

The Office of Air and Radiation of the U.S. Environmental Protection Agency does not endorse the emission estimates for the "NA" categories in the *1970-1997 NAPET*. Hence, the emission estimates in this report do not supersede the official estimates in *National Air Pollutant Emissions Trends Update: 1970-1997*.

### 1.2. *Organization of the Report*

The remainder of this report consists of the following sections. In Section 2, the methodology for allocating process emissions among industries is described. In Section 3, the procedure for allocating fuel combustion emissions among industries is described. Finally, section 4 summarizes the findings of this report and potential future extensions.

Appendix A lists the names and SIC codes of the national energy accounts (NEA) sectors of the nonmanufacturing portion of the industrial sector. Appendix B lists the assignments of SIC and NEA codes to various subcategories of the Solvent Utilization and Storage & Transport (Tier I) categories. Appendix C summarizes information on the percentage of emissions in 1985 from categories whose emissions are listed as "NA" in 1984. Appendix D describes the procedures employed to estimate missing observations for energy consumption and emissions. Appendix E lists the estimates of emissions of the six criteria air pollutants for 1970 through 1997 for the twenty two-digit SIC manufacturing industries (SIC 20-39).[6] Appendix F describes the organization of the spreadsheet (SIC7097.WK3) whose contents are described in this report. Finally, Appendix G describes the preparation of the report and the peer review process.

## 2. PROCESS EMISSIONS FROM THE INDUSTRIAL SECTOR

In the *1970-1997 NAPET*, the methodology used to estimate process emissions for 1970 to 1984 is based on the methodology used in the *1940-1990 NAPEE*. From 1970 to 1984, estimates of process emissions are the product of (1) the activity level, (2) the emission factor and (3) the control efficiency of each source category. In the *1970-1997 NAPET*, the emission estimates for 1985 to 1997 are derived primarily from the Aerometric Information Retrieval System (AIRS) data, and extrapolations of 1985 data from the National Acid Precipitation Assessment Program (NAPAP) and 1990 data from the National Emission Trends (U.S. EPA, 1998a, pp. 4-42, 4-44, 4-50, 4-52, and 4-56).

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[6] Since the most recent Manufacturing Energy Consumption Survey (MECS) reports data for 1994 and the most recent economic census contains data are from 1992, the allocation of fuel combustion emissions for 1993 to 1997 is preliminary.

## 2.1. *Assigning SIC and NEA Codes to Categories of Process Emissions*

Unlike the *1940-1990 NAPEE*, the *1970-1997 NAPET* does not assign SIC codes to its process categories. As a result, information from *1970-1990 Emissions* and the *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a) is used to assign SIC and NEA codes to the categories of process emissions in the *1970-1997 NAPET*. The assignment of SIC and NEA codes is complicated by the fact that the *1970-1997 NAPET* and the *1940-1990 NAPEE* assign different names to some of the categories of process emissions.

Table 1 identifies (X) which industries in the nonmanufacturing portion of the industrial sector are assigned process emissions in *1970-1990 Emissions*. The two-digit SIC manufacturing industries assigned process emissions in *1970-1990 Emissions* are identified (X) in Table 2. Only industries assigned VOC emissions from categories classified as industrial processes in *1970-1990 Emissions* and the *1970-1997 NAPET* are marked "X." The following source categories, which are classified as industrial processes in *1970-1990 Emissions*, are not classified as industrial processes in the *1970-1997 NAPET*: (1) petroleum marketing & production, (2) miscellaneous organic solvent evaporation, (3) surface coating, and (4) graphic arts. Section 2.2. discusses the assignment of VOC emissions from these categories. If the only VOC emissions assigned to an industry in *1970-1990 Emissions* are from categories the *1970-1997 NAPET* does not classify as industrial processes, it is identified with a symbol other than an "X."

The U.S. EPA (1998a, p. 4-2) organizes its categories of emissions of criteria pollutants into four levels (i.e., tiers). The Tier I and Tier II categories are identical for each of the six criteria pollutants. The Tier III categories differ among the pollutants. Finally, Tier IV corresponds to source classification code (SCC). Each SCC represents a "unique process or function" that produces emissions. The Tier III categories represent the most disaggregated data available for 1970 to 1997.[7]

Table 3 summarizes the assignment of two-digit SIC codes (manufacturing industries) and NEA codes (nonmanufacturing industries) to the Tier II categories of process emissions in the *1970-1997 NAPET*. For the Chemical & Allied Product Mfg. (Tier I) category, its Tier II categories are not listed because all emissions are assigned to a single two-digit SIC code. However, the Tier II categories associated with the Petroleum & Related Industries, Metals Processing, and Other Industrial Processes (Tier I) categories are listed in Table 3. Information contained in Table 3 is derived from the methodology used to estimate emissions for the years prior to 1985 (see U.S. EPA, 1998a, Section 3); however, it serves as the principal guide for distributing process emissions for 1970 to 1997.

[7] Data on emissions from SCCs are available for the years from 1985 to the present.

*Table 1*
**Nonmanufacturing Industries Assigned Process Emissions, *1970-1990 Emissions***

| NEA Code | Industry Title | PM | $SO_x$ | $NO_x$ | VOCs | CO | Pb |
|---|---|---|---|---|---|---|---|
| | AGRICULTURE | | | | | | |
| 01000 | Livestock and livestock products | X | | | | | |
| 02000 | Other agricultural products | X | | | (MO) | | |
| 03000 | Forestry and forestry products | | | | | | |
| 04000 | Agricultural, forestry and fishery services | | | | | | |
| | MINING | | | | | | |
| 05000 | Iron and feroalloy ores mining | X | | | | | |
| 06001 | Uranium - radium - vanadium ores mining | | | | | | |
| 06002 | Nonferrous metal ores mining | X | | | | | X |
| 07010 | Anthracite coal mining | | | | | | |
| 07020 | Bituminous and lignite coal mining | X | | | | | |
| 08001 | Crude petroleum | | | | (PMP) | | |
| 08002 | Natural gas | | | | | | |
| 08003 | Natural gas liquids | | | | (PMP) | | |
| 09000 | Stone and clay mining and quarrying | X | | | | | |
| 10000 | Chemical and fertilizer mineral mining | X | | | | | |
| | CONSTRUCTION | | | | | | |
| 11001 | Oil and gas well drilling | | | | | | |
| 11002 | New construction | | | | (MO) | | |
| 12000 | Maintenance and repair construction | | | | (MO) | | |

Notes:
PMP = VOC emissions from only the Petroleum Marketing & Production category
MO = VOC emissions from only the Miscellaneous Organic Solvent Evaporation category

*Table 2*

**Manufacturing Industries Assigned Process Emissions, *1970-1990 Emissions***

| SIC code | **Industry Groups** | PM | $SO_x$ | $NO_x$ | VOCs | CO | Pb |
|---|---|---|---|---|---|---|---|
| 20 | Food and kindred products | X | | | X | | |
| 21 | Tobacco products | | | | | | |
| 22 | Textile mill products | | | | X | | |
| 23 | Apparel | | | | | | |
| 24 | Lumber and wood products, except furniture | X | | | (SC) | | |
| 25 | Furniture and fixtures | | | | (SC) | | |
| 26 | Paper and allied products | X | X | X | (SC) | X | |
| 27 | Printing, publishing, and allied products | | | | (GA) | | |
| 28 | Chemicals and allied products | X | X | X | X | X | X |
| 29 | Petroleum refining and related products | X | X | X | X | X | |
| 30 | Rubber and miscellaneous plastics products | | | | (SC) | | |
| 31 | Leather and leather products | | | | | | |
| 32 | Stone, clay, glass, and concrete products | X | X | X | X | X | X |
| 33 | Primary metal products | X | X | X | X | X | X |
| 34 | Fabricated metals products, ex. machinery and transportation equipment | | | | (SC) | | X |
| 35 | Industrial and commercial machinery and computer equipment | | | | (SC) | | X |
| 36 | Electronic and other electrical equip. and components, ex. computer equip. | | | | (SC) | | X |
| 37 | Transportation equipment | | | | (SC) | | |
| 38 | Measuring, analyzing and controlling instruments; photographic, medical and optical goods; watches and clocks | | | | | | |
| 39 | Miscellaneous manufacturing industries | | | | | | |

Notes: SIC 34 and SIC 35 reported positive quantities of Pb in all years except in 1990.
SC = VOC emissions from only the Surface Coating category
GA = VOC emissions from only the Graphic Arts category

*Table 3*
**Concordance Between Categories of Process Emissions and NEA/SIC Codes**

| Tier I Category | Tier II Category | SIC codes (NEA codes in parentheses) |
|---|---|---|
| Chemical & Allied Product Mfg. | ---- | 28 |
| Metals Processing | Nonferrous Metals Processing | 33 |
| Metals Processing | Ferrous Metals Processing | 33 |
| Metals Processing | Not Elsewhere Classified | 33, (NEA 05000, 06001, 06002) |
| Petroleum & Related Industries | Oil & Gas Production | (NEA 08001, 08002 and 08003) |
| Petroleum & Related Industries | Petroleum Refineries & Related Industries | 29 |
| Petroleum & Related Industries | Asphalt Manufacturing | 29 |
| Other Industrial Processes | Agriculture, Food, & Kindred Products | 20, (NEA 01000, 02000, 03000 and 04000) |
| Other Industrial Processes | Textiles, Leather, & Apparel Products | 22, 23, 31 |
| Other Industrial Processes | Wood, Pulp & Paper, & Publishing Products | 24, 25, 26 |
| Other Industrial Processes | Rubber & Miscellaneous Products | 30 |
| Other Industrial Processes | Mineral Products | 32, (NEA 09000 and 10000) |
| Other Industrial Processes | Machinery Products | 34 |
| Other Industrial Processes | Electronic Equipment | 36 |
| Other Industrial Processes | Transportation Equipment | 37 |
| Other Industrial Processes | Construction | (NEA 11001, 11002, and 12000) |
| Other Industrial Processes | Miscellaneous Industrial Processes | (see discussion in section 2.1.13.) |

Several of the Tier II categories in Table 3 include emissions from more than one industry (e.g., "Textiles, Leather and Apparel Products" includes three two-digit SIC industries). Some applications of the emission estimates require information about two-digit SIC manufacturing industries. Hence, rules are devised to allocate the emissions among the industries associated with each Tier II category. The following "Allocation Rules," which are listed in the order in which they are invoked, are used to assign process emissions from Tier II categories to industries:[8]

(1) If only one SIC or NEA code is assigned to a Tier II category, then emissions of all pollutants are assigned to that industry. In this case, an industry may be assigned emissions of a pollutant even if it was not assigned emissions of that pollutant in *1970-1990 Emissions*.

(2) If two or more SIC or NEA codes belong to a Tier II category, but only one of the industries is assigned emissions in *1970-1990 Emissions*, then all emissions are allocated to the industry assigned emissions in *1970-1990 Emissions*. In this case, an industry is not assigned emissions of a pollutant if it was not assigned emissions in *1970-1990 Emissions*.

(3) If two or more of the SIC or NEA codes of a Tier II category are assigned emissions in *1970-1990 Emissions*, the shares of emissions assigned to each of those industries in *1970-1990 Emissions* are used to assign the emissions from the *1970-1997 NAPET* for 1970 to 1990. The percentage of the emissions assigned to each industry for 1991 to 1997 is estimated by adjusting the industry's 1990 share of emissions by changes in its share of the output of the industries assigned to that Tier II category. For each year from 1991 to 1997, the emission-output ratio for each industry is scaled so that the sum of the emissions from the industries equals the emissions from the Tier II category.

(4) If two or more industries are assigned to a Tier II category and none of the industries are assigned emissions in *1970-1990 Emissions*, the emissions are allocated to industries based on the output shares of the industries assigned to that Tier II category. This allocation rule assumes that the ratio of process emissions to industry output is identical for all industries that belong to the Tier II category.

While the percentages vary from year to year, in 1997 more than 99 percent of $SO_2$, CO, and Pb process emissions are assigned using Allocation Rules 1 and 2. In 1997, more than 97 percent of $NO_x$ emissions, more than 92 percent of PM-10 emissions, and more than 92 percent of VOC emissions are assigned using Allocation Rules 1 and 2.[9]

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[8] These rules are modified in some instances when (1) additional information and/or (2) emission estimates for Tier III categories are available.

[9] If the percentage of VOC emissions includes emissions from the industrial process, solvent utilization, and storage and transport categories, then more than 78 percent of VOC emissions are assigned by Allocation Rules 1 and 2.

The remainder of Section 2.1. describes the rationale for assigning SIC and NEA codes to the Tier II and Tier III categories of the four Tier I categories that comprise the industrial sector: (1) chemical and allied product mfg., (2) metals processing, (3) petroleum and related industries, and (4) other industrial processes. Specific mention is made when "Allocation Rule 3" or "Allocation Rule 4" is used to allocate emissions to industries.

### 2.1.1. Chemical & Allied Product Mfg.

The Chemical & Allied Product Mfg. (Tier I) category consists of seven Tier II categories (see Table 4). The chemicals and allied products industry (SIC 28) is assigned the emissions from the Chemical & Allied Product Mfg. category.

### 2.1.2. Metals Processing

The Metals Processing (Tier I) category consists of three Tier II categories. SIC 33 is assigned emissions of all pollutants from the Nonferrous Metals Processing (Tier II), and the Ferrous Metals Processing (Tier II) categories.

The Metals Processing, NEC (Tier II) category reports lead (Pb) emissions from the "metals mining" and "other" (Tier III) categories. In *1970-1990 Emissions,* Pb emissions are assigned to the metals mining industries, which are part of the mining sector. A comparison of the quantity of Pb emissions assigned to the mining sector in the SIC7090.WK3 spreadsheet and the *1970-1997 NAPET* indicates that emissions from the "metals mining" (Tier III) category should be assigned to the mining sector. SIC 33 is assigned the Pb emissions from the "other" (Tier III) category.

Prior to 1985, PM-10 emissions from the Metals Processing, NEC (Tier II) category are associated with the mining operations subcategory (U.S. EPA, 1998a, p. 3-124). Although some of the processes in the Metals Processing, NEC (Tier II) category should be assigned to SIC 33 (see U.S. EPA 1998a, p. 4-12), the mining sector is assigned all PM-10 emissions from this category.

Since no emissions of $SO_2$, $NO_x$, VOCs, and CO are assigned to the metal mining industry in *1970-1990 Emissions*, Allocation Rule 2 indicates that emissions from the Metals Processing, NEC (Tier II) category should be assigned to SIC 33. In addition, processes associated with SIC 33 are included in the Metals Processing, NEC (Tier II) category (see U.S. EPA 1998a, p. 4-12). However, SIC 33 is assigned emissions of these pollutants from the Nonferrous Metals Processing (Tier II), and the Ferrous Metals Processing (Tier II) categories. As a result, the metal mining industry is assigned all $SO_2$, $NO_x$, VOCs, and CO emissions from the Metals Processing, NEC (Tier II) category.

### 2.1.3. Petroleum & Related Industries

The Petroleum and Related Industries (Tier I) category includes emissions from three Tier II categories. SIC 29 is assigned emissions of all pollutants from the Petroleum Refineries and Related Industries (Tier II), and the Asphalt Manufacturing (Tier II) categories.

For $SO_2$ emissions, the Oil & Gas Production (Tier II) category includes the following Tier III categories: (1) natural gas and (2) other. Natural gas production and crude oil production are two of the processes included in the Oil & Gas Production category (U.S. EPA, 1998a, p. 3-128). The *1970-1990 Emissions* assigns emissions from "sulfur recovery plants" processes to SIC 28, and the *1940-1990 NAPEE* assigned these emissions to the mining sector. Appendix D of *1970-1990 Emissions* discussed this discrepancy between it and the *1940-1990 NAPEE*. Since many of the processes in this Tier II category are related to mining activities and the North American Industrial Classification System (NAICS) assigns sulfur recovered from natural gas to the mining sector (see Appendix D of *1970-1990 Emissions*), emissions of all pollutants from the Oil & Gas Production category are assigned to the mining sector. Hence, this represents a change from *1970-1990 Emissions*.

### 2.1.4. Other Industrial Processes - Agriculture, Food & Kindred Products

The Agriculture, Food & Kindred Products (Tier II) category includes PM-10 emissions from two Tier III categories of grain elevators, four Tier III categories of grain mills, and the "other" (Tier III) category.

Emissions of PM from the (1) country elevators and (2) terminal elevators categories are assigned to the agriculture sector in *1970-1990 Emissions*. Appendix D of *1970-1990 Emissions* contains a discussion of the allocation of emissions from these categories. As a result, this report assigns the PM-10 emissions from these two Tier III categories to the agriculture sector.

In this report, emissions of PM-10 from the (1) feed mills, (2) soybean mills, (3) wheat mills, (4) other grain mills (Tier III) categories are assigned to SIC 20 (see *1970-1990 Emissions*, p. A-5).

PM-10 emissions from the following processes are assigned to the "other" (Tier III) category (U.S. EPA, 2000, p. A-5): cotton ginning, cattle feedlots, and alfalfa dehydrators. In *1970-1990 Emissions*, emissions from cattle feedlots are assigned to NEA 01000 and emissions from cotton ginning are assigned to NEA 04000 (i.e., SIC 0724). The alfalfa dehydrators source category is assigned to SIC 20 in *1970-1990 Emissions*. Hence, "Allocation Rule 3" (see Section 2.1.) assigns PM-10 emissions from the Agriculture, Food & Kindred Products category to the agriculture sector and SIC 20. From 1970 to 1990, the cotton ginning and cattle feedlots source categories generated between 94.5 and 97 percent and the alfalfa dehydrators source category generated between 3 and 5.5 percent of the PM-10 emissions.

From 1985 to 1997, the Agriculture, Food, and Kindred Products (Tier II) category accounts for between 11 and 16 percent of the PM-10 process emissions from the Other Industrial Processes (Tier I) category. The Agriculture, Food, and Kindred Products category accounts for between 7 and 10 percent of the PM-10 process emissions of the industrial sector.

Since no VOC process emissions are assigned to the agriculture sector in *1970-1990 Emissions*, all VOC emissions are assigned to SIC 20 (see U.S. EPA 2000, p. A-9). The following Tier III categories: (1) vegetable oil mfg., (2) whiskey fermentation: aging, (3) bakeries, and (4) other are associated with VOC emissions from the Agriculture, Food, and Kindred Products (Tier II) category.

$SO_2$, $NO_x$, and CO process emissions are assigned to neither the agriculture sector nor SIC 20 in *1970-1990 Emissions*. As a result, "Allocation Rule 4" is used to allocate $SO_2$, $NO_x$, and CO emissions between the agriculture sector and Food and kindred products (SIC 20).

Between 1985 and 1997, the Agriculture, Food, and Kindred Products (Tier II) category accounts for between 0.5 and 1 percent of $SO_2$ process emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category accounts for less than 0.5 percent of $SO_2$ process emissions from the industrial sector.

Between 1985 and 1997, the Agriculture, Food, and Kindred Products (Tier II) category produces less than 1.5 percent of $NO_x$ process emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category accounts for less than 1 percent of $NO_x$ process emissions from the industrial sector.

Between 1985 and 1997, the Agriculture, Food, and Kindred Products (Tier II) category produces less than 1 percent of CO process emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category accounts for less than 0.1 percent of CO process emissions from the industrial sector.

### 2.1.5. Other Industrial Processes - Textiles, Leather, & Apparel Products

In *1970-1990 Emissions* of the three industries (SIC 22, SIC 23, and SIC 31) that comprise the Textiles, Leather, & Apparel Products (Tier II) category, only SIC 22 is assigned VOC process emissions. Hence, SIC 22 is assigned all VOC emissions from the Textiles, Leather, & Apparel Products category.

Emissions of PM-10, $SO_2$, $NO_x$ and CO are each less than 0.5 thousand short tons. Between 1985 and 1997, this Tier II category accounts for less than 0.1 percent of PM-10, $SO_2$, $NO_x$ and CO process emissions from the industrial sector. Since none of these pollutants are assigned to SIC 22, SIC 23, or SIC 31 in *1970-1990 Emissions*, "Allocation Rule 4" is used to allocate emissions from the Textiles, Leather, & Apparel Products (Tier II) category among the three industries.

### 2.1.6. Other Industrial Processes - Wood, Pulp & Paper, & Publishing Products

The Wood, Pulp & Paper, & Publishing Products (Tier II) category includes CO emissions from the following Tier III categories: (1) sulfate pulping: rec. furnace/evaporator, (2) sulfate (kraft) pulping: lime kiln and (3) other. For PM-10 emissions, the Wood, Pulp & Paper, & Publishing Products (Tier II) category includes the following Tier III categories: (1) sulfate (kraft) pulping: lime kiln and (2) other.

In *1970-1990 Emissions*, SIC 24 and SIC 26 are assigned PM emissions. Based on a comparison of the quantity of PM-10 emissions assigned to SIC 24 and SIC 26 in the SIC7090.WK3 spreadsheet and emissions of the two Tier III categories in the *1970-1997 NAPET*, SIC 26 is assigned emissions from the sulfate (kraft) pulping (Tier III) category and SIC 24 is assigned PM-10 emissions from "other" (Tier III) category.

In *1970-1990 Emissions*, SIC 26 is assigned all $SO_2$ and $NO_x$ emissions from the Wood, Pulp & Paper, & Publishing Products category. In this report, SIC 26 is assigned all $SO_2$ and $NO_x$ emissions from the Wood, Pulp & Paper, & Publishing Products category.

In *1970-1990 Emissions*, SIC 26 is assigned all CO emissions from the Wood, Pulp & Paper, & Publishing Products category. Starting in 1985, the "other" (Tier III) category in the *1970-1997 NAPET* reports some CO emissions. Section 2.3.3. discusses the possibility that emissions from the sulfate (kraft) pulping: lime kiln (Tier III) category were transferred to the other two Tier III categories starting in 1985. Although some of the "other" (Tier III) processes are associated with SIC 24 and SIC 25, "Allocation Rule 2" indicates that emissions from the "other" (Tier III) category should be assigned to SIC 26. As a result, SIC 26 is assigned all CO emissions from Wood, Pulp & Paper, & Publishing Products category.

In *1970-1990 Emissions*, no VOC process emissions are assigned to any of the three two-digit SIC codes that comprise the Wood, Pulp & Paper, & Publishing Products (Tier II) category. As a result, "Allocation Rule 4" is used to allocate VOC emissions among the three industries of the Wood, Pulp & Paper, & Publishing Products category. During 1985 to 1997, this Tier II category produces between 10.5 and 28.5 percent of the VOC emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category accounts for between 2 and 8.5 percent of the VOC emissions of the industrial sector.

### 2.1.7. Other Industrial Processes - Rubber & Miscellaneous Products

SIC 30 is assigned emissions from the Rubber and Miscellaneous products category. For VOC emissions, the "Rubber and Miscellaneous Plastics Products" (Tier II) category consists of these Tier III categories: (1) rubber tire mfg., (2) green tire spray, and (3) other.

2.1.8. Other Industrial Processes - Mineral Products

For PM-10 emissions, the "Minerals Products" (Tier II) category includes the following Tier III categories: (1) cement mfg., (2) surface mining, (3) stone quarrying/processing, and (4) other. For $NO_x$ emissions, the Minerals Products category consists of the following Tier III categories: (1) cement mfg., (2) glass mfg., and (3) other.

SIC 32 is assigned emissions of PM-10 from the cement mfg. (Tier III) category. In *1970-1990 Emissions*, PM emissions are assigned to the mineral mining (NEA 10000) and coal mining (NEA 07020) industries. The Mineral Products category includes emissions from mineral and coal mining (see U.S. EPA, 1998a, p. 3-156). Hence, this report assumes PM-10 emissions from coal mining are assigned to the "surface mining" (Tier III) category. This report also assumes that PM-10 emissions from mineral mining activities are assigned to the "stone quarrying/processing" (Tier III) category. The mining sector is assigned emissions from the "other" (Tier III) category. This assignment is based on information about the quantities of PM emissions assigned to SIC 32 and the mining sector by the SIC7090.WK3 spreadsheet and the quantities of emissions from the four Tier III categories in the *1970-1997 NAPET*.

The *1970-1997 NAPET* assigns all Pb emissions from the Minerals Products category to the cement mfg. (Tier III) category. As a result, SIC 32 is assigned all Pb emissions from the Mineral Products category.

$SO_2$, $NO_x$, CO, or VOC emissions are assigned to neither the mineral mining nor the coal mining industries in *1970-1990 Emissions*; however, SIC 32 is assigned $SO_2$, $NO_x$, CO, and VOC emissions. In this report, SIC 32 is assigned emissions of these pollutants.

2.1.9. Other Industrial Processes - Machinery Products

SIC 34 is assigned emissions from the Machinery Products (Tier II) category.

2.1.10. Other Industrial Processes - Electronic Equipment

SIC 36 is assigned emissions from the Electronic Equipment (Tier II) category.

2.1.11. Other Industrial Processes - Transportation Equipment

SIC 37 is assigned emissions from the Transportation Equipment (Tier II) category.

2.1.12. Other Industrial Processes - Construction

For VOC emissions, the *1970-1997 NAPET* estimates emissions from the Construction (Tier II) category. In *1970-1990 Emissions*, NEA 11002 and NEA 12000, which are associated with the construction sector, are assigned VOC emissions.

PM-10 is the only other pollutant with a separate estimate of emissions from the Construction category.

2.1.13. Other Industrial Processes - Miscellaneous Industrial Processes

All industries in the industrial sector assigned emissions in *1970-1990 Emissions* are assigned emissions in this report. This section discusses the rationale for not assigning emissions from the Miscellaneous Industrial Processes (Tier II) category.

The only SIC code mentioned in the list of processes associated with the Miscellaneous Industrial Processes category is SIC 35 (U.S. EPA, 1998a, p. 4-15). In addition, this category includes several processes assigned to SIC 36. There is also a listing for fabricated metal products - arc welding, which is part of SIC 34. Finally, there is one process (photocopying equipment mfg., toner grinding) included in this category that is assigned to SIC 38. Since no additional information is available, industries are not assigned emissions from the Miscellaneous Industrial Processes (Tier II) category.

Between 1985 and 1997, this Tier II category produces between 12.5 and 28 percent of the VOC emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this category accounts for between 1 and 2.5 percent of VOC emissions from all industrial processes.

Between 1985 and 1997, this Tier II category produces between 0.5 and 1.5 percent of the CO emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category accounts for less than 0.5 percent of the VOC process emissions from the industrial sector.

Between 1985 and 1997, this Tier II category accounts for between 3.5 and 5 percent of the PM-10 emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this category produces between 2.5 and 3 percent of the PM-10 process emissions from the industrial sector.

Between 1985 and 1997, this Tier II category accounts for between 2 and 3 percent of the $NO_x$ emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this Tier II category produces between 0.5 and 1.5 percent of the $NO_x$ process emissions from the industrial sector.

Between 1985 and 1997, this Tier II category accounts for between 0.5 and 1.5 percent of the $SO_2$ emissions from the Other Industrial Processes (Tier I) category. Between 1985 and 1997, this category produces less than 0.5 percent of the $SO_2$ process emissions of the industrial sector.

## 2.2. *Assigning SIC and NEA Codes to Other Categories of Emissions*

The assignment of emissions from the "Solvent Utilization" (Tier I) category is discussed in Section 2.2.1. Section 2.2.2. discusses the assignment of emissions from the "Petroleum and Petroleum Product Storage," the "Organic Chemical Storage," and the "Inorganic Chemical Storage" (Tier II) categories, which are part of the "Storage & Transport" (Tier I) category. Appendix B lists the concordance between SIC and NEA codes and the Tier II and Tier III categories of the Solvent Utilization and Storage & Transport (Tier I) categories.

Except for VOCs, emissions of all pollutants from these source categories are reported as "NA" for the years prior to 1985. According to the post-1984 data, these source categories are relatively small contributors to non-VOC emissions. As a result, only the VOC emissions from these categories are assigned SIC or NEA codes.

There are other categories of VOC emissions that could be assigned to nonmanufacturing industries within the industrial sector. Since the focus of this report is assigning emissions to manufacturing industries, these remaining categories of VOC emissions are not assigned to industries.

### 2.2.1. Solvent Utilization

*1970-1990 Emissions* assigns VOC emissions ("Miscellaneous Solvent Evaporation - pesticides") to NEA 02000. The closest match to this category in the *1970-1997 NAPET* is the "Solvent Utilization - pesticide application" (Tier III) category.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions,* the construction sector is assigned VOC emissions from the "Solvent Utilization - Nonindustrial, cutback asphalt" (Tier III) category.

*1970-1990 Emissions* assigns VOC emissions ("Miscellaneous Solvent Evaporation - architectural coating") to NEA 11002. The closest match to this category in the *1970-1997 NAPET* is the "Surface Coating - architectural" (Tier III) category.

*1970-1990 Emissions* assigns VOC emissions ("Surface Coating Operations - Maintenance Coatings") to NEA 12000. The closest match to this category in the *1970-1997 NAPET* is the "Surface Coating - maintenance coating" (Tier III) category.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions,* SIC 22 is assigned VOC emissions from the "Surface Coating - fabrics" (Tier III) category.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions,* SIC 24 is assigned VOC emissions from the "Surface Coating - flatwood" (Tier III) category. SIC 25 is assigned emissions from the "Surface Coating - wood furniture" and "Surface Coating - metal

furniture" (Tier III) categories. SIC 26 is assigned emissions from the "Surface Coating - paper" (Tier III) category. SIC 27 is assigned emissions from the "Solvent Utilization - Graphic Arts" (Tier III) category.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions*, SIC 30 is assigned VOC emissions from the "Solvent Utilization - other industrial, plastic parts" and VOC emissions from the "Solvent Utilization - Surface Coating, rubber & plastics mfg." (Tier III) categories.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions*, SIC 33 is assigned VOC emissions from the "Solvent Utilization - Surface Coating, metal coils" and from the "Solvent Utilization - Surface Coating, magnet wire" (Tier III) categories.

In *1970-1990 Emissions*, Sic 34 is assigned emissions from the following Surface Coating Operations (Tier III) categories: (1) Cans, (2) Other Metal Products, and (3) Miscellaneous Processes. It is assumed that the "metal cans" (Tier III) category of the Solvent Utilization (Tier I) category in the *1970-1997 NAPET* corresponds to the "Cans" category. Neither the "Other Metal Products" nor the "Miscellaneous Processes" categories are listed in the *1970-1997 NAPET*. It is assumed that the (1) misc. metal parts and (2) steel drums (Tier III) categories in the *1970-1997 NAPET* correspond to the "Other Metal Products" and the "Miscellaneous Processes" categories.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions*, SIC 35 is assigned VOC emissions from the "Solvent Utilization - Surface Coating, machinery" (Tier III) category.

SIC 36 is assigned VOC emissions from the "Surface Coating Operations - Large Appliances" source (Tier III) category. In addition, SIC 36 is assigned VOC emissions from the "Solvent Utilization - Surface Coating, electronic & other electrical" (Tier III) category, which is in the *1970-1997 NAPET*. The "electronic & other electrical" (Tier III) category is not listed in either the *1940-1990 NAPEE* or *1970-1990 Emissions*.

Using assignments of Solvent Utilization categories in *1970-1990 Emissions*, SIC 37 is assigned VOC emissions from the "Solvent Utilization - Surface Coating, autos & light trucks," "Solvent Utilization - Surface Coating, large ships," "Solvent Utilization - Surface Coating, aircraft," and "Solvent Utilization - Surface Coating, railroad" (Tier III) categories.

### 2.2.2. Storage & Transport

In *1970-1990 Emissions*, SIC 29 is assigned the emissions of selected Tier III categories from the "Petroleum & Petroleum Storage" (Tier II) category. First, SIC 29 is assigned emissions from the "Petroleum Marketing and Production - Crude Oil Storage, Refinery Storage" category in *1970-1990 Emissions*. In the *1940-1990 NAPEE*, this source is part of the "Crude Oil

Production, Storage and Transfer" category. The *1940-1990 NAPEE* assigned this category to SIC industries 1311 and 4463. Second, SIC 29 is assigned emissions from the "Petroleum Marketing and Production - Gasoline Storage at Refineries" category in *1970-1990 Emissions*. Appendix D in *1970-1990 Emissions* discusses the differences in the assignment of VOC emissions to industries between *1970-1990 Emissions* and the *1940-1990 NAPEE*.

The Petroleum and Petroleum Product Storage (Tier II) category includes emissions from the storage of gasoline and crude oil at refineries (SIC 29) and emissions from the oil field storage of crude oil (NEA08001) (U.S. EPA, 1998a, p. 3-192). Hence, "Allocation Rule 3" (see section 2.1.) assigns VOC emissions from the Petroleum and Petroleum Product Storage category to the Oil and gas extraction industry (SIC 13) and petroleum refining (SIC 29). During 1970 to 1990, between 70 and 78 percent of the VOC emissions from the Petroleum and Petroleum Product Storage category are assigned to SIC 29. The remainder of the VOC emissions from the Petroleum and Petroleum Product Storage category are assigned to SIC 13.

The Organic Chemical Storage (Tier II) category includes emissions from (1) waste solvent recovery and (2) waste disposal from petrochemical manufacturing (U.S. EPA, 1998a, p. 3-200). As a result, VOC emissions from this Tier II category are assigned to SIC 28.

## 2.3. *Assigning Values to Categories of Process Emissions listed as "NA"*

In the *1970-1997 NAPET*, estimates of emissions from some source categories are not available (NA) until 1985.[10] The availability of data to estimate emissions for 1970 to 1984 is discussed in Section 3 of *National Air Pollutant Emissions Trends Procedures Document, 1900-1993* (U.S. EPA, 1994) and Section 3 of *National Air Pollutant Emissions Trends Procedures Document, 1900-1996, Projections 1999-2010* (U.S. EPA, 1998a). Each cell in Table 4 that is marked with an "X" represents a Tier II category for which information about the activity levels, emission factors, and control efficiencies are available prior to 1985. The empty cells are those Tier II categories for which there is no discussion of data sources in either *Procedures Document*. Empty cells in Table 4 also correspond to those Tier II categories assigned a "NA" from 1970 to 1984 in the *1970-1997 NACEPT*.

Section 3 of the *National Air Pollutant Emissions Trends Procedures Document, 1900-1993* (U.S. EPA, 1994), section 3 of the *National Air Pollutant Emissions Trends Procedures Document, 1900-1996, Projections 1999-2010* (U.S. EPA, 1998a), and source categories listed in

[10] For a limited number of Tier II categories, emissions are not reported until 1990. These categories are Paint, Varnish, Lacquer, Enamel Mfg. (CO and $SO_2$ emissions; the $SO_2$ emissions are not reported until 1992), Electronic Equipment ($NO_x$ emissions), Construction (PM-10 and VOC emissions). When emissions are finally reported for these categories, they produce small quantities of emissions. As a result, these categories do not affect the discussion in section 2.3. In addition, an "NA" cell can indicate that the emissions associated with that category are "... contained in a more aggregate estimate" during the years prior to 1985.

*Table 4*
***Procedures Document* Describes the Procedure to Estimate Emissions from Selected Tier II Categories of Process Emissions**
("X" = discussion of available data on activity levels, emission factors, and control efficiencies)

| Tier I Category | Tier II Category | PM-10 | $SO_2$ | $NO_x$ | CO | VOC |
|---|---|---|---|---|---|---|
| Chemical & Allied Product Mfg. | Organic Chemical Mfg. | X | | X | X | X |
| Chemical & Allied Product Mfg. | Inorganic Chemical Mfg. | X | X | X | X | X |
| Chemical & Allied Product Mfg. | Polymer & Resin Mfg. | | | | | X |
| Chemical & Allied Product Mfg. | Agricultural Chemical Mfg. | X | | | | |
| Chemical & Allied Product Mfg. | Paint, Varnish, Lacquer, Enamel Mfg. | | | | | X |
| Chemical & Allied Product Mfg. | Pharmaceutical Mfg. | | | | | X |
| Chemical & Allied Product Mfg. | Other Chemical Mfg | X | X | | X | X |
| Metals Processing | Nonferrous Metals Processing | X | X | | X | |
| Metals Processing | Ferrous Metals Processing | X | X | X | X | X |
| Metals Processing | Not Elsewhere Classified | X | | | | |
| Petroleum & Related Industries | Oil & Gas Production | | X | | | X |
| Petroleum & Related Industries | Petroleum Refineries & Related Industries | X | X | X | X | X |
| Petroleum & Related Industries | Asphalt Manufacturing | X | | | | X |

*(Table 4 continued)*
***Procedures Document* Describes the Procedure to Estimate Emissions from Selected Tier II Categories of Process Emissions**
("X" = discussion of available data on activity levels, emission factors, and control efficiencies)

| Tier I Category | Tier II Category | PM-10 | $SO_2$ | $NO_x$ | CO | VOC |
|---|---|---|---|---|---|---|
| Other Industrial Processes | Agriculture, Food, & Kindred Products | X | | | | X |
| Other Industrial Processes | Textiles, Leather, & Apparel Products | | | | | |
| Other Industrial Processes | Wood, Pulp & Paper, & Publishing Products | X | X | X | X | |
| Other Industrial Processes | Rubber & Miscellaneous Products | | | | | X |
| Other Industrial Processes | Mineral Products | X | X | X | X | X |
| Other Industrial Processes | Machinery Products | | | | | |
| Other Industrial Processes | Electronic Equipment | | | | | |
| Other Industrial Processes | Transportation Equipment | | | | | |
| Other Industrial Processes | Construction | | | | | |
| Other Industrial Processes | Miscellaneous Industrial Processes | | | | | |

Appendix A of *1970-1990 Emissions*, "NA" cells for Tier II industrial processes indicate the unavailability of information required to estimate the emissions of those categories.[11] Prior to 1985, some Tier II categories marked with an "X" may have Tier III categories whose emissions are listed as "NA." Although there is no written discussion of changes in the assignment of emissions from Tier III categories, it appears that many of the "NA" cells of Tier III categories represent cases when emissions are included in other Tier III categories prior to 1985.[12]

Since it is assumed that the "NA" cells of Tier II categories represent cases when the emissions are not estimated, emissions from Tier II categories that list "NA" are estimated using the backward indexing method. Since it is assumed that "NA" cells of Tier III categories represent cases when the emissions are included in another Tier III category, in most instances emissions for these "NA" cells are not estimated.

The only Tier III categories whose "NA" cells are estimated are the following: misc. metal parts, steel drums, and electronic & other electrical categories. These categories are associated with VOC emissions from the Surface Coating (Tier II) category. Emissions from the misc. metal parts and steel drums categories are assigned to SIC 34. Metal cans, which is the only other Surface Coating process assigned to SIC 34, reported an increase in emissions between 1984 and 1985. Emissions from "electronic & other electrical" are assigned to SIC 36. The only other Surface Coating process assigned to SIC 36 - large appliances - reported a small decrease in emissions between 1984 and 1985. In addition, between 1984 and 1985 there is a substantial decline in VOC emissions from the miscellaneous (Tier III) category, which is not assigned to an industry. As a result, it is assumed that prior to 1985, VOC emissions from these three Tier III categories were included in the miscellaneous (Tier III) category. If this assumption is correct, assigning values to the "NA" cells of these three Tier III categories does not overestimate the VOC emissions assigned to the industrial sector.

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[11] An e-mail correspondence (dated May 30, 2000) from Mr. Bill Barnard, of E.H. Pechan and Associates, indicates that CO emissions from the Agricultural Chemical Mfg. (Tier II) category is a case when no information existed prior to 1985. He also mentions that CO emissions from fireplaces and woodstoves (Tier II) categories are contained in the aggregate emissions for residential burning (Tier II) category.

[12] Comparing the trend in emissions of the Tier III category between 1970 and 1984 in the SIC 7090.WK3 spreadsheet (or the NEA7085.WK3 spreadsheet) with the trend in emissions in the SIC7097.WK3 spreadsheet makes it possible to determine if the emissions of "NA" cells of a Tier III category were included in another Tier III category prior to 1985. Since some emission factors, control efficiencies, and activity levels were revised, the emissions estimates for 1970 to 1984 in the SIC7090.WK3 spreadsheet and the SIC7097.WK3 spreadsheets are not identical. However, there are similarities in the levels and trends of emissions reported by the two spreadsheets. If the change in emissions reported by the two spreadsheets diverges between 1984 and 1985, this is interpreted as evidence that starting in 1985 there was a reassignment of emissions among the Tier III categories.

In the *1940-1990 NAPEE*, process emissions are the product of (1) the activity level, (2) the emission factor and (3) control efficiency associated with each source category. For 1970 to 1984, the *1970-1997 NAPET* employs the same methodology to estimate emissions as the *1940-1990 NAPEE*. Information on changes in emission factors, control efficiencies, and activity levels relative to 1985 is required to estimate emissions for Tier II categories whose emissions are recorded as "NA" for 1970 to 1984. Since it not possible to determine the emission factors and control efficiencies for the categories whose emissions are recorded as "NA," emissions from these Tier II categories are estimated by adjusting their 1985 emissions based solely on changes in the activity level of the category.[13] This approach assumes that the emission factor and control efficiency for these Tier II categories are constant between 1970 and 1985.

Physical outputs of processes were the activity levels used by the U.S. EPA (1998a, pp. 3-2 to 3-5) to estimate emissions for 1970 to 1984. After 1984, the U.S. EPA (1998a, pp. 4-42 and 4-43) uses the growth of earnings (i.e., payments to labor) by two-digit SIC industry from the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce to update point source emission estimates. This report uses changes in the value of "real" output of the agriculture sector, the four two-digit SIC mining industries, the construction sector and the twenty two-digit SIC manufacturing industries.

The industrial production indexes of the Board of Governors of the Federal Reserve System are used to estimate changes in "real" output for the four two-digit SIC mining industries and the twenty two-digit SIC manufacturing industries (see Armitage and Tranum, 1990 and Board of Governors, 1999). Estimates of output of the agriculture and construction sectors are from the Bureau of Economic Analysis of the U.S. Department of Commerce (Yuskavage, 1996; Lum and Yuskavage, 1997; and Lum and Moyer, 1998).[14]

The relative importance of the Tier II categories whose process emissions are listed as "NA" in the *1970-1997 NAPET* varies among the pollutants. Appendix C reports the percentage

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[13] If the actual emission factor is higher and/or the control efficiency is lower prior to 1985 and only the change in the activity level is used to estimate emissions between 1970 and 1984, then emissions from a process are underestimated. Since only changes in the activity level are used to estimate emissions, the estimates probably underestimate the emissions. However, for the purposes of this report, underestimating emissions is preferable to assuming that those Tier II categories generated no emissions for 1970 to 1984.

[14] BEA data on gross product by industry (i.e., value added) for 1977 to 1997 are derived using a different methodology than the methodology that it employed to estimate the gross product by industry for 1970 to 1976. The estimates of output produced by the Board of Governors of the Federal Reserve System are also generated by a different methodology than that used by the BEA for 1977 to 1997.

of process emissions in 1985 for those categories whose emissions are estimated in this report.[15] Appendix D describes the backward indexing method used to estimate emissions for the categories listed as "NA" prior to 1985.

The remainder of Section 2.3. discusses source categories whose emissions are listed as "NA" in the *1970-1997 NAPET*. In addition, evidence is presented on the accuracy of the assumption that emission factors and control efficiencies are constant during the years from 1970 to 1985.[16] Finally, instances of significant changes in emissions between 1984 and 1985, which are reported in the SIC7097.WK3 spreadsheet, are discussed. This allows an analysis of errors resulting from assuming all "NA"cells of Tier II categories must be estimated and "NA"cells of Tier III categories reflect emissions included in other Tier III categories prior to 1985.

### 2.3.1. $NO_x$ emissions

Tier II categories that report "NA" for emissions in 1984, account for 39.3 percent of $NO_x$ process emissions in 1985. The seventeen source categories of $NO_x$ process emissions, which are in the SIC7090.WK3 spreadsheet, report no control efficiencies from 1970 to 1985. In addition, the *National Air Pollutant Emissions Trends Procedures Document, 1900-1996, Projections 1999-2010*, (U.S. EPA, 1998a) indicates that no control efficiencies are associated with processes that generate $NO_x$ emissions. Except for the emission factors of the (1) nitric acid and (2) iron & steel - roll & finish processes, which show higher emission factors from 1970 to 1984 relative to their 1985 emission factors, there are constant emission factors for the source categories. As a result, with the exception of two processes previously mentioned, changes in activity levels are the sole determinants of changes in $NO_x$ process emissions.

Between 1984 and 1985, there is a substantial decline in $NO_x$ emissions from the Inorganic Chemicals (Tier II) category. The quantity of $NO_x$ emissions from the Agricultural Chemicals (Tier II) category changed from "NA" in 1984 to a substantial amount in 1985. In spite of this, Agricultural Chemicals is a Tier II category and it is assumed that the "NA" for its emissions indicates that data are not available prior to 1985.

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[15] In Appendix C, the value in the column entitled "1985 Emissions of cells listed as 'NA' in 1984" for the Other Industrial Processes (Tier I) category includes the emissions from the Miscellaneous Industrial Processes (Tier II) category. Emissions from the Miscellaneous Industrial Processes (Tier II) category are not assigned to an industry.

[16] The SIC7090.WK3 spreadsheet, which contains the data used to estimate the emissions reported in *1970-1990 Emissions*, provides insights into the extent of changes in emission factors and control efficiencies from 1970 to 1985. Appendix A of *1970-1990 Emissions* contains a complete listing of the source categories in the SIC7090.WK3 spreadsheet that are referred to in the remainder of Section 2.3.

2.3.2. VOC emissions

Tier II categories that report "NA" for emissions in 1984, account for 9.6 percent of the VOC process emissions in 1985. If the categories from the Solvent Utilization and Storage & Transport categories assigned to industries in this report are included, then source categories that report "NA" for VOC emissions in 1984, represent 6.6 percent of the VOC emissions in 1985.

The SIC7090.WK3 spreadsheet and the *National Air Pollutant Emissions Trends Procedures Document* (U.S. EPA, 1998a) report constant emission factors for the two processes assigned to SIC 33 (metals processing). In addition, the SIC7090.WK3 spreadsheet reports no control efficiencies for either of these source categories. Hence, in the SIC7090.WK3 spreadsheet only changes in activity levels determine changes in VOC emissions from SIC 33.

Of the six processes from the "Other Industrial Processes" category assigned to industries, no control efficiencies are reported by either the SIC7090.WK3 spreadsheet or the *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a). According to the SIC7090.WK3 spreadsheet, all processes in this Tier I category had constant emission factors between 1970 and 1985. This category accounts for 57 percent of the VOC process emissions in 1985 that are reported a "NA" in 1984.

Among the fifty processes assigned to SIC 28 (chemicals) in the SIC7090.WK3 spreadsheet, the emission factors changed for the following two processes: (1) manufacture of petrochemicals - other products and (2) manufacture of petrochemicals - fugitive. From 1970 to 1984, the control efficiencies of five processes in this Tier I category were lower than their 1985 control efficiencies.

According to the SIC7090.WK3 spreadsheet, the eleven processes assigned to SIC 29 (petroleum industry) had constant emission factors between 1970 and 1985. From 1970 to 1984, the control efficiencies of five of these processes were less than their 1985 levels.

Of the source categories in the SIC7090.WK3 spreadsheet that correspond to processes within either the Solvent Utilization or Storage & Transport (Tier I) categories, only the gasoline storage at refineries category is assigned control efficiencies. From 1970 to 1984, the control efficiencies of this process were less than its 1985 level. According to the SIC7090.WK3, the Graphics Arts category and the five categories associated with oil production and storage spreadsheet exhibit constant emission factors between 1970 and 1985. However, the emission factors were higher from 1970 to 1984, relative to their 1985 levels, for fourteen of the eighteen categories that belong to Surface Coating Operations category in the SIC7090.WK3 spreadsheet.

There are several instances in which "NA" cells might represent cases when the emissions of a category are classified in another category prior to 1985. There are five Tier III categories associated with the Other Chemical Mfg. (Tier II) category. Of these five categories, the carbon black mfg. (Tier III) category is the only one that reports emissions prior to 1985. The

printing ink mfg., fugitives unclassified, carbon black furnace: fugitives, and the "other" (Tier III) categories report "NA" emissions. Until 1984, the changes in the emissions from the carbon black category in the SIC7090.WK3 spreadsheet are similar to the changes reported for the carbon black mfg. (Tier III) category in the SIC7097.WK3 spreadsheet. The SIC7097.WK3 spreadsheet reports a substantial decline in the VOC emissions between 1984 and 1985 from the carbon black mfg. (Tier III) category. This decline is not reported for the carbon black category in the SIC7090.WK3 spreadsheet. The increase in emissions between 1984 and 1985 from the Other Chemical Mfg. (Tier II) category can be explained if starting in 1985 some emissions were transferred from the carbon black mfg. (Tier III) category to the other Tier III categories.

Five Tier III categories are associated with VOC emissions from the Petroleum Refineries & Related Industries (Tier II) category. Prior to 1985, the vacuum distillation, cracking units, and "other" (Tier III) categories report emissions. The "process units turnarounds" and "petroleum refinery fugitives" (Tier III) categories report "NA." Until 1984, changes in emissions from the vacuum distillation, cracking units, and "other" (Tier III) categories in the SIC7097.WK3 spreadsheet are similar to the changes reported by their corresponding categories in the SIC7090.WK3 spreadsheet. However, between 1984 and 1985 the SIC7097.WK3 spreadsheet reports substantial declines in the emissions from all three (Tier III) categories. These declines are not reported for the comparable categories in the SIC7090.WK3 spreadsheet. Adding emissions from the "process units turnarounds" and "petroleum refinery fugitives" (Tier III) categories to the emissions from the other three Tier III categories yields a larger decline in the emissions from the Petroleum Refineries & Related Industries (Tier II) category in the SIC7097.WK3 spreadsheet than the SIC7090.WK3 spreadsheet. Hence, emissions from the "process units turnarounds" and petroleum refinery fugitives (Tier III) categories may not have been included in the vacuum distillation, cracking units, and "other" (Tier III) categories prior to 1985. Since they are Tier III categories, the "NA" cells for the "process units turnarounds" and "petroleum refinery fugitives" categories are not estimated.

There are four Tier III categories of VOC emissions associated with the Agriculture, Food, & Kindred Products (Tier II) category. Three of these categories report emissions for 1970 to 1984: (1) vegetable oil mfg., (2) whiskey fermentation: aging, and (3) bakeries. The only Tier III category that does not report emissions is the "other" category. The changes between 1984 and 1985 in the emissions associated with the whiskey fermentation: aging, and bakeries source categories in the SIC7090.WK3 spreadsheet are similar to the changes in the SIC7097.WK3 spreadsheet. Between 1984 and 1985, the SIC7097.WK3 spreadsheet reports a substantial decline in emissions from the vegetable oil mfg. (Tier III) category; however, a small decrease is reported in the SIC7090.WK3 spreadsheet for its corresponding source categories. The emissions of the Agriculture, Food, & Kindred Products (Tier II) category in the SIC7097.WK3 spreadsheet and the comparable categories in the SIC7090.WK3 spreadsheet are similar for 1984 and 1985. Hence, it appears that most - maybe all - of the decline in the emissions from the vegetable oil mfg. (Tier III) category is the consequence of emissions being reassigned from the vegetable oil mfg. (Tier III) category to the "other" (Tier III) category.

Three Tier III categories are associated with VOC emissions from the Rubber & Miscellaneous Plastic Products (Tier II) category. Among these Tier III categories, only the ruber tire mfg. (Tier III) category reports emissions prior to 1985. Prior to 1985, emissions from the green tire spray and "other" Tier III categories are reported as "NA." Until 1984, the changes in emissions from the rubber tire category in the SIC7090.WK3 spreadsheet are similar to the changes reported for the rubber tire mfg. (Tier III) category of the SIC7097.WK3 spreadsheet. A significant decline in the emissions between 1984 and 1985 is reported for the rubber tire mfg. (Tier III) category in the SIC7097.WK3 spreadsheet; however, there is only a slight decline in emissions reported for the rubber tire category by the SIC7090.WK3 spreadsheet. In the SIC7097.WK3 spreadsheet, the decline in emissions between 1984 and 1985 from the Rubber & Miscellaneous Plastic Products (Tier II) category is not as substantial as the decline reported for the ruber tire mfg. (Tier III) category. Starting in 1985, emissions are reported for the green tire spray and "other" Tier III categories. Hence, the decline in VOC emissions associated with the ruber tire mfg. (Tier III) category seems to be at least partly the result of reassigning emissions from the rubber tire (Tier III) category to the other Tier III categories.

### 2.3.3. CO emissions

Tier II categories that have "NA" listed for emissions in 1984, account for 1.5 percent of the CO process emissions in 1985. According to the SIC7090.WK3 spreadsheet, the emission factors of all twenty-seven sources of CO emissions are constant from 1970 to 1985.

Of the two processes from the "Other Industrial Processes" category assigned to industries, no control efficiencies are reported by either the SIC7090.WK3 spreadsheet or *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a). Hence, in the SIC7090.WK3 spreadsheet only changes in activity levels determine changes in CO emissions from the "Other Industrial Processes" category.

Of the thirteen source categories assigned to SIC 28 (chemical industry), control efficiencies are reported for three categories (charcoal, carbon black production - oil process, and carbon black production - gas process. During 1970 to 1984, the control efficiencies of these three processes were lower than their 1985 control efficiencies.

Of the five source categories assigned to SIC 29 (petroleum industry) in the SIC7090.WK3 spreadsheet, control efficiencies are reported for two categories (Petroleum refineries, fluid catalytic cracking [FCC] and Petroleum refineries, thermal catalytic cracking [TCC]). During 1970 to 1984, the control efficiencies of these two processes were lower than their 1985 levels.

Of the seven source categories assigned to SIC 33 (metals processing) in the SIC7090.WK3 spreadsheet, control efficiencies are reported for two categories (Iron Foundries and Steel Manufacturing - B.O.F.). During 1970 to 1984, the control efficiencies of these two processes were lower than their 1985 control efficiencies.

There are several instances in which "NA" cells might represent cases when emissions of a category are assigned to another category prior to 1985. There are three Tier III categories associated with the Other Chemical Mfg. (Tier II) category. Of these three categories, the carbon black mfg. (Tier III) category is the only Tier III category that reports emissions prior to 1985. The carbon black furnace: fugitives, and the "other" (Tier III) categories report that emissions are "NA." Until 1984, the changes in emissions from the carbon black category in the SIC7090.WK3 spreadsheet are similar to the changes in CO emissions reported for the carbon black mfg. (Tier III) category. Between 1984 and 1985, the SIC7097.WK3 spreadsheet reports a larger decline in the CO emissions from the carbon black mfg. (Tier III) category than is reported in the SIC7090.WK3 spreadsheet. Between 1984 and 1985, there is an increase in CO emissions from the Other Chemical Mfg. (Tier II) category as a result of emissions being assigned to the carbon black furnace: fugitives, and the "other" (Tier III) categories. Hence, emissions from the carbon black furnace: fugitives and the "other" (Tier III) categories might have been excluded from the carbon black mfg. (Tier III) category prior to 1985. However, since they are Tier III categories, the "NA" cells for these two categories are not estimated.

Three Tier III categories are associated with the Nonferrous Metals Processing (Tier II) category. The aluminum anode baking and prebake aluminum cell (Tier III) categories report emissions prior to 1985, while the "other" (Tier III) category reports "NA." From 1970 through 1984, the changes in CO emissions from the aluminum source category in the SIC7090.WK3 spreadsheet are similar to the changes of the combined emissions from the aluminum anode baking and prebake aluminum cell (Tier III) categories in the SIC7097.WK3 spreadsheet. The change in the CO emissions between 1984 and 1985 of the Nonferrous Metals Processing (Tier II) category is similar to the change in the aluminum source category in the SIC7090.WK3 spreadsheet. However, between 1984 and 1985 there is a substantial decline in emissions associated with the aluminum anode baking (Tier III) category. The amount of the decline is similar to the emissions reported for the "other" (Tier III) category. Hence, the decline in emissions associated with the aluminum anode baking (Tier III) category is assumed to be the consequence of a transfer of emissions from it to the "other" source category.

Three Tier III categories are associated with the Wood, Pulp & Paper, and Publishing Products (Tier II) category. Only the sulfate (kraft) pulping: lime kiln (Tier III) category reports emissions prior to 1985. The sulfate pulping: rec. furnace/evaporator and the "other" (Tier III) categories report "NA." Until 1984, the changes in emissions from the kraft pulping source category reported in the SIC7090.WK3 spreadsheet are comparable to the changes in CO emissions reported for the sulfate (kraft) pulping: lime kiln (Tier III) category. However, the SIC0797.WK3 spreadsheet reports a substantial decline in the CO emissions between 1984 and 1985 from the sulfate (kraft) pulping: lime kiln (Tier III) category. This decline in emissions is not reported in the SIC7090.WK3 spreadsheet. Even after including emissions from all three Tier III categories, the decline in CO emissions from the Wood, Pulp & Paper, and Publishing Products (Tier II) category that is reported in the SIC7097.WK3 spreadsheet is not comparable with the change in emissions from the kraft pulping source category in the SIC7090.WK3 spreadsheet. Hence, it appears that there is a transfer of emissions from the sulfate (kraft)

pulping: lime kiln (Tier III) category to the sulfate pulping: rec. furnace/evaporator and the "other" (Tier III) categories.

### 2.3.4. PM-10 emissions

The *1970-1997 NAPET* reports no process emissions of PM-10 for all source categories for 1971 to 1974. This report estimates those emissions through the use of the two-way indexing method that is discussed in Appendix D.

Tier II categories that report "NA" emissions in 1984, account for 4.9 percent of the PM-10 process emissions in 1985. Of the 135 processes that are sources of PM emissions in SIC7090.WK3, only four exhibit higher emission factors for 1970 to 1984 relative to their emission factors for 1985. The SIC7090.WK3 spreadsheet indicates control efficiencies for a number of the source categories of PM-10 emissions, fluctuated between 1970 and 1985. For example, of the fourteen processes assigned to SIC 28 (chemical industry) in the SIC7090.WK3 spreadsheet, the control efficiencies of nine are constant between 1970 and 1985. During 1970 to 1984, the control efficiencies of three processes were both higher and lower than their 1985 emission factors, and the control efficiencies of two processes were lower than their 1985 emission factors.

No "NA" cells appear to represent instances when the emissions of a category are classified in another category prior to 1985. This reflects the fact that emissions from the categories whose cells are listed as "NA"in 1984 are a relatively small percentage of PM-10 emissions in 1985.

### 2.3.5. $SO_2$ emissions

Tier II industrial process categories reporting "NA" emissions in 1984, account for 2.2 percent of the $SO_2$ process emissions in 1985. From 1970 to 1985, no control efficiencies for any of the source categories that generate $SO_x$ emissions are reported by either the SIC7090.WK3 spreadsheet or the *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a). Hence, only changes in the emission factors and activity levels influence changes in the twenty-five categories of $SO_x$ process emissions.

The SIC7090.WK3 spreadsheet lists four processes, which are assigned to industries, in the "Other Industrial processes" category. During 1970 to 1985, the emission factors of three of the categories were constant. During 1970 to 1984, the emission factor of one process (cement manufacturing) was both higher and lower than its 1985 emission factor.

In the SIC7090.WK3 spreadsheet, four processes are the source of the $SO_x$ emissions from SIC 29 (chemical industry). Among the processes in the Chemical & Allied Products Mfg. (Tier I) category, "carbon black" is assigned a "NA" in 1970 and 1971. Since the SIC7090.WK3 spreadsheet reports no emission factor for the carbon black source category in 1970 and 1971,

this report assigns no emissions to the carbon black process category for 1970 and 1971. The $SO_x$ emission factor from carbon black processes increased between 1972 and 1985. From 1970 to 1984, the emission factors of the four processes are higher than their 1985 levels.

Of the twelve processes assigned to SIC 33 (metals processing) in the SIC7090.WK3 spreadsheet, eight exhibited constant emission factors during 1970 to 1985. During 1970 to 1984, the emission factor for the Iron and steel (roll and finish) process fluctuated both above and below its 1985 emission factor. During 1970 to 1984, the emission factors of the three copper smelting processes are higher than their 1985 emission factors.

Of the five processes assigned to SIC 29 (petroleum industry), three exhibited constant emission factors between 1970 and 1985. During 1970 to 1984, the emission factor of oil process heaters is higher than its 1985 emission factor. Between 1970 and 1984, the emission factor of gas process heaters is below its 1985 level.

No "NA" cells appear to represent the case when the emissions of a category are classified in another source category prior to 1985. This reflects the fact that 1985 emissions associated with categories whose cells are listed as "NA"in 1984 are a relatively small percentage of $SO_2$ emissions.

### 2.3.6. Pb emissions

Those source categories that have "NA" listed for emissions in 1984, account for no Pb emissions in 1985.

## 3. EMISSIONS FROM FUEL COMBUSTION

The second step in assigning emissions to industries is to allocate emissions from fuel combustion. An industry's allocation of fuel combustion emissions is based on its consumption of fuel for heat and power.[17] An industry's share of consumption of a fuel for heat and power is assumed to equal its share of the emissions from combustion of that fuel. The product of an industry's share of consumption of a type of fuel by the industrial sector and emissions from combustion of that fuel by the industrial sector yields the estimate of that industry's emissions

[17] The values of fuels purchased for heat, power and electricity generation are used to allocate fuel combustion emissions among the industries of the industrial sector. The estimates of emissions assigned to electric utilities in the *1940-1990 NAPEE* and the *1970-1997 NAPET* are for emissions from electric utility plants (see *National Air Pollutant Emission Trends Procedures Document, 1900-1996 Projections 1999-2010*, U.S. EPA, 1998). All SCCs associated with cogeneration are classified in either the Fuel Combustion Industrial or the Fuel Combustion Other (Tier I) categories. Hence, it is assumed that emissions from electricity generated by industries in the industrial sector are included in emission estimates from fuel combustion of the industrial sector.

from combustion of that fuel. This procedure, which is identical to the procedure used in *1970-1990 Emissions*, assumes that a standard boiler is used by all industries.

### 3.1. *Fuel Consumption of the Manufacturing Portion of the Industrial Sector*

Emissions from fuel combustion by the twenty two-digit SIC industries of the manufacturing sector are allocated using information on fuel consumption for heat and power. The two primary sources of information on fuel consumption by the manufacturing sector are the National Energy Accounts (NEA) and the Derived Annual Estimates of Manufacturing Energy Consumption (DAEMEC) data (U.S. DOE, 1992 and 1998a). Among the fuels that the NEA provides information on are the following: (1) coal (NEA energy product code 130), (2) wood for fuel (NEA energy product code 180), (3) natural gas (dry from gas plants) and other utility gases (NEA code energy product 221), (4) still gas, (5) coke oven gas, (6) distillate fuel oil (NEA energy product code 243), and (7) residual fuel oil (NEA energy product code 250).

The DAEMEC (U.S. DOE, 1992 and 1998a) provides data on energy consumption for heat and power (in Btu) by the twenty two-digit SIC manufacturing industries for 1974 to 1994 for the following fuels: (1) coal (excluding coal coke and breeze), (2) residual fuel oil, (3) distillate fuel oil, (4) natural gas, (5) LPG, (6) coke and breeze, and (7) "other" fuels.[18] The energy consumption data for 1985, 1988, 1991, and 1994, which are published in the DAEMEC, are from the "Total Consumption of Offsite-Produced Energy for Heat, Power, and Electricity Generation" tables in the Manufacturing Energy Consumption Survey (U.S. DOE, 1988a, 1991, 1994, and 1997).[19] These data are consistent with the energy consumption data published in the *Annual Survey of Manufactures*, which is the basis of the pre-MECS estimates in the DAEMEC for the manufacturing industries (U.S. DOE, 1992, p. 4).

Although the NEA and DAEMEC data are derived using different assumptions (see U.S. DOE, 1992, pp. 3-4), there are three advantages to using the NEA data.[20] First, the NEA provides data from 1958 to 1985, while the DAEMEC data starts in 1974. Hence, using the NEA

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[18] In 1994, over two-thirds of the consumption of "other" fuels (in Btu) is accounted for by the following three industries (see U.S. DOE, 1997, p. 70): (1) paper and allied products (SIC 26), (2) chemicals and allied products (SIC 28), and (3) petroleum and coal products (SIC 29).

[19] Throughout the remainder of this report, the 1985 MECS, 1988 MECS, 1991 MECS and 1994 MECS refer to the U.S. Department of Energy (U.S. DOE) publications (U.S. DOE, 1988a, 1991, 1994, 1997) that report the results of the triennial Manufacturing Energy Consumption Survey.

[20] Among the differences between the DAEMEC and NEA data, the DAEMEC estimates include only offsite-produced energy; while NEA data includes off-site produced energy and some sources of onsite-produced energy (see U.S. DOE, 1992, p. 4 and Price and Wendling, 1986, p. 4).

allows an annual time series of emissions to start in 1970. Second, NEA data provide estimates of fuel consumption by the nonmanufacturing industries of the industrial sector. When the *Annual Survey of Manufactures* did not report fuel consumption by an industry, the NEA estimated the fuel consumption of those industries.

Given the availability of data about energy consumption and emissions from fuel combustion, emissions from the combustion of the following fuels are assigned to industries: (1) coal, (2) residual fuel oil, (3) distillate fuel oil, (4) natural gas, (5) wood, and (6) coke oven gas and still gas. Consumption of (1) wood and (2) coke oven gas and natural gas reflects fuel produced and consumed at the same establishment. The sources of the estimates of consumption of these fuels are discussed in Sections 3.3.3. and 3.3.4.

Following the procedures discussed in Sections 3.2.1.2. and 3.2.1.3. in *1970-1990 Emissions*, adjustments are made to the fuel consumption data from 1970 to 1984 for selected industries. The change in the methodology employed by the U.S. EPA to estimate emissions from fuel combustion provides the rationale for switching from the NEA data to the DAEMEC data. As a result, the NEA data are used to allocate fuel combustion emissions among industries for 1970 through 1984. DAEMEC (U.S. DOE, 1992 and 1998a) provides the data on fuel consumption employed to allocate fuel combustion emissions among the twenty two-digit SIC manufacturing industries for 1985 to 1994.[21] Energy consumption for 1995 to 1997 by manufacturing industries is estimated using the forward indexing method (see Appendix D). Although the fuel consumption data for 1985 to 1997 are listed in Btu, these data are used to distribute emissions in the same manner as the data for 1970 to 1984.

The magnitude of the discrepancies between the NEA and DAEMEC data on fuel consumption for heat and power by the manufacturing sector are illustrated in the following table. This table lists the respective totals for 1981, which is the last year the *Annual Survey of Manufactures* collected information on the quantities of fuels consumed by the manufacturing sector:[22]

[21] The shares of coal, residual fuel oil, distillate fuel oil, and natural gas consumption assigned to industries in Sheets AB, AC, AD, and AG of the SIC7097.WK3 spreadsheet do not appear to experience a dramatic change between 1984 (NEA data) and 1985 (DAEMEC data).

[22] Since 1981 is the last year the NEA data reports survey estimates of fuel consumption by the manufacturing sector, the NEA estimates of energy consumption for 1982 to 1985 are generated by a forward indexing method.

| Fuel for Heat and Power, Manufacturing (1981) | DAEMEC | NEA |
|---|---|---|
| Coal (1000 short tons) | 52,945 | 56,393 |
| Natural Gas (billion cu. ft.) | 5,437 | 5,555 |
| Distillate Fuel Oil (1000 barrels) | 33,193 | 41,713 |
| Residual Fuel Oil (1000 barrels) | 120,754 | 147,199 |

It is not possible to determine the source of the discrepancies between the NEA and DAEMEC data on an industry-by-industry basis. The NEA data include fuels produced and consumed for heat and power at the same establishment in the petroleum refining, coke ovens, and blast furnace and steel mills industries (see Price and Wendling, 1986, p. 4). For 1970 to 1984, the U.S. EPA adjusts the consumption of some fuels before it estimates fuel combustion emissions (see U.S. EPA, 1998a, pp. 3-35, 3-38, 3-39, 3-43 and U.S. EPA, 2000, pp. 21-23). The adjustments by the U.S. EPA include subtracting residual fuel oil, distillate fuel oil, and natural gas consumed by the petroleum refining industry, and residual fuel oil and natural gas consumed by the blast furnace industry. Although Price and Wendling do not supply information regarding which fuel consumption estimates in the NEA are adjusted, it is likely that most - maybe all - of the NEA adjusted fuel consumption quantities are subtracted before allocating fuel combustion emissions (see Section 3.3.2. for a discussion of MECS data on energy produced and consumed at the same establishment). As a result, the procedure used to assign fuel combustion emissions is unaffected by the NEA adjustments to fuel consumption in the petroleum refining, coke ovens, and blast furnace and steel mills industries.

## 3.2. *Fuel Consumption of the Nonmanufacturing Portion of the Industrial Sector*

This section discusses the estimates of energy consumption by the agriculture, construction, and mining sectors.[23] The NEA data are used to assign emissions from industrial fuel combustion for 1970 through 1984. For 1985 to 1997, it is necessary to derive estimates of fuel consumption for heat and power by these nonmanufacturing sectors. The *1991 Manufacturing Consumption of Energy* (U.S. DOE, 1994, pp. 467-478) discusses an attempt to reconcile estimates of the industrial sector's energy consumption reported in the *State Energy Data Report* (SEDR) with the energy consumption estimates reported in the MECS. The data in the SEDR is considered to be conceptually similar to the "Total Primary Consumption of Energy for All Purposes" table in the 1985, 1988, and 1991 MECS. This table, which includes energy consumed for purposes other than heat and power, was renamed "Total First Use of Energy for

[23] Energy consumption by the mining sector consists of energy consumption by the following four industries: (1) metal mining, (2) coal mining, (3) oil and gas extraction, and (4) nonmetallic minerals, except fuels.

All Purposes" in the 1994 MECS. The basis of the derivation of estimates of fuel consumption by the nonmanufacturing sectors for 1985 to 1997 is the 1991 MECS and Price and Wendling (1986).

Several publications provide the information required to estimate fuel consumption by the nonmanufacturing sectors for 1985 to 1997. *Fuel Oil and Kerosene Sales* (U.S. DOE, various years) provides data on the annual consumption of distillate fuel oil by the agriculture sector. Since the *Census of Agriculture* (natural gas) (U.S. Department of Commerce, 1994), the *Census of Mineral Industries* (natural gas, residual fuel oil, distillate fuel oil, and coal) (U.S. Department of Commerce, 1990b and 1996b), and the *Census of Construction* (natural gas) (U.S. Department of Commerce, 1990a and 1996a) are only available for 1987 and 1992, it is necessary to estimate fuel consumption by these sectors for the remaining years. The two-way indexing method estimates fuel consumption in 1985, 1986, and 1988 to 1991. The forward indexing method estimates fuel consumption for 1993 to 1997.[24]

The following discussion of the estimates of fuel consumption by the nonmanufacturing sectors, highlights the discrepancies between the fuel consumption estimates derived in the NEA and the procedure used by this report to estimate fuel consumption for 1985 to 1997. In addition to this discontinuity in the data, the NEA assigned the fuel consumption of selected SIC codes of industries in the *Census of Mineral Industries* to the construction sector. Due to these inconsistencies, although estimates of fuel consumption by the agriculture, mining, and construction sectors are in SIC7097.WK3, these estimates are not reported in Appendix E.

### 3.2.1. Wood, Coke and Breeze, and LPG

According to the NEA, the nonmanufacturing sectors purchased neither (1) wood (NEA energy product code 180) nor (2) coke and breeze (NEA energy product code 291) for energy between 1958 and 1985. The lack of consistent historical data results in the SEDR excluding consumption of the "... pulping liquor; wood chips, bark, wood waste; net steam and hot water; and miscellaneous energy sources" (U.S. DOE, 1994, p. 477) category, which is included in the MECS. The 1991 MECS (U.S. DOE, 1994, p. 477) also concludes that the *State Energy Data Report* (SEDR) and MECS data for petroleum coke consumption were "... quiet close and judged to be comparable." As a result, it is assumed that the nonmanufacturing sectors consume neither wood nor coke and breeze for heat and power from 1986 to 1997.

According to the1991 MECS (U.S. DOE, 1994, p. 476), the difference between the SEDR and MECS data for purchases of liquified petroleum gas (LPG) can be assigned to the nonmanufacturing sectors. These purchases of LPG include energy consumed for purposes other than heat and power. The NEA also assigned LPG consumption for purposes other than heat and power to the nonmanufacturing sectors.

[24] Appendix D describes the procedures used to estimate the missing observations of fuel consumption for heat and fuel by the nonmanufacturing sectors.

### 3.2.2. Distillate fuel oil

The SEDR reports the following values (in millions of barrels) for consumption of distillate fuel oil by the industrial sector: 225 in 1982, 204 in 1985, 211 in 1987, 210 in 1988, 196 in 1991, and 196 in 1992 (U.S. DOE, 1996, p. 24). It is useful to remember that the SEDR data includes energy consumed for purposes other than heat and power. According to the 1991 MECS (U.S. DOE, 1994, p. 476), the difference between the SEDR and MECS estimates of distillate fuel oil purchases can be assigned to the nonmanufacturing sectors.

According to the MECS, consumption (in 1,000 barrels) of distillate fuel oil for all purposes by the manufacturing sector was 35,739 in 1985, 37,865 in 1988, and 25,016 in 1991. The *Census of Mineral Industries* (U.S. Department of Commerce, 1985, 1990b, 1996b) reports (in 1,000 barrels) the following values for distillate fuel oil consumption for heat and power by the mineral industries of 35,118.9 in 1982, 28,943.8 in 1987, and 27,244.5 in 1992. According to the 1991 MECS (U.S. DOE, 1994, p. 476), distillate fuel oil consumed by the agricultural and construction sectors account for the discrepancy between the SEDR and MECS estimates. However, consumption of diesel fuel, a type of distillate fuel oil, for off-highway motor vehicle use by the agricultural and construction sectors complicates the process of estimating distillate fuel oil consumption for heat and power by these two sectors (U.S. DOE, *Fuel Oil and Kerosene Sales, 1997*, pp. 52-53 ).

In 1985, four industries in the agricultural sector consumed distillate fuel oil for heat and power: NEA 01000 (803.53 thousand barrels), NEA 02000 (5,107.5 thousand barrels), NEA 03000 (0.04 thousand barrels), and NEA 04000 (186.21 thousand barrels). *Fuel Oil and Kerosene Sales* was the source of the NEA estimates of distillate fuel oil consumption by the agricultural sector (Price and Wendling, 1986). In *Fuel Oil and Kerosene Sales*, distillate fuel oil sales to farms are classified as either (1) diesel or (2) "other distillate." This report assumes that the "other distillate" category measures distillate fuel oil consumption for heat and power by farms (NEA 01000 and NEA 02000). *Fuel Oil and Kerosene Sales 1985* (U.S. DOE, 1986) reported "other distillate" sales to farms of 148,086 gallons (3,525.86 barrels). The "adjusted" sales (i.e., deliveries) to farms of "other distillate" were 149,971 gallons (3,570.74 barrels). In this report, the adjusted value of "other distillate" is the estimate of distillate fuel oil consumed by farms. As a result, this report's estimates of distillate fuel oil consumption by agriculture (NEA 01000 and NEA 02000) for 1985 to 1997 are less than the NEA values. Since it is not possible to determine the source of the NEA estimates of distillate fuel oil consumption by NEA 03000 and NEA 04000, there are no estimates for these industries for 1985 to 1997.

From 1985 through 1988, the results of the "Fuel Oil and Kerosene" survey appeared as an appendix in two U.S. DOE publications. Distillate oil fuel consumption by farms for 1985 through 1987 appears in *Petroleum Marketing Monthly* (U.S. DOE, 1986, 1987, and 1988b). Distillate fuel oil consumption by farms in 1988 is in *Petroleum Marketing Annual* (U.S. DOE, 1989). For 1989 through 1997, *Fuel Oil and Kerosene Sales* (U.S. DOE, various issues) is the source of "other distillate" fuel oil sales to farms.

According to the NEA, 42,850.3 thousand barrels of distillate fuel oil were consumed for heat and power by the mining (26,514.3 thousand barrels) and construction (16,336 thousand barrels) sectors in 1982. According to the *Census of Mineral Industries* (U.S. Department of Commerce, 1985), the mineral industries purchased 35,118.9 thousand barrels of distillate fuel oil for heat and power in 1982. The NEA assigns the energy consumption of some industries (i.e., pt. SIC 11, pt. SIC 12, SIC 138, and pt. SIC 148), which is reported in the *Census of Mineral Industries*, to the construction sector (NEA 11001, NEA 11002, and NEA 12000).

It is not possible to determine the source of the discrepancy (7,721.4 thousand barrels) between the NEA and *Census of Mineral Industries* estimates of residual fuel oil consumption in 1982. Relative to the NEA, this report underestimates residual fuel oil consumption by the nonmanufacturing sectors from 1985 to 1997 .[25] The relative importance of this discrepancy can also be illustrated by recalling the amounts of distillate fuel oil consumed by the manufacturing sector. According to the U.S. DOE (1992, Errata, p. 29), 28,859 thousand barrels were consumed by manufacturing industries in 1982. However, the NEA estimates that 39,396 thousand barrels were consumed by the manufacturing sector in 1982.

### 3.2.3. Coal

The EIA's *Quarterly Coal Report* is the source of the SEDR estimates of coal consumption. In attempting to reconcile the discrepancy between the SEDR and MECS estimates of coal consumption, the 1991 MECS (U.S. DOE, 1994, pp. 470-472) estimates nonmanufacturing coal consumption by subtracting the SEDR estimate of coal consumption by manufacturing plants from its estimate of coal consumption by "other industrial" plants.[26]

According to Price and Wendling (1986, pp. 3-4), the primary source of information used by the NEA to estimate the coal consumption of the mineral industries was the *Census of Mineral Industries*.[27] Aside from the mineral industries, coal was consumed coal for heat and power by one other nonmanufacturing industry - livestock and livestock products (NEA 01000).

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[25] For 1985 to 1997, distillate fuel oil consumption by the mining and construction sectors are estimated by using data from the 1982, 1987 and 1992 *Census of Mineral Industries* (U.S. Department of Commerce, 1985, 1990b, and 1996b), and two-way indexing, backward indexing, and forward indexing methods. The backward indexing is used with estimates from the *1987 Census of Mineral Industries* to estimate distillate fuel oil consumption for those industries whose consumption is not disclosed in the *1982 Census of Mineral Industries*.

[26] "other industrial" corresponds to "industrial" establishments minus coke plants

[27] According to the *1982 Census of Mineral Industries* (U.S. Department of Commerce, 1985), the mining sector purchased 3,046.2 thousand short tons of coal for heat and power. The NEA reported the consumption of 3,110.74 thousand short tons of coal for heat and power by the mining sector. It is not possible to determine the source of this discrepancy.

Livestock and livestock products (NEA 01000) consumed 41.48 thousand short tons of coal in 1982. Price and Wendling (1986) do not cite any source for the estimate of coal consumption by NEA 01000. In addition, no estimates of coal purchases by NEA 01000 for 1986 to 1997 could be located. Comparing the estimates of coal purchases by the nonmanufacturing sectors for 1987 and 1992 that are derived from the *Quarterly Coal Report* with the values reported in the 1987 and 1992 *Census of Mineral Industries* (U.S. Department of Commerce, 1990b and 1996b) provides a check on the equivalence of the SEDR and NEA data.

According to the *Quarterly Coal Report*, coal purchases by the nonmanufacturing sectors totaled 6,108 thousand short tons in 1987 (Oct-Dec. 1991, p. 39, and Oct-Dec. 1988, p. 46) and 8,877 thousand short tons in 1992 (Oct-Dec. 1995, p. 79, and Oct-Dec. 1993, p. 80 ). The *Census of Mineral Industries* (U.S. Department of Commerce, 1990b and 1996b) reported coal purchases (1000 short tons) of 3,098.7 in 1987 and 2,847.8 in 1992. According to the *Census of Mineral Industries*, the following quantities (1000 short tons) were produced and consumed at the same establishment for heat and power: 276.7 in 1987 and 301.8 in 1992. Hence, the *Quarterly Coal Report* assigns more coal consumption for heat or power to the nonmanufacturing sectors than the estimates derived using the NEA methodology.

The magnitude of this discrepancy can be appreciated by remembering that DAEMEC estimates 48,004 thousand short tons of coal were consumed by the manufacturing sector in 1982 (see U.S. DOE, 1992, Errata, p. 35) and the NEA estimates the manufacturing sector consumed 52,196 thousand short tons of coal. In this report coal consumption by the mining and construction sectors for 1985 to 1997, are estimated using data from the 1982, 1987 and 1992 *Census of Mineral Industries*, and the two-way indexing and forward indexing methods.

### 3.2.4. Residual fuel oil

The 1991 MECS reported more consumption of residual fuel oil for heat and power by the manufacturing sector than the SEDR reported for the entire industrial sector (U.S. DOE, 1994, p. 475). There is no explanation for this inconsistency between the MECS and SEDR estimates of purchases of residual fuel oil by the nonmanufacturing sectors. As a result, this report utilizes the same sources of information as the NEA.

The NEA reports no consumption of residual fuel oil by NEA 01000 and NEA 02000. *Fuel Oil and Kerosene Sales* (U.S. DOE, various years) provides some insights into the quantity of residual oil consumed by farms (NEA 01000 and NEA 02000). In 1994, the residual fuel oil consumed by farms is combined with the following consumers of residual fuel oil: (1) residential, (2) railroad, (3) on-highway diesel use, (4) off-highway use, and (5) all other uses. These six end-use categories combine for 5.9 percent of residual fuel oil sales to industrial and oil company end-users in 1986 and 0.2 percent of residual fuel oil sales to industrial and oil company end-

users in 1994.[28] In 1989, there was a dramatic decline in sales to these six end-use categories. Since *Fuel Oil and Kerosene Sales* indicates relatively little residual fuel oil is consumed by farms, this study assigns no residual fuel oil to NEA 01000 and NEA 02000.

In addition to the mining sector, the NEA reported the consumption of residual fuel oil for heat and power to the following NEA 03000, NEA 11001, NEA 11002, and NEA 12000. In 1982, NEA 03000 consumed 0.05 thousand barrels, NEA 11001 consumed 1,797.31 thousand barrels, NEA 11002 consumed 2623.88 thousand barrels, and NEA 12000 consumed 537.43 thousand barrels. The NEA assigned 12,615.4 thousand barrels to the mining (7,656.8 thousand barrels) and construction (4,958.6 thousand barrels) sectors in 1982. According to the *1982 Census of Mineral Industries* (U.S. Department of Commerce, 1985), the mineral industries purchased 9,241.7 thousand barrels in 1982. The *Census of Mineral Industries* collects data for industries (i.e., pt. SIC 11, pt. SIC 12, SIC 138, and pt. SIC 148) assigned to the construction sector (NEA 11001, NEA 11002 and NEA 12000) by the NEA. It is not possible to determine the source of the difference (3,373.7 thousand barrels) between the NEA estimate of residual fuel oil consumed by the mining and construction sectors and the *Census of Mineral Industries* estimate for 1982.

In this report, the *Census of Mineral Industries* provides the estimates of residual fuel oil consumed by the mining and construction sectors. As a result, this report underestimates residual fuel oil consumed for heat and power by the nonmanufacturing sectors for 1985 to 1997 relative to the method employed by the NEA. The magnitude of this discrepancy can be appreciated by remembering that the DAEMEC reports 92,667 thousand barrels of residual fuel oil were consumed by manufacturing industries in 1982 (see U.S. DOE, 1992, Errata, p. 31). According to the NEA, 127,728 thousand barrels of residual fuel oil were purchased by the manufacturing sector in 1982. For 1985 to 1997, residual fuel oil consumption by the mining and construction sectors is estimated by using data from the 1987 and 1992 *Census of Mineral Industries* (U.S. Department of Commerce, 1990b and 1996b) and the two-way indexing and forward indexing methods for non-census years. Since data on residual fuel oil consumption are not disclosed in the *1982 Census of Mineral Industries*, data from the *1987 Census of Mineral Industries* and the backward indexing method is used to estimate residual fuel oil consumption in 1985 and 1986.

### 3.2.5. Natural gas

In attempting to reconcile the SEDR and MECS data on natural gas consumption, the 1991 MECS refers to the *Census of Mineral Industries*. The *Census of Mineral Industries* was also used by the NEA to estimate the natural gas consumption of the mining sector. As a result, for 1985 to 1997, natural gas consumption by the mineral industries is estimated using data from the 1982, 1987 and 1992 *Census of Mineral Industries*, and the two-way indexing and forward indexing methods.

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[28] For this survey, the industrial sector consists of mines, smelters, and manufacturing (excluding oil company use) (see U.S. DOE, *Fuel Oil and Kerosene Sales 1997*, p. 52).

The SEDR estimates of natural gas consumption exclude the agriculture and construction sectors (see U.S. DOE, 1994, p. 473). According to the NEA, heat and power is the sole use of natural gas consumed by the agriculture (NEA 01000 and NEA 02000) and construction (NEA 11001, NEA 11002, and NEA 12000) sectors. When estimating natural gas consumption by these two sectors, this study adopts the NEA methodology. The 1992 *Census of Agriculture* (U.S. Department of Commerce, 1994, p. 29) provides estimates of natural gas purchases (in dollars) by SIC 01 and SIC 02 (i.e., NEA 01000 and NEA 02000) for 1982, 1987, and 1992. The 1982, 1987, and 1992 *Census of Construction* (U.S. Department of Commerce, 1984, 1990a, 1996a) provide estimates of natural gas purchases (in dollars) by the construction sector. The *1992 Census of Construction* reports a combined value for purchases of natural and manufactured gas, which serves as the proxy for natural gas consumption by the construction sector. For the non-census years from 1985 to 1997, natural gas consumption by the agriculture and construction sectors is estimated using the two-way indexing and forward indexing methods.

Since only monetary values of natural gas purchases by the agriculture and construction sectors are available, an average price for natural gas is used to estimate the quantity of natural gas purchased by these two sectors in 1987 and 1992. *Historical Natural Gas Annual 1930 Through 1997* (U.S. DOE, 1998b) is the source of the average price of natural gas delivered to U.S. industrial customers, which is used for both the agriculture and construction sectors.[29] Prior to 1996 (see *Historical Natural Gas Annual 1930 Through 1997,* U.S. DOE, 1998b, p. 12), natural gas consumption by the agriculture sector was classified as a commercial use. However, the price of natural gas for industrial consumers, which is less than the price of natural gas paid by commercial consumers, is used because it yields an estimate of the quantity of natural gas consumed that is closer to the NEA estimate for the agriculture and construction sectors in 1982.

According to the NEA, 352.93 billion cubic feet of natural gas were consumed by the mining sector and 75.49 billion cubic feet were consumed by the construction sector.[30] According to the *1982 Census of Mineral Industries* (U.S. Department of Commerce, 1985), 375.7 billion cubic feet of natural gas were purchased by the mineral industries. The estimate of natural gas purchases by the construction sector reported in the *1982 Census of Construction* (U.S. Department of Commerce, 1984) and the prices reported in *Historical Natural Gas Annual 1930 Through 1997* (U.S. DOE 1998b) are combined to derive an estimate of 69.75 billion cubic feet of natural gas purchases by the construction sector.

According to the NEA, farms (NEA 01000 and NEA 02000) consumed 94.36 billion cubic feet of natural gas in 1982 (7.93 billion cubic feet by NEA 01000, and 86.43 billion cubic feet by NEA 02000). The estimate of natural gas purchases by the agriculture sector in the *1982*

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[29] The NEA converted the cost of purchased natural gas using prices from *Gas Facts* (Price and Wendling, p. 4)

[30] The NEA excluded the 663.2 billion cubic feet of natural gas produced and consumed for heat and power by the same establishment in the minerals industries in 1982.

*Census of Agriculture* is combined with the prices in *Historical Natural Gas Annual 1930 Through 1997* to derive an estimate of 86.98 billion cubic feet of natural gas purchases by farms.

It is also possible to compare the NEA and DAEMEC estimates of natural gas consumed by the manufacturing sector in 1982. According to the DAEMEC, 4,577 billion cubic feet of natural gas were consumed by manufacturing industries (U.S. DOE, 1992, Errata, p. 33). The NEA estimates the manufacturing sector consumed 4,952 billion cubic feet of natural gas.

### 3.3. *Energy Produced and Consumed at the Same Establishment*

In addition to the consumption of energy purchased from off-site sources, there are instances when an establishment produces and consumes energy for heat and power. Since emissions are generated by the combustion of the fuels produced and consumed by an establishment, this consumption is included in the fuel consumption estimates used to assign the emissions. The remainder of Section 3.3. discusses the sources of the estimates of energy produced and consumed at the same establishment.

#### 3.3.1. Nonmanufacturing

In the nonmanufacturing sectors, coal is produced and consumed at the same establishment in NEA 07010 and NEA 07020, and natural gas is produced and consumed at the same establishment in NEA 08002 and NEA 08003. According to the *1987 Census of Minerals Industries* (U.S. Department of Commerce, 1990), 39.4 percent of the total energy consumed (in Btu) for heat and power by the mineral industries is from fuels produced and consumed at the same establishment.[31]

In 1982, a small quantity of natural gas was produced and consumed at the same establishment in SIC 138. There was no natural gas produced and consumed at the same establishment in SIC 138 in 1987 or 1992. Since the NEA did not include this consumption in its "produced and consumed" category for either NEA 11001 or NEA 12000, this fuel consumption is excluded from the estimates used to assign fuel combustion emissions.

Estimates of energy produced and consumed at the same establishment by the mining sector are available in the 1982, 1987, and 1992 *Census of Minerals Industries* (U.S. Department of Commerce, 1985, 1990b, and 1996b). Fuel produced and consumed at the same establishment in the mining sector for 1985, 1986 and 1988 to 1991 is estimated by the two-way indexing method, and estimates for 1993 to 1997 are generated using the forward-indexing method.

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[31] The estimate in the NEA for the consumption and production of natural gas by the establishments in NEA 08002 in 1982 is different than the value in the *1982 Census of Mineral Industries* (U.S. Department of Commerce, 1985). As a result, the NEA estimates for natural gas produced and consumed at the same establishment in NEA 08002 for 1978 to 1985 are re-estimated.

3.3.2. Manufacturing: Natural gas, Residual fuel oil, and distillate fuel oil

NEA estimates of fuel consumed for heat and power include fuel produced and consumed at the same establishment in the petroleum refining, coke ovens and blast furnaces, and steel mills industries (see Price and Wendling 1986, p. 4). However, the NEA reports no separate estimates of these quantities.

DAEMEC data, which are used to distribute fuel combustion emissions, consist solely of off-site produced energy. However, the differences between the "Total Inputs of Energy for Heat, Power, and Electricity" and "Total Consumption of Offsite-Produced Energy for Heat, Power, and Electricity" tables in the MECS are assumed to represent fuels produced and consumed at the same establishment.

Combining the MECS estimate of distillate fuel oil and residual fuel oil produced and consumed at the same petroleum refining (SIC 29) establishment with the DAEMEC estimate of distillate fuel oil and residual fuel oil purchased by SIC 29 generates an estimate of distillate and residual fuel oil consumption that is consistent with the NEA data. Fuel produced and consumed at the same establishment in SIC 29 for 1986, 1987, 1989, 1990, 1992, and 1993 is estimated using the two-way indexing method. Estimates of fuel consumption for 1993 to 1997 are derived by the forward-indexing method. Since Price and Wendling (1986, p. 4) did not adjust for energy produced and consumed at the same establishment in other industries, fuel produced and consumed at the same establishment in other industries is not used to assign fuel combustion emissions.[32] The remainder of this section discusses evidence from the MECS that fuels may be produced and consumed at the same plant in other industries.

In addition to SIC 29, residual fuel oil is produced and consumed at the same establishment in SIC 28 during 1985, 1988, and 1991. In 1988, a small amount of residual fuel oil is produced and consumed at the same establishment in SIC 33. During 1985, 1988, and 1991, establishments in SIC 29 account for at least 91 percent of the residual fuel oil produced and consumed at the same establishment. In 1994, SIC 29 account for all residual fuel oil produced and consumed at the same establishment. Since Price and Wendling (1986, p. 4) did not adjust for energy produced and consumed at the same establishment in SIC 28 and SIC 33, residual fuel oil produced and consumed at the same establishment in these industries is not used when assigning fuel combustion emissions.

In addition to SIC 29, distillate fuel oil is produced and consumed at the same establishment in SIC 28 during 1985, 1988 and 1991. In 1994, there is a small amount of residual

[32] According to Price and Wendling (1986, p. 4), fuel produced and consumed at the same establishment in SIC 33 are included in the NEA data. Since the estimates in MECS of the quantities of fuels produced and consumed at the same establishment in SIC 33 are relatively small, their exclusion from the estimates of fuel consumption does not appear to have a substantial impact on the assignment of emissions for 1985 to 1997.

fuel oil being produced and consumed at the establishment in SIC 37. In 1985, 1988, 1991 and 1994, establishments in SIC 29 account for a minimum of 85 percent of the distillate fuel oil produced and consumed at the same establishment. Since Price and Wendling (1986, p. 4) did not adjust for energy produced and consumed at the same establishment in SIC 28 and SIC 37, distillate fuel oil produced and consumed at the same establishment in these industries is not used to assign fuel combustion emissions.

In 1985 and 1988, coal was produced and consumed at the same establishment in SIC 28 and SIC 32.[33] In 1985 and 1988, SIC 28 accounts for at least 80 percent of coal produced and consumed at the same establishment. In 1991, SIC 28 and SIC 26 both account for approximately one-half of the coal produced and consumed at the same establishment. This consumption is not used when assigning fuel combustion emissions. In 1994, no coal is produced and consumed at the same establishment in the manufacturing sector.

In 1985 and 1988, natural gas is produced and consumed at the same establishment in SIC 28. In 1991, natural gas is also produced and consumed at the same establishment in SIC 28, SIC 35, and SIC 37. Since Price and Wendling (1986, p. 4) did not adjust for energy produced and consumed at the same establishment in these industries, natural gas produced and consumed at the same establishment in SIC 28, SIC 35 and SIC 37 is not used to assign fuel combustion emissions.

The following summarizes the percentage of different fuels consumed by the manufacturing sector, but not assigned to an industry:

| | 1985 | 1988 | 1991 | 1994 |
|---|---|---|---|---|
| Residual Fuel Oil | 0.28 | 0.10 | 0.22 | 0.00 |
| Distillate Fuel Oil | 0.45 | 0.24 | 0.35 | 0.15 |
| Coal | 0.08 | 0.08 | 0.72 | 0.00 |
| Natural Gas | 1.02 | 0.14 | 0.13 | 0.39 |

These percentages are derived by adding the quantity of off-site produced energy for all manufacturing industries and the amount of energy produced and consumed by the same establishment in SIC 29 and dividing the total by the “Total Inputs of Energy for Heat, Power...” for all manufacturing industries. Hence, the table shows the relative importance of the unassigned amounts of energy produced and consumed by the same establishment.

[33] Coal produced and consumed by SIC 28 may reflect coke oven activities that are typically assigned to SIC 33.

### 3.3.3. Manufacturing: Wood

In addition to pulping (or black) liquor, the "Total Inputs of Selected Wood and Wood-Related Products for Heat, Power, and Electricity Generation" table lists four "biomass" fuels consumed for heat and power (U.S. DOE 1997, pp. 405-406). Excluding agricultural waste, the remaining three fuels are related to the consumption of wood: (1) wood harvested directly from trees, (2) wood residues and byproducts from mill processing, and (3) wood-related and paper-related refuse. The (1) wood harvested directly from trees and (2) wood residues and byproducts from mill processing constitute the "wood chips, bark" category in the "Total Inputs of Selected Byproduct Energy for Heat, Power, and Electricity Generation" table in the 1988 MECS (U.S. DOE 1991, p. 47), the 1991 MECS (U.S. DOE 1994, p. 85), and the 1994 MECS (U.S. DOE 1997, p. 82). The data in these tables include purchased energy, and energy produced and consumed at the same establishment.

The NEA provides information on wood consumption for heat and power for 1970 to 1984. The MECS "wood chips, bark" category is the source of estimates of wood consumption in 1988, 1991, and 1994. Estimates of the combustion of wood for 1985-87, 1989-90, 1992-93, and 1995-97 are derived by combining the MECS data with backward-indexing, two-way indexing, and forward-indexing methods.

The NEA assigns all consumption of wood for heat and power to NEA 20990 (SIC 24) and NEA 24990 (SIC 26). The 1988 MECS assigns almost 95 percent of wood consumption to SIC 24 and SIC 26. However, the 1985 NEA assigns 24 percent of wood consumption to SIC 24, while the 1988 MECS assigns 41 percent. The 1985 NEA assigns 76 percent of wood consumption to SIC 26, while the 1988 MECS assigns 54 percent. This results in a discrepancy between the 1970-1984 and 1985-1997 estimates when assigning emissions from wood combustion.

### 3.3.4. Manufacturing: Blast furnace / coke oven gases and still gas

According to the NEA, still gas (NEA energy product code 222) is consumed by the petroleum refining industry (NEA 31011, which is part of SIC 29) and coke oven gas (NEA energy product 223) is consumed by the coke oven industry (NEA 37011, which is part of SIC 33).[34] The 1988 MECS (U.S. DOE, 1991, p. 47), the 1991 MECS (U.S. DOE, 1994, p. 85), and the 1994 MECS (U.S. DOE, 1997, p. 82) provides data ("Total Inputs of Selected Byproduct Energy for Heat, Power, and Electricity Generation" table) on the consumption of blast furnace / coke oven gases and waste gas. According to the 1994 MECS, waste gas is produced and consumed primarily by the following two industries: (1) chemicals (SIC 28) - 15 percent and (2)

[34] The terms "waste gas" and "still gas" refer to the same fuel.

petroleum refining (SIC 29) - 85 percent (U.S. DOE, 1997, p. 82).[35] The MECS "Total Inputs" table also shows that small amounts of waste gas were produced and consumed at the same establishment by SIC 20, SIC 24, and SIC 32. The primary metals industry (SIC 33) is the sole producer and consumer of blast furnace / coke oven gases (U.S. DOE, 1997, p. 82).

MECS data, which are reported in Btu, for the consumption of blast furnace / coke oven gases and waste gas are converted to physical units using the NEA thermal conversion factors for coke oven gas and still gas, respectively. The backward indexing method is used to estimate consumption of these fuels from 1985 to 1987. The two-way indexing method is utilized when estimating consumption in 1989, 1990, 1992, and 1993. The forward indexing method is used to estimate consumption of these fuels for 1995 to 1997.

### 3.4. *Physical units vs. Btu*

Since emission factors are stated in terms of emissions per physical units of fuel consumption, when assigning fuel combustion emissions, physical units of fuel consumption are preferred to fuel consumption in Btu. The NEA provides estimates of fuel consumption in physical units, and these values are used to allocate fuel combustion emissions for 1970 to 1984. In a given year, the NEA uses the same conversion factor for a fuel across all industries. As a result, physical units and Btu generate the same assignment of emissions.

The DAEMEC publishes estimates in Btu for 1974 to 1994; however, only the 1974 to 1988 data are reported in physical units. As a result for 1985 to 1997, energy consumption data in Btu are used to assign fuel combustion emissions. For a given year, the DAEMEC employs the same thermal conversion factor for a fuel.[36] The U.S. DOE conversion factors for natural gas, residual fuel oil, and distillate fuel oil (U.S. DOE, 1999) are used to convert energy consumption estimates for the agriculture and construction sectors from physical units to Btu. In addition, the estimates of fuel consumption (in physical units) reported in the *Census of Mineral Industries* are converted to Btu with the conversion factors reported in the *Census of Mineral Industries*.

Identical thermal conversion factors for distillate fuel oil and residual fuel oil are specified by the *Census of Mineral Industries* (U.S. Department of Commerce, 1985, 1990b, and

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[35] Smaller industries may also produce a waste gas that is consumed for other space heating or other combustion related use (electricity generation on-site). For example, landfill operations often produce methane which is a "process gas" and it is sometimes consumed on-site and is sometimes sold to electric generators for use on the power grid. (10/22/99 e-mail correspondence with Sharon Nizich)

[36] According to the U.S. DOE (1992, p. 94), coal consumed for fuel and coal consumed for coking have different heat rates (see U.S. DOE 1988a, p. 61; U.S. DOE 1991, p. 148; U.S. DOE 1994, p. 455; and U.S. DOE 1997, p. 431).

1996b) and the U.S. DOE.[37] There are minor discrepancies between these sources for the thermal conversion factors for natural gas. Hence, using either physical quantities or Btu has little or no effect on the allocation of fuel combustion emissions from the consumption of residual fuel oil, distillate fuel oil, and natural gas. However, the thermal conversion factors reported by the NEA and the *Census of Mineral Industries* (U.S. Department of Commerce, 1981 and 1985) in 1977 and 1982 are higher than those reported by the U.S. DOE (1999). This discrepancy in thermal conversion factors results in a slight increase in the share of coal combustion emissions assigned to mineral industries for 1984 to 1986.

### 3.5. *Concordance Between Fuel Consumption Categories and Emissions Categories*

Table 5 reports which pollutants (marked with an "X") are generated by the "Fuel Combustion - Industrial" (Tier I) category (U.S. EPA, 1998b).[38] Before allocating fuel combustion emissions among industries, a concordance is established between the fuel consumption categories listed by the fuel consumption surveys (e.g., NEA and MECS) and fuel categories listed in the *1970-1997 NAPET* (U.S. EPA, 1998b).

Coal (bituminous, subbituminous, anthracite & lignite) emissions are aggregated and assigned to industries based on the quantity of coal consumed by each industry. If this assumption is a good approximation of reality, then the distribution of coal consumption by industries is an adequate proxy for the distribution of emissions from the consumption of each category of coal (e.g., bituminous).

Emissions from the combustion of residual fuel oil and distillate fuel oil are assigned to industries based on their consumption of residual and distillate fuel oil. However, CO and VOC emissions are reported for an aggregate fuel oil source category. The *1970-1990 Emissions* spreadsheet (SIC7090.WK3) reports no control efficiencies for CO or VOC emissions from either residual or distillate fuel oil combustion. In addition, it reports the following constant emission factors (in millions of pounds of emissions per million gallons of fuel consumed):

| | Residual fuel oil | Distillate fuel oil |
|---|---|---|
| VOC | 0.3 | 1 |
| CO | 4.5 | 7 |

[37] Conversion factors for coal and natural gas consumed by mineral industries in non-census years are estimated by simple linear interpolation of conversion factors from census years.

[38] The "Fuel Combustion - Industrial " source category reports emissions from fuel combustion by industries that belong to the industrial sector.

*Table 5*
**Pollutants Emitted by the "Fuel Combustion - Industrial" Source Category**

| | PM-10 | $SO_2$ | $NO_x$ | VOCs | CO | Pb |
|---|---|---|---|---|---|---|
| Coal | X | X | X | X | X | X |
| *bituminous* | X | X | X | | | X |
| *subbituminous* | X | X | X | | | X |
| *anthracite & lignite* | X | X | X | | | X |
| *other* | X (NA) | X (NA) | X (NA) | | | |
| | | | | | | |
| Oil | X | X | X | X | X | X |
| *residual* | X | X | X | | | X |
| *distillate* | X | X | X | | | X |
| *other* | X | X | X | | | |
| | | | | | | |
| Gas | X | X | X | X | X | |
| *natural* | X | | X | | | |
| *process* | X | | X | | | |
| *other* | X (NA) | | X | | | |
| | | | | | | |
| Other | X | X | X | X | X | |
| *wood/bark waste* | X | | X | | | |
| *liquid waste* | X (NA) | | X (NA) | | | |
| *other* | X | | X | | | |
| | | | | | | |
| Internal Combustion | X (NA) | X (NA) | X (NA) | X (NA) | X (NA) | |

NOTE: An "NA" indicates that estimates of emissions are not reported until 1985. No PM-10 emissions are reported for any fuel combustion category for 1971 to 1974.

Since the SIC7090.WK3 spreadsheet reports constant emission factors for these fuels and pollutants for 1970 to 1990, it is assumed that these emission factors are valid for 1991 to 1997. The consumption of residual fuel oil is converted into an equivalent amount of distillate fuel oil. The conversion is based on the emission factors for VOC and CO emissions. For example, for a gallon of residual fuel oil generates the same quantity of VOC emissions as 0.3 gallons of distillate fuel oil. VOC emissions from fuel oil combustion are then distributed among industries based on the consumption of distillate fuel oil and the distillate equivalent of the residual fuel oil. The same procedure is followed when distributing the CO emissions from the combustion of residual fuel oil and distillate fuel oil.

The petroleum refining industry (SIC 29) (see U.S. EPA, 1998a, pp. 3-38 and 3-39) is assigned the PM-10, $SO_2$, and $NO_x$ emissions from the "Oil - Other" subcategory.

Natural gas is assumed to be the principal source of the VOC, $SO_2$, and CO emissions from gas combustion. Hence, these emissions are assigned to industries based on their consumption of natural gas. PM-10 and $NO_x$ emissions from the combustion of natural gas are assigned to industries based on the share of natural gas consumption by each industry.

PM-10 and $NO_x$ emissions from the "Gas-Other" subcategory are assigned to the petroleum refining industry (SIC 29) (see U.S. EPA, 1998a, p. 3-43).

In addition to emissions from natural gas combustion, PM-10 and $NO_x$ emissions are generated by the consumption of processed gas.[39] For 1970 to 1984, the EPA estimates of emissions from gas combustion include emissions from the combustion of coke-oven gas by the iron and steel industry and emissions from process heaters in the petroleum refining industry (see U.S. EPA, 1998a, pp. 3-42 and 3-43). Emission estimates from the "gas - processed" category for 1985 to 1997 includes the following consumers of processed gas: (1) chemical manufacturing, (2) primary metal production, (3) secondary metal production, (4) petroleum industry, (5) oil and gas production, and (6) miscellaneous manufacturing industries (U.S. EPA 1998a, pp. 4-7 and 4-8). As a result, emissions from the gas-processed category are assumed to be generated by the consumption of "waste gas" and "blast furnace / coke oven gases."

Section 3.3.4 discusses the estimates of fuel consumption used to allocate "gas-processed" emissions of PM-10 and $NO_x$ among industries. From 1970 to 1984, the combustion of processed gas accounts for a small percentage of PM-10 and $NO_x$ emissions. This is due, in part, to classifying emissions from natural gas consumption by petroleum refining and steel mills as process emissions prior to 1985 (see *1970-1990 Emissions*, sections 3.2.1.2. and 3.2.1.3.).

[39] Processed gas refers to still gas, refinery gas, waste gas, or coke oven gas.

The U.S. EPA (1990, p. 23) provides the following emission factors:

| | Emission factors (pounds of emissions per million of cu. ft. of fuel consumed) | |
|---|---|---|
| | PM-10 | $NO_x$ |
| Petroleum refinery gas | 3.00 | 140.00 |
| Blast furnace gas | 2.90 | 23.00 |
| Coke oven gas | 4.35 | 80.00 |

The emission factor for petroleum refinery gas is equivalent to the emission factor for still gas. Emissions from the consumption of blast furnace / coke oven gas are derived using a simple average of the emission factors for blast furnace gas and coke oven gas. For example, the average PM-10 emission factor for blast furnace and coke oven gases is 3.625. These emission factors are assumed to be valid for 1970 through 1997. Consumption of blast furnace / coke oven gases is converted into a still gas equivalent based on the emission factors for PM-10 and $NO_x$ emissions. For example, for PM-10 emissions a unit of blast furnace / coke oven gas is equivalent to 1.21 (=3.625/3) units of still gas. PM-10 emissions from the combustion of processed gas are then assigned to industries based on their share of consumption of still gas and the still gas equivalent of coke oven gas. The same procedure is followed when distributing $NO_x$ emissions from the combustion of coke oven gas and still gas.

Wood consumed for heat and power by each industry (see discussion in Section 3.3.3.) determines the assignment of PM-10 and $NO_x$ emissions from the "Other - wood/bark waste" category.

## 3.6. *Excluded Fuel Combustion Source Categories*

The 1988 MECS (U.S. DOE, 1991, p. 47), the 1991 MECS (U.S. DOE, 1994, p. 85), and the 1994 MECS (U.S. DOE, 1997, p. 82) publish estimates ("Total Inputs of Selected Byproduct Energy for Heat, Power, and Electricity Generation" table) of the consumption of the following byproduct fuels: (1) blast furnace/coke oven gases, (2) waste gas, (3) petroleum coke, (4) pulping liquor, (5) wood chips, bark, and (6) waste oils / tars and waste materials. In 1994 (U.S. DOE, 1997, p. 82), the following industries account for most of the consumption of these fuels: Lumber and Wood Products (SIC 24), Paper and Allied Products (SIC 26), Chemicals and Allied products (SIC 28), Petroleum Refining (SIC 29), and Primary Metal Industries (SIC 33).
Of these fuels, emissions from the (1) blast furnace/coke oven gases, (2) waste gas, and (3) wood chips, bark categories are assigned to industries.

In addition to a lack of information about the "coal - other" (Tier III) category, there is limited information about the following (Tier II) categories in the Fuel Combustion - Industrial (Tier I) category: (1) Other and (2) Internal Combustion. In *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a, p. 3-46), the "other" (Tier II) category includes emissions from the following fuel sources: (1) coke, (2) bagasse, (3) kerosene, (4) liquid petroleum gas, and (5) wood.[40] Combustion of "other" fuels - excluding wood - is the source of PM-10 and $NO_x$, emissions from the "Other, other" category.

Unfortunately, data on emissions from "Other" fuels are not available for 1970 to 1990. The only information available for the consumption of wood and other fuels by the industrial sector is for 1990 in the SIC7090.WK3 spreadsheet, which provides information on the quantity of fuel consumed and the emission factors.[41] If identical control efficiencies exist on the combustion of each fuel for each pollutant, the product of the quantities of fuel consumed and the emission factors provide an estimate of the relative share of emissions associated with these fuels. Within the "other fuel" category, coke (55.3 percent) and coke-oven gases (36.8) account for more than 92 percent of $SO_x$ emissions. Wood accounts for 93.6 percent of VOC emissions, and bagasse accounts for 94 percent of the remaining VOC emissions.[42] Wood accounts for 85.7 percent of the PM emissions. Bagasse (72.9 percent) and coke (23.5 percent) account for most of the remaining PM emissions. Wood accounts for 83.6 percent of the $NO_x$ emissions. Most of the remaining $NO_x$ emissions are the result of combustion of coke (50.1 percent) and LPG (23.4 percent). Wood accounts for 96.1 percent of the CO emissions, with bagasse (57.2 percent) and LPG (21.3 percent) accounting for most of the remaining CO emissions from the "other fuel" category.

Since the *1970-1997 NAPET* provides no additional information about the types of fuels included in the "Other" fuel combustion category for $SO_2$, VOC, and CO emissions, these emissions are not assigned to industries. In addition, PM-10 and $NO_x$ emissions from the "Other - other" and "Other - liquid waste" categories are not assigned to industries. Finally, industries are not assigned emissions for the "Internal Combustion" category.

In conclusion, emissions from the following "fuel combustion, industrial" categories are not assigned to industries: (1) coal - other, (2) other (when listed as a single quantity of emissions), (3) other - liquid waste, (4) other - other, and (5) internal combustion. As a result, emissions from the combustion of the following fuels for heat and power are not assigned to

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[40] "coke" includes both petroleum coke and coal coke (U.S. EPA 1998a, p. 3-46 and 3-37)

[41] The *1940-1990 NAPEE* (U.S. EPA, 1991, pp. 70-74) provides separate estimates of emissions from wood and an aggregate of the remaining fuels in the "other" subcategory for 1970, 1975, 1979-1990.

[42] Bagasse is consumed at sugar mills (SIC 20) (see U.S. EPA, 1996, Supplement B, Chapter 1, Section 8).

industries: (1) coke and breeze, (2) LPG, (3) kerosene, (4) petroleum coke, (5) pulping liquor, (6) waste oils / tars and waste materials, (7) agricultural waste (includes bagasse), and (8) wood-related and paper-related refuse.

### 3.7 *Fuel Consumption and Fuel Combustion Source Categories listed as "NA"*

When the DAEMEC lists a "NA" or "W," it is necessary to estimate the energy consumption of that industry. Since there are discrepancies between the NEA and the DAEMEC estimates of fuel consumption and the heat content of fuels, the DAEMEC estimates of fuel consumption are used to estimate the missing observations. This allows the estimates to be consistent with the data from the DAEMEC. Appendix D describes the procedures used to estimate missing observations in the DAEMEC.

Table 5 lists a "NA" for those fuel combustion categories that do not report emissions prior to 1985. Emissions from these categories are assumed to represent cases when the emissions were included in another category prior to 1985. As a result, no emissions are assigned to these Tier III categories for 1970 to 1984. The only exceptions are $NO_x$ emissions from the "Gas, other" and "Oil, other" category in 1970. Since these two categories reports emissions for 1960 and 1971 to 1984, the backward indexing method is used to estimate the emissions from these two categories in 1970.

In addition, the *1970-1997 NAPET* does not estimate fuel combustion emissions of PM-10 for 1971 to 1974. Appendix D provides a description of the two-way indexing method, which in combination with changes in fuel consumption by the industrial sector, used by this study to estimate PM-10 emissions for 1971 to 1974.

## 4. OVERVIEW OF THIS REPORT

This report developed procedures to assign emissions of criteria air pollutants among the twenty two-digit SIC manufacturing industries in the United States for 1970 to 1997.[43] For 1993 to 1997, the allocation of fuel combustion emissions is preliminary because the 1994 MECS and the 1992 economic census for the agriculture, construction, and mineral industries represent the most recent estimates of energy consumption. In addition, the Board of Governors of the Federal Reserve System has revised its estimates of industrial production for 1992 to 1997. When the 1997 economic census and the 1998 MECS are published, it will be possible to revise the assignment of emissions from fuel combustion for 1993 to 1997.

There are several explanations for the divergence between this report's emission estimates and those in the *1970-1997 NAPET* (U.S. EPA, 1998b). First, this report only assigns emissions to industries of the industrial sector. Sources such as motor vehicles emissions are not

[43] The *1970-1997 NAPET* (U.S. EPA, 1998b), which is the source of the emission estimates used in this report, estimates emissions from electric utilities for 1970 to 1997.

assigned to industries. Second, this report estimates emissions from Tier II categories whose emissions are listed as "NA" for 1970 to 1984 by the *1970-1997 NAPET* (see Section 2.3.). Third, this report does not assign emissions from the "Miscellaneous Industrial Processes" category to industries. Finally, this report excludes emissions from the combustion of several types of fuel because there is insufficient information about the consumption of those fuels by individual industries (see Section 3.6.).

Table 6 lists the sources of emissions assigned to industries. The "Spreadsheet Estimates" portion of Table 6 shows the quantity of emissions assigned to the electric utility and industrial sectors. In Table 6, industrial process emissions include VOC emissions from those Solvent Utilization and Storage & Transport (Tier I) categories assigned to industries by this report. In addition to emissions from miscellaneous fuels and processes, and various categories within the Solvent Utilization and Storage & Transport (Tier I) categories, all emissions from the Waste Disposal & Recycling, On-road Vehicles, Off-road Vehicles and, Natural Sources, and Miscellaneous (Tier I) categories are not assigned to industries.

The "Percentage of National Estimates in Spreadsheets" section of Table 6 lists the percentage of emissions from all sources assigned to the electric utility and industrial sectors. In 1997, the industrial and electric utility sectors generated 88 percent of $SO_2$ emissions, and 59 percent of Pb emissions.

$NO_x$ is produced by both stationary and mobile sources, and VOCs and CO are more closely associated with mobile sources. As a result, the industrial and electric utility sectors account for a smaller percentage of the emissions of these four pollutants: for $NO_x$, 39 percent; for VOCs, 22 percent; for CO, 7 percent; and, for PM-10, 4 percent.

The increased share of Pb emissions from the industrial and electric utility sectors results from a decline in Pb emissions from the On-Road Vehicles (Tier I) category. After 1984, the decline in the percentage of PM-10 emissions assigned to the industrial and electric utility sectors results from changes in the quantity of emissions reported for the Natural Resources and Miscellaneous (Tier I) categories. Emissions from the Fugitive Dust (Tier II) category, which is in the Miscellaneous category, account for more than 55 percent of PM-10 emissions in 1997.

There are two potential sources of discontinuities in the time series of emissions. The first occurs as a result of using data from the NEA and DAEMEC to allocate emissions from fuel combustion. The second source is associated with changes in the methodology used by the U.S. EPA to estimate process emissions. These changes resulted in one methodology being employed to estimate process emissions for 1970 to 1984, and another methodology being used to estimate emissions for 1985 to 1997. The next few paragraphs review these issues.

*Table 6*

**Emission Estimates in the Spreadsheet and the Percentage of EPA National Estimates of Emissions in the Spreadsheet**

| | | SPREADSHEET ESTIMATE* | | | PERCENTAGE OF EPA NATIONAL ESTIMATES IN THE SPREADSHEET** | | |
|---|---|---|---|---|---|---|---|
| POLLUTANT | CATEGORY | 1970 | 1984 | 1997 | 1970 | 1984 | 1997 |
| $SO_2$ | Industrial Process | 7.14 | 3.30 | 1.66 | 22.88 | 14.01 | 8.15 |
| | Industrial Fuel | 4.50 | 2.67 | 3.19 | 14.41 | 11.33 | 15.65 |
| | Electric Utility Fuel | 17.40 | 16.02 | 13.08 | 55.75 | 68.12 | 64.23 |
| | Total | 29.03 | 21.98 | 17.93 | 93.04 | 93.47 | 88.02 |
| $NO_x$ | Industrial Process | 1.00 | 0.80 | 0.79 | 4.64 | 3.17 | 3.37 |
| | Industrial Fuel | 4.45 | 3.35 | 2.33 | 20.62 | 13.29 | 9.87 |
| | Electric Utility Fuel | 4.90 | 7.27 | 6.18 | 22.69 | 28.84 | 26.20 |
| | Total | 10.36 | 11.42 | 9.30 | 47.95 | 45.30 | 39.44 |
| VOC | Industrial Process | 7.59 | 7.04 | 4.18 | 24.61 | 27.02 | 21.74 |
| | Industrial Fuel | 0.08 | 0.06 | 0.09 | 0.27 | 0.25 | 0.49 |
| | Electric Utility Fuel | 0.03 | 0.04 | 0.05 | 0.10 | 0.17 | 0.26 |
| | Total | 7.71 | 7.15 | 4.32 | 24.98 | 27.44 | 22.50 |
| PM-10 | Industrial Process | 7.68 | 2.34 | 0.84 | 58.68 | 36.00 | 2.49 |
| | Industrial Fuel | 0.62 | 0.61 | 0.24 | 4.70 | 9.43 | 0.71 |
| | Electric Utility Fuel | 1.78 | 0.63 | 0.29 | 13.56 | 9.76 | 0.86 |
| | Total | 10.07 | 3.58 | 1.37 | 76.95 | 55.19 | 4.07 |
| CO | Industrial Process | 9.89 | 5.18 | 4.78 | 7.71 | 4.48 | 5.46 |
| | Industrial Fuel | 0.61 | 0.48 | 0.54 | 0.47 | 0.42 | 0.61 |
| | Electric Utility Fuel | 0.24 | 0.32 | 0.41 | 0.19 | 0.27 | 0.46 |
| | Total | 10.73 | 5.98 | 5.72 | 8.37 | 5.18 | 6.54 |
| Pb | Industrial Process | 24.87 | 2.10 | 2.23 | 11.26 | 6.16 | 56.94 |
| | Industrial Fuel | 0.24 | 0.03 | 0.02 | 0.11 | 0.09 | 0.43 |
| | Electric Utility Fuel | 0.33 | 0.09 | 0.06 | 0.15 | 0.26 | 1.63 |
| | Total | 25.43 | 2.22 | 2.31 | 11.51 | 6.50 | 59.01 |

* In millions of short tons, except Pb, which is in thousands of short tons. One short ton equals two thousand pounds.

** Category totals and percentages are calculated from estimates in sheet AR of SIC7097.WK3. Percentages do not total 100 percent of EPA emission estimates because the spreadsheets exclude emissions from miscellaneous fuels, commercial/institutional, residential and mobile sources, some solvent utilization VOC emissions, and various miscellaneous sources.

There are differences between the NEA and DAEMEC estimates of energy consumption by manufacturing industries. There are also differences between the NEA estimates of energy consumed by the nonmanufacturing sectors and estimates for these sectors generated by the modified-NEA methodology developed in this report for 1985 to 1997. As a result, some differences exist between the energy consumption data for 1970 to 1984 and the data for 1985 to 1997. However, the differences between these two sources of data do not appear to have a substantial impact on the assignment of fuel combustion emissions.

The use of energy consumption data to allocate emissions is further complicated by changes in industry definitions within the SIC system. The 1972 SIC industry definitions are used by the 1985 MECS (see U.S. DOE, 1988a, p. 105) and the NEA (see Price and Wendling, 1986, p. 1). However, the MECS data from 1988, 1991, and 1994 use the 1987 SIC industry definitions. Estimates of energy consumption for 1974 to 1986,which are published in the DAEMEC, use the 1972 SIC classification scheme, and the DAEMEC estimates of energy consumption data for the years after 1986 utilize the 1987 SIC classification scheme (see U.S. DOE, 1992, p. 97). Since the 1972 and 1987 SIC industry definitions differ, in some cases it might be necessary to combine the Electronic and other electric equipment (SIC 36) and Instruments and related products (SIC 38) sectors.[44]

The allocation of fuel combustion emissions can be improved with a complete reconciliation of the estimates of fuel consumption for 1985 to 1997 from this report and the NEA estimates, which are used to allocate emissions for 1970 to 1984. A reconciliation of the energy consumption data would allow a more consistent allocation of emissions.

Allocating emissions from the industrial fuel combustion category among the industries is complicated by changes in the treatment of the combustion of certain fuels by selected industries. The differences between the methodology employed to estimate emissions for 1970 to 1984, and the methodology used to estimate emissions for 1985 to the present are discussed in Section 3.2.1.2. of *1970 to 1990 Emissions* (U.S. EPA 2000). Changes in the EPA methodology may explain the decline in PM-10 process emissions from the cement mfg. (Tier III) category and the increase in PM-10 emissions from coal, oil, and gas combustion by the industrial sector. They may also explain the decline in $SO_2$ process emissions from the petroleum refineries (Tier III),

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[44] Links to the documentation for the BEA employment data (FTE, FTPT, and PEP variables) and the zipped data files are available under "Gross Product by Industry" (Gross Product by Industry and the Components of Gross Domestic Income that define current dollar GPO) at the following URL: http://www.bea.doc.gov/bea/dn2.htm. Zipped data files in GPO4797.EXE are available. Data from 1948 through 1987 use the 1972 SIC codes and are in the spreadsheet file GPO72SIC.WK1. Data from 1987 through 1997 use the 1987 SIC codes and are in the spreadsheet file GPO87SIC.WK1. Comparing employment by two-digit SIC manufacturing industries in 1987 using the 1972 and 1987 code definitions, it can be seen that Electronic and other electrical equipment (SIC 36) and Instruments and related products (SIC 38) should be combined to maintain common industry definitions for two-digit SIC codes across the 1972 and 1987 code definitions.

cement mfg. (Tier III), and ferrous metals processing (Tier II) categories. Finally, the increase in $SO_2$ emissions from the oil and gas combustion (Tier II) categories may be explained by the change in methodology.

Assigning process emissions to industries, requires assigning SIC codes to the Tier I, Tier II, and Tier III categories.[45] There are differences between the procedures used by the *1970-1997 NAPET* to estimate process emissions for the years prior to 1985 and the procedures used estimate process emissions from 1985 to 1997. Although changing from NEA to DAEMEC data may account for some discontinuities in the assignment of fuel combustion emissions, it appears that changes in the methodology used to estimate process emissions account for most of the major changes in emissions between 1984 and 1985. For example, there were substantial declines in PM-10 emissions reported for the following categories, which are assigned to the nonmanufacturing portion of the industrial sector: (1) Agriculture, Food & Kindred Products, country elevators (Tier III), (2) Agriculture, Food & Kindred Products, terminal elevators (Tier III), (3) Mineral Products, surface mining (Tier III), and (4) Metals Processing, NEC (Tier II).

For manufacturing industries, most of the substantial changes in emissions between 1984 and 1985 are the result of changes in emissions from processes or solvent utilization. For example, declines in VOC emissions from SIC 24, SIC 26, SIC 28, and SIC 29 can be explained as follows. The decline in VOC emissions from SIC 24 results from the decline in emissions associated with the flatwood products (Tier III) category of the Solvent Utilization (Tier I) category. The decline in VOC emissions from SIC 26 is the result of a decline in emissions from the paper (Tier III) category of the Solvent Utilization (Tier I) category. The decline in VOC emissions from SIC 28 results from the decline in emissions associated with several Tier II categories of the Chemical & Allied Product Mfg. (Tier I) category. Finally, the decline in VOC emissions from SIC 29 is the result of a decline in emissions from the petroleum refineries & related industries (Tier II) category of the Petroleum & Related Industries (Tier I) category.

Changes in PM-10 emissions from SIC 24 and SIC 26 result from a decrease in emissions from the wood/bark waste (Tier III) category of the Fuel Combustion Industrial, Other (Tier II) category. The declines in PM-10 emissions from SIC 28 and SIC 29 are associated with declines in the process emissions from several Tier II categories within the Chemical & Allied Product Mfg. (Tier I) category, and the Asphalt Manufacturing (Tier II) category of the Petroleum & Related Industries (Tier I) category.

Recently, the statistical agencies of several countries have developed estimates of emissions from industries. For example, Statistics Denmark (1998) developed an inventory of emissions for Denmark, and Stahmer, Kuhn, and Braun (1998) developed an inventory of emissions for Germany. These two reports provide information on some of the assumptions needed to derive the estimates of emissions. Statistics Denmark (1998, p. 11) acknowledge that while it is preferable to assign emissions from solvents to the end-users, they believed that it was

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[45] The *National Air Pollutant Emissions Trends Procedures Document, 1900-1996 Projections 1999-2010* (U.S. EPA, 1998a, p. 4-2) discusses the difficulty of matching SCCs and SIC codes.

too burdensome. Hence, they do not allocate emissions from solvents. Emissions from fuel combustion are the product of fuel consumption (in joules) and an emission factor associated with each sector, fuel type and pollutant combination. In most cases, the emissions factors are the same for different industries (Statistics Denmark, 1998, p.13). In addition, energy consumed for transportation by an industry is included in emissions from that sector (see Statistics Denmark, 1998, p.13 , "the emission... per unit of gasoline is the same whether the gasoline is used in the dairy sector or in the sector for book printing"). Stahmer, Kuhn, and Braun (1998, p. 22) also estimate air emissions by calculating the product of the quantity (tones, joules) of a fuel consumed for combustion and an emission coefficient.

The procedures developed in this report are comparable to those developed by other efforts, such as those described in the previous paragraph, to allocate emissions among industries. The next MECS will report data for the year 1998, and subsequent MECS will be administered quadrennially. If the methodology specified in this report is acceptable and the necessary data are available, it should be possible to update these estimates of emissions of criteria air pollutants from the twenty two-digit SIC manufacturing industries.

The ongoing implementation of the NAICS poses a challenge to maintaining a consistent time series of emissions from industries. Within the next few years, the NAICS system will replace the SIC system. It will be possible to derive more than two-thirds of all 4-digit SICs from the NAICS system (see Executive Office of the President, Office of Management and Budget, 1998, p. 23). The U.S. Department of Commerce (1999, pp. 9 and 11) provides preliminary, summary statistics of revenue, payroll, and number of employees for the twenty three-digit NAICS manufacturing industries that correspond to the twenty two-digit SIC manufacturing industries.[46] Several forthcoming reports will provide additional insights into the importance of the discrepancies between the SIC and NAICS industries. Converting the time series of emissions from the twenty two-digit SIC manufacturing industries, which was developed in this report, to the twenty three-digit NAICS manufacturing industries, requires historical data on output and fuel consumption by three-digit and perhaps four-digit SIC industries. Until additional information is available, it is not possible to determine the feasibility of developing a consistent historical time series of estimates of emissions for the three-digit NAICS manufacturing industries.[47]

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[46] There have been a number of additions and deletions to the manufacturing sector of the United States. For example, the logging industry (SIC 2411) is part of the Agriculture, Forestry, Fishing, and Hunting sector (NAICS 11) in NAICS (Executive Office of the President 1998, p. 772), and the newspaper printing and publishing industry (SIC 2711) is moved to the Information sector (NAICS 51) in the NAICS system (Executive Office of the President 1998, p. 864).

[47] The following URL provides links to the implementation plans of various agencies of the U.S. government: http://www.census.gov/epcd/www/naics.html
The Bureau of the Census of the U.S. Department of Commerce addresses some of the issues concerning the breaks in time series of data at the following URL: http://www.census.gov/epcd/www/naicsusr.html#BREAKS.

There are two potential extensions of the data developed in this report. The first extension involves generating estimates of fuel consumption by industries for transportation. This would enable the assignment of emissions from on-road and off-road vehicles to industries.

The second extension involves developing of estimates of emissions at a more disaggregated level. Estimates of process emissions are available by SCC for 1985 to the present. It would be necessary to develop a concordance between the SCCs and the SIC or NAICS codes. Since information on fuel consumption is required to allocate emissions from the combustion of fuel in the industrial sector, the principal constraint on developing more disaggregated estimates of emissions is the availability of information on fuel consumption by industries, and the output data required to estimate fuel consumption for the years in which data are not collected.

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The Bureau of Economic Analysis of the U.S. Department of Commerce (Seskin, Eugene and David F. Sullivan, 2000, pp. 27-28) has described its plans for implementing the NAICS system. It appears that neither the Bureau of the Census nor the BEA plan to reclassify their estimates of industry output (from SIC to NAICS) for the years prior to implementing NAICS. At this time, the U.S. Department of Energy does not plan to reclassify SIC-based data collected previous to 1998. However, the 1998 MECS will provide information on energy consumption using both NAICS and SIC codes (see http://www.eia.doe.gov/emeu/mecs/mecs98/naics/naics8.html). The Board of Governors of the Federal Reserve System plans to reclassify some of its estimates of production by industries from the SIC system to the NAICS. However, it is uncertain how far back in time the Board of Governors will be able to reclassify its estimates of industrial output.

## REFERENCES

Armitage, Ken and Dixon A. Tranum (1990), "Industrial Production: 1989 Developments and Historical Revisions," *Federal Reserve Bulletin*, 76, (April), 187-204.

Board of Governors, Federal Reserve System (1999), "Industrial Production and Capacity Utilization, G-17," (downloaded on 9/3/99 from the following URL: http://www.bog.frb.fed.us/releases/G17/).

Executive Office of the President, Council of Economic Advisers (1987), *Economic Report of the President, 1987*, Washington, DC: U.S. Government Printing Office.

Executive Office of the President, Office of Management and Budget (1987), *Standard Industrial Classification Manual*, National Technical Information Service, Springfield, Virginia PB-87-100012. (The following URLs have information on the 1987 SIC codes: http://www.osha.gov/oshstats/sicser.html and http://www.lib.virginia.edu/socsci/sic.html)

Executive Office of the President, Office of Management and Budget (1998), *North American Industrial Classification System: United States, 1997*, National Technical Information Service, Springfield, Virginia, PB98-127293.

Lum, Sherlene K.S. and Brian C. Moyer (1998), "Gross Product by Industry," *Survey of Current Business*, 78, No. 11 (November), 20-40. (see "Industry Estimates" at the following URL: http://www.bea.doc.gov/bea/an1.htm for PDF and HTML versions of the article. The data are available at http://www.bea.doc.gov/dn2/gpo.htm under "Detailed Data Files.")

Lum, Sherlene K.S. and Robert E. Yuskavage (1997), "Gross Product by Industry, 1947-96," *Survey of Current Business*, 77, No. 11 (November), 20-34. (HTML and PDF files are located at the following URL under "Industry Estimates": http://www.bea.doc.gov/bea/an1.htm).

Nestor, Deborah Vaughn and Carl A. Pasurka, Jr. (1998), "USA: Environmental Protection Activities and Their Consequences," in *Environmental Accounting in Theory and Practice*, Vol. 11 of Economy and Environment series, eds. Kimio Uno and Peter Bartelmus, pp. 131-142, Boston: Kluwer Academic Publishers.

Price, Lori H. and Robert M. Wendling (1986), "National Energy Accounts: An Overview," Capital, Energy and Productivity Studies Division, Office of Business Analysis, U.S. Department of Commerce, Draft, March 1986.

Seskin, Eugene P. and David F. Sullivan (2000), "Annual Revision to the National Income and Product Estimates," *Survey of Current Business*, 80, No. 8 (August), 6-33.

Stahmer, C., M. Kuhn, and N. Baum (1998), "Physical Input-Output Tables for Germany, 1990," Eurostat Working Paper No. 2/1998/B/1, European Commission.

Statistics Denmark (1998), *Danish NAMEA, 1980-1992*, in cooperation with Eurostat.

U.S. Department of Commerce, Bureau of the Census (1981), *1977 Census of Mineral Industries*, Washington, DC: U.S. Government Printing Office.

U.S. Department of Commerce, Bureau of the Census (1984), *1982 Census of Construction*, Washington, DC: U.S. Government Printing Office.

U.S. Department of Commerce, Bureau of the Census (1985), *1982 Census of Mineral Industries*, Washington, DC: U.S. Government Printing Office.

U.S. Department of Commerce, Bureau of the Census (1990a), *1987 Census of Construction*, Washington, DC: U.S. Government Printing Office.

U.S. Department of Commerce, Bureau of the Census (1990b), *1987 Census of Mineral Industries*, Washington, DC: U.S. Government Printing Office.

U.S. Department of Commerce, Bureau of the Census (1994), *1992 Census of Agriculture*, Washington, DC: U.S. Government Printing Office. (http://www.census.gov/prod/2/agr/92area/aca51.pdf)

U.S. Department of Commerce, Bureau of the Census (1996a), *1992 Census of Construction*, Washington, DC: U.S. Government Printing Office. (http://www.census.gov/prod/1/constr/92area/cca10f.pdf)

U.S. Department of Commerce, Bureau of the Census (1996b), *1992 Census of Mineral Industries, Fuels and Electric Energy Consumed*, MIC92-S-2, it was last modified in September 1996 (HTML file is located at: http://www.census.gov/econ/www/minesum.html#p2)

U.S. Department of Commerce, Bureau of the Census (1999), *1997 Economic Census*, Advance Report, Core Business Statistics Series, EC97X-CS1, (PDF file is located at: http://www.census.gov/epcd/www/advance2.htm).

U.S. Department of Energy, Energy Information Administration (1986), *Petroleum Marketing Monthly*, DOE/EIA-0380(86), July.

U.S. Department of Energy, Energy Information Administration (1987), *Petroleum Marketing Monthly*, DOE/EIA-0380(87), July.

U.S. Department of Energy, Energy Information Administration (1988a), *1985 Manufacturing Energy Consumption Survey*, DOE/EIA-0512(85), Washington, D.C. (HTML, PDF, and WK1 files are located at: http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1988b), *Petroleum Marketing Monthly*, DOE/EIA-0380(88), June.

U.S. Department of Energy, Energy Information Administration (1989), *Petroleum Marketing Annual*, DOE/EIA-0487(88).

U.S. Department of Energy, Energy Information Administration (1991), *1988 Manufacturing Energy Consumption Survey*, DOE/EIA-0512(88), Washington, D.C. (HTML, PDF, and WK1 files are located at: http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1992), *Derived Annual Estimates of Manufacturing Energy Consumption 1974-1988*. DOE/EIA-0555(92)/3, Washington, D.C. (HTML file is located at: http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1994), *1991 Manufacturing Energy Consumption Survey*, DOE/EIA-0512(91), Washington, D.C. (HTML, PDF, and WK1 files are located at: http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1996), *State Energy Data Report: 1995*, DOE/EIA-0214(95), Washington, D.C. (updated files are at http://www.eia.doe.gov/emeu/states/_states.html).

U.S. Department of Energy, Energy Information Administration (1997), *1994 Manufacturing Energy Consumption Survey*, DOE/EIA-0512(94), Washington, D.C. (HTML, PDF, and WK1 files are located at: (http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1998a), *Derived Annual Estimates of Manufacturing Energy Consumption 1988-1994*, Energy Consumption Series, it was last modified on August 14, 1998 (HTML file is located at: http://www.eia.doe.gov/emeu/consumption)

U.S. Department of Energy, Energy Information Administration (1998b), *Historical Natural Gas Annual 1930 Through 1997, Report*, DOE/EIA-0110(97) (http://www.eia.doe.gov/oil_gas/natural_gas/nat_frame.html).

U.S. Department of Energy, Energy Information Administration (1999), *Monthly Energy Review On-line*, (thermal conversion factors for various fuels were downloaded on 1/16/99 and 3/2/99, and are located under "Thermal Conversion Factors" at http://tonto.eia.doe.gov/mer/)

U.S. Department of Energy, Energy Information Administration (various issues), *Quarterly Coal Report*, DOE/EIA-0121.

U.S. Department of Energy, Energy Information Administration (various issues), *Coal Industry Annual*, DOE/EIA-0584.

U.S. Department of Energy, Energy Information Administration (various issues), *Fuel Oil and Kerosene Sales*, DOE/EIA-0535.

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1990) *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*, EPA 450/4-90-003 (NTIS code: PB90-207242).

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1991), *National Air Pollutant Emission Estimates*, 1940-1990. EPA-450/4-91-026.

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1994), *National Air Pollutant Emissions Trends, Procedures Document 1900-1993*, EPA 454/R-95-002.

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1996), *AP-42, Fifth Edition, Supplement B*, (http://www.epa.gov/ttn/chief/ap42supp.html#sup B)

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1998a), *National Air Pollutant Emission Trends Procedures Document, 1900-1996. Projections 1999-2010*, EPA 454/R-98-008. (http://www.epa.gov/ttn/chief/ei_data.html#ETDP)

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and Standards (1998b), *National Air Pollutant Emission Trends Update: 1970-1997*. EPA 454/E-98-007. (http://www.epa.gov/ttn/chief/trends97/emtrnd.html)

U.S. Environmental Protection Agency, Office of Policy, Economics and Innovation, National Center for Environmental Economics (2001), *Statistical Methodology for Assigning Emissions to Industries in the United States: 1970 to 1990*, EPA 240-R-01-002. (http://www.epa.gov/economics/)

Yuskavage, Robert E. (1996), "Improved Estimates of Gross Product by Industry, 1959-94," *Survey of Current Business*, 76, No. 8 (August), 133-155. (HTML and PDF files are located at: http://www.bea.doc.gov/bea/an1.htm).

# APPENDIX A

## NEA SECTORING PLAN

| NEA Code | Industry Title | SIC Code |
|---|---|---|
| | AGRICULTURE | |
| 01000 | Livestock and livestock products | 02 (ex. 0254, pt. 0219, pt. 0259, pt. 0291), pt. 0191 |
| 02000 | Other agricultural products | 01 (ex. pt. 0191), pt. 0219, pt. 0259, pt. 0291 |
| 03000 | Forestry and forestry products | 08 (ex. 085), 09 (ex. 092) |
| 04000 | Agricultural, forestry and fishery services | 0254, 07 (ex. 074), 085, 092 |
| | MINING | |
| 05000 | Iron and feroalloy ores mining | 101, 106 |
| 06001 | Uranium - radium - vanadium ores mining | 1094 |
| 06002 | Nonferrous metal ores mining | 102, 103, 104, 105, pt. 108, 109 (ex. 1094) |
| 07010 | Anthracite coal mining | pt. 11 |
| 07020 | Bituminous and lignite coal mining | pt. 12 |
| 08001 | Crude petroleum | pt. 131 |
| 08002 | Natural gas | pt. 131 |
| 08003 | Natural gas liquids | 132 |
| 09000 | Stone and clay mining and quarrying | 141, 142, 144, 145, pt. 148, 149 |
| 10000 | Chemical and fertilizer mineral mining | 147 |
| | CONSTRUCTION | |
| 11001 | Oil and gas well drilling | pt. 138 |
| 11002 | New construction | pt. 15, pt. 16, pt. 17, pt. 108, pt. 11, pt. 12, pt.148 |
| 12000 | Maintenance and repair construction | pt. 15, pt. 16, pt. 17, pt. 138 |

Source: Price and Wendling (1986, Appendix B)

# APPENDIX B

## CONCORDANCE BETWEEN THE SOLVENT UTILIZATION AND STORAGE & TRANSPORT CATEGORIES, AND THE NEA AND SIC CODES

| **SOLVENT UTILIZATION** | **SIC code (NEA codes in parentheses)** |
|---|---|
| Degreasing | NA |
| Graphic Arts | 27 |
| Dry Cleaning | 721 (not part of the industrial sector) |
| Surface Coating | |
| *industrial adhesives* | NA |
| *fabrics* | 22 |
| *paper* | 26 |
| *large appliances* | 36 |
| *magnet wire* | 33 |
| *auto & light trucks* | 37 |
| *metal cans* | 34 |
| *metal coil* | 33 |
| *wood furniture* | 25 |
| *metal furniture* | 25 |
| *flatwood products* | 24 |
| *plastic parts* | 30 |
| *large ships* | 37 |
| *aircraft* | 37 |
| *misc. metal parts* | 34 |
| *steel drums* | 34 |
| *architectural* | (NEA 11002) |
| *traffic markings* | NA |
| *maintenance coatings* | (NEA 12000) |
| *railroad* | 37 |
| *auto refinishing* | 7532 (not part of the industrial sector) |

| **SOLVENT UTILIZATION** (continued) | **SIC code (NEA codes in parentheses)** |
|---|---|
| *machinery* | 35 |
| *electronic & other electrical* | 36 |
| *general* | NA |
| *miscellaneous* | NA |
| *thinning solvents* | NA |
| *other* | NA |
| Other Industrial | |
| *miscellaneous* | NA |
| *rubber & plastics mfg.* | 28 |
| *other* | NA |
| Nonindustrial | |
| *cutback asphalt* | (NEA 12000) |
| *other asphalt* | NA |
| *pesticide application* | (NEA 02000) |
| *adhesives* | NA |
| *consumer solvents* | NA |
| *other* | NA |
| Other | NA |
| **STORAGE & TRANSPORT** | |
| Bulk Terminals & Plants | NA |
| Petroleum & Petroleum Product Storage | |
| *fixed roof gasoline* | 29 |
| *fixed roof crude* | 29 |
| *floating roof gasoline* | 29 |

| **STORAGE & TRANSPORT** (continued) | **SIC code (NEA codes in parentheses)** |
|---|---|
| *floating roof crude* | 29 |
| *efr / seal gasoline* | 29 |
| *efr / seal crude* | 29 |
| *ifr / seal gasoline* | 29 |
| *ifr / seal crude* | 29 |
| *variable vapor space gasoline* | 29 |
| *area source: crude* | 29 |
| *other* | 29 |
| Petroleum & Petroleum Product Transport | NA |
| Service Stations: Stage I | NA |
| Service Stations: Stage II | NA |
| Service Stations: Breathing & Emptying | NA |
| Organic Chemical Storage | 28 |
| Organic Chemical Transport | NA |
| Inorganic Chemical Storage | 28 |
| Inorganic Chemical Transport | NA |
| Bulk Materials Storage | NA |

NA = not assigned to an industry

NOTE: Tier I category names are in **BOLD**, Tier II category names are in the regular font, and Tier III category names are in *italics*.

# APPENDIX C

## PERCENTAGE OF 1985 PROCESS EMISSIONS WITH MISSING DATA FROM 1970 TO 1984

| **CO Emissions** (in thousand short tons) | 1985 Emissions | 1985 Emissions of cells listed as "NA" in 1984 | Percent of 1985 Emissions listed as "NA" in 1984 |
|---|---|---|---|
| Coal | 86 | | |
| Oil | 47 | | |
| Gas | 257 | | |
| Other | | | |
| TOTAL - Fuel Comb. Industrial | 390 | | |
| | | | |
| Chemicals | 1845 | 34 | 1.9 |
| Metals | 2223 | 6 | 0.3 |
| Petroleum | 462 | 13 | 2.8 |
| Other | 694 | 24 | 3.4 |
| TOTAL - Industrial Processes | 5224 | 77 | 1.5 |

| **NOx Emissions** (in thousand short tons) | 1985 Emissions | 1985 Emissions of cells listed as "NA" in 1984 | Percent of 1985 Emissions listed as "NA" in 1984 |
|---|---|---|---|
| Coal | 608 | | |
| Oil | 309 | | |
| Gas | 1520 | | |
| Other - wood/bark waste | 118 | | |
| TOTAL - Fuel Comb. Industrial | 2554 | | |
| | | | |
| Chemicals | 262 | 203 | 77.4 |
| Metals | 87 | 29 | 33.0 |
| Petroleum | 124 | 69 | 55.4 |
| Other | 327 | 14 | 4.4 |
| TOTAL - Industrial Processes | 800 | 315 | 39.3 |

| **VOC Emissions** (in thousand short tons) | 1985 Emissions | 1985 Emissions of cells listed as "NA" in 1984 | Percent of 1985 Emissions listed as "NA" in 1984 |
|---|---|---|---|
| Coal | 7 | | |
| Oil | 17 | | |
| Gas | 57 | | |
| Other | | | |
| | | | |
| TOTAL - Fuel Comb. Industrial | 81 | | |
| | | | |
| Chemicals | 881 | 11 | 1.3 |
| Metals | 76 | 19 | 25.5 |
| Petroleum | 703 | | 0.0 |
| Other | 390 | 165 | 42.4 |
| | | | |
| TOTAL - Industrial Processes | 2049 | 196 | 9.6 |
| | | | |
| Solvent Utilization | 2056 | 93 | 4.5 |
| Storage & Transport | 257 | | |
| | | | |
| GRAND TOTAL | 4362 | 289 | 6.6 |

| **$SO_2$ Emissions** (in thousand short tons) | 1985 Emissions | 1985 Emissions of cells listed as "NA" in 1984 | Percent of 1985 Emissions listed as "NA" in 1984 |
|---|---|---|---|
| Coal | 1818 | | |
| Oil | 862 | | |
| Gas | 397 | | |
| Other | | | |
| TOTAL - Fuel Comb. Industrial | 3076 | | |
| | | | |
| Chemicals | 456 | 27 | 5.8 |
| Metals | 1042 | 18 | 1.7 |
| Petroleum | 505 | 1 | 0.2 |
| Other | 425 | 8 | 1.8 |
| TOTAL - Industrial Processes | 2428 | 53 | 2.2 |

| **PM-10 Emissions** (in thousand short tons) | 1985 Emissions | 1985 Emissions of cells listed as "NA" in 1984 | Percent of 1985 Emissions listed as "NA" in 1984 |
|---|---|---|---|
| Coal | 71 | | |
| Oil | 52 | | |
| Gas | 47 | | |
| Other - wood/bark waste | 67 | | |
| TOTAL - Fuel Comb. Industrial | 236 | | |
| | | | |
| Chemicals | 58 | 4.9 | 8.4 |
| Metals | 220 | 0.0 | 0.0 |
| Petroleum | 63 | 0.3 | 0.5 |
| Other | 611 | 41.2 | 6.7 |
| TOTAL - Industrial Processes | 952 | 46.3 | 4.9 |

# APPENDIX D

## TREATMENT OF MISSING OBSERVATIONS

This appendix discusses the treatment of missing observations (i.e., when the data are listed as withheld, W, or are not available, NA, for energy consumption and emissions). Rather than assign a value of zero to an observation with a "W" or "NA," many missing observations are assigned values. In addition, observations recorded as "*" (less than 0.5 trillion Btu) in *Derived Annual Estimates of Manufacturing Energy Consumption* (U.S. DOE 1992 and 1998a) are treated as zeros. The procedures described in this appendix mirror those used by *Derived Annual Estimates of Manufacturing Energy Consumption* (U.S. DOE) when it estimates energy consumption for years between the MECS survey and the estimates of missing observations in the NEA (see Price and Wendling 1986).

## D.1. MANUFACTURING ENERGY CONSUMPTION

Some observations in the DAEMEC are withheld (W) or not available (NA). The preferred procedure for estimating these missing observations is the two-way indexing method (see U.S. DOE 1992, p. 8 and Appendix A). The two-way indexing method estimates fuel consumption for a missing year y by using data from a known starting-year (i.e., the year prior to the first missing year) and a known ending-year (i.e., the first year after the last missing year). A "known" year is one in which consumption (in Btu) of that fuel is reported by the U.S. DOE. The two "known" observations are adjusted by changes in the level of production of the two-digit SIC industry between the known years and the missing year y. A weighted average (i.e., a linear interpolation) of the two estimates of fuel consumption in year y yields the estimate of fuel consumption (in Btu) in year y. Weights are determined by the relative distance of the known starting-year and known ending-year from the missing year. The two-way indexing method for estimating missing observations for consumption (in Btu) of the $i^{th}$ type of fuel ($BTU^{i}_{ys}$) by a two-digit SIC manufacturing industry (s) for each missing year (y) can be specified as:

$$BTU^{i}_{ys} = \left(\frac{L-y}{L}\right)\left(\frac{A_{ys}}{A_{0s}}\right)BTU^{i}_{0s} + \left(\frac{y}{L}\right)\left(\frac{A_{ys}}{A_{Ls}}\right)BTU^{i}_{Ls}$$

where $A_{ys}$ is the Federal Reserve Board's production index for the two-digit SIC manufacturing industry (Armitage and Tranum 1990) for year y, and $A_{os}$ is the index/ output for the starting year (y=0) and $A_{Ls}$ is the index / level of output for the ending year (y=L).

If an estimate of fuel consumption (in Btu) for a year prior to 1985 is required to serve as the known starting-year, the Btu value from the DAEMEC is used. DAEMEC data are used in order to maintain consistency with the post-1984 observations.

When a "W" or "NA" is reported in the 1994 MECS, there is no known ending-year. As a result, it is not possible to utilize the two-way indexing method to estimate the missing observations. For these cases, the forward indexing method is used to estimate the missing observations (see U.S. DOE 1992, p. 8 and Appendix A). The forward indexing method can be specified as:

$$BTU_{ys}^{i} = \left(\frac{L-y}{L}\right)\left(\frac{A_{ys}}{A_{0s}}\right)BTU_{0s}^{i}$$

For these cases, fuel consumption (in Btu) for 1988 or 1991, which is then adjusted by changes in the output of the two-digit SIC manufacturing industry associated with the process source category, is used to estimate fuel consumption for all subsequent years to 1994.

It is also not possible to utilize the two-way indexing method to estimate fuel consumption for 1995 through 1997 for any industries. As a result, energy consumption for 1995 to 1997 are estimated using the forward indexing method. In this case, fuel consumption (in Btu) for 1994, adjusted by the change in the output of the industry, is used to estimate the fuel consumption (in Btu) of each fuel type by an industry for 1995 through 1997. Until the 1998 MECS becomes available, all estimates of fuel consumption derived using the forward indexing method are preliminary.

## D.2. NONMANUFACTURING ENERGY CONSUMPTION

During 1985 to 1997, the *Census of Agriculture*, the *Census of Mineral Industries*, and the *Census of Construction* are only available for 1987 and 1992. Depending on whether data are available in the 1982 economic census, either the two-way indexing method or the backward indexing method is used to estimate fuel consumption for 1985 and 1986. The two-way indexing method to estimate the consumption of coal, and natural gas for heat and power for 1988 to 1991. First, fuel consumption coefficients (i.e., the fuel-output ratios) for 1988 to 1991 are derived by linearly interpolating the fuel consumption coefficients from the 1987 and 1992 economic census. These fuel consumption coefficients are then multiplied by the U.S. BEA constant dollar estimate of output of the agriculture, mining, and construction sectors, respectively. This yields estimates of fuel consumption by these sectors for 1988 through 1991. The forward indexing method is also used to estimate fuel consumption for 1993 to 1997. Fuel consumption by the three sectors within the nonmanufacturing portion of the industrial sector is estimated by multiplying their 1992 fuel consumption coefficients by their constant dollar output for 1993 to 1997. Until the results of the 1997 economic census are available, the post-1992 estimates of fuel consumption are preliminary.

The *Census of Mineral Industries* provides information on the conversion factors used to convert physical quantities of energy consumed for heat and power by the mining industries into Btu. The conversion factors for natural gas, residual fuel oil, and distillate fuel oil from *Monthly Energy Review On-line* (U.S. DOE 1999) are used to convert physical quantities fuel consumption by the agriculture and construction sectors to Btu.

## D.3. *PROCESS EMISSIONS - INDUSTRIAL SECTOR*

In the *1970-1997 NAPET*, no industrial process emissions of PM-10 are reported from 1971 to 1974. As a result, PM-10 process emissions are estimated using the two-way indexing method (see U.S. DOE 1992, p. 8 and Appendix A). This is described in section D.2. Industrial

process emissions for a missing year y, are estimated by the two-way indexing method, which uses industrial process emissions for a "known" starting-year and a "known" ending-year. PM-10 industrial process emissions in 1970 and 1975 are the "known" starting-year and ending-year observations for the interpolation. These observations are adjusted by changes in the level of production of the industry between the know-year and the missing-year. A weighted average (i.e. a linear interpolation) of the two estimates of industrial process emissions in year y yields an estimate of industrial process emissions in year y.

Emissions of the pollutant (p) generated by industrial process source category "c" ($EMIT_{ycp}$) for each missing year (y) can be specified as:

$$EMIT_{ycp} = \left(\frac{L-y}{L}\right)\left(\frac{A_{yc}}{A_{0c}}\right)EMIT_{0cp} + \left(\frac{y}{L}\right)\left(\frac{A_{yc}}{A_{Lc}}\right)EMIT_{Lcp}$$

where $A_{yc}$ is the Federal Reserve Board production index for the two-digit SIC manufacturing industry (Armitage and Tranum 1990) for year y, and $A_{os}$ is the index/ output for the starting year (y=0) and $A_{Lc}$ is the index/ level of output for the ending year (y=L).

In addition to the missing PM-10 emissions for 1971 to 1974, there are other missing observations for various Tier II categories. Most of the missing observations are from 1970 to1984. As a result, the two-way indexing method cannot be implemented. Instead, the backward indexing method, in which 1985 is the known ending-year, is used to estimate emissions for the preceding years:

$$EMIT_{ycp} = \left(\frac{y}{L}\right)\left(\frac{A_{yc}}{A_{Lc}}\right)EMIT_{Lcp}$$

## D.4. FUEL COMBUSTION EMISSIONS - INDUSTRIAL SECTOR

The *1970-1997 NAPET* report does not estimate the PM-10 emissions from industrial fuel combustion for 1971 to 1974. The two-way indexing method is employed to estimating these missing PM-10 emissions. In this case, PM-10 emissions in 1970 and 1975 are the "known" starting-year and ending-year observations.

The "known" observations are adjusted by changes in the level of fuel consumption of the industrial sector, which is reported by the NEA, between the know-year and the missing-year. A weighted average (i.e., a linear interpolation) of the two estimates of industrial fuel combustion emissions in year y yields an estimate of industrial fuel combustion emissions in year y. This procedure is followed for each type of fuel. This is the same procedure used to estimate missing fuel consumption observations for the manufacturing industries after 1985 (see section D.1.).

The two-way indexing method for estimating missing emissions of the pollutant (p) generated by combustion of the $i^{th}$ type of fuel ($EMIT^{i}_{yp}$) by the industrial sector for each missing year (y) can be specified as:

$$EMIT^{i}_{yp} = \left(\frac{L-y}{L}\right)\left(\frac{F^{i}_{y}}{F^{i}_{0}}\right)EMIT^{i}_{0p} + \left(\frac{y}{L}\right)\left(\frac{F^{i}_{y}}{F^{i}_{0}}\right)EMIT^{i}_{Lp}$$

where $F^{i}_{y}$ is the quantity of the $i^{th}$ fuel consumed for heat and power by the industrial sector in year y, and $F^{i}_{0}$ is the quantity of the $i^{th}$ fuel consumed by the industrial sector in the starting-year (y=0) and $F^{i}_{L}$ is the quantity of the $i^{th}$ fuel consumed by the industrial sector in the ending-year (y=L).

There is one difference between the "index" used to estimate fuel combustion emissions and the one that estimates missing observations in sections D.1.through D.3.. Industrial fuel combustion emissions are estimated using fuel consumed for heat and power as the activity indicator; while fuel consumption and process emissions are derived using output as the activity indicator.

# APPENDIX E

## EMISSIONS FROM TWENTY TWO-DIGIT SIC MANUFACTURING INDUSTRIES*

* The highlighted cells in the tables of Appendix E represent emissions that include estimates of the "NA" cells. Most of the highlighted cells represent cases when "NA" values for certain Tier II categories of process emissions are estimated. The other cases involve estimates of PM-10 emissions from fuel combustion for 1971 to 1974, and the estimates of VOC emissions from several Tier III categories (misc. Metal parts, steel drums, and electronic & other electrical) within the Surface Coating (Tier II) category. Aside from the cases associated with estimating PM-10 emissions from fuel combustion for 1971 to 1974, instances when the estimate of the "NA" cell is less than 0.5 thousand short tons are noted at the bottom of each table.

*Table E-1*
**Emissions from SIC 20 (Food and Kindred Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 69.03 | 421.15 | 384.35 | 216.15 | 55.68 | 23.38 |
| 1971 | 65.56 | 365.29 | 379.21 | 216.78 | 59.39 | 16.00 |
| 1972 | 65.01 | 380.44 | 373.88 | 214.21 | 58.27 | 12.69 |
| 1973 | 62.07 | 368.77 | 365.70 | 209.02 | 57.20 | 11.59 |
| 1974 | 55.19 | 280.15 | 320.04 | 206.12 | 50.40 | 7.35 |
| 1975 | 52.50 | 283.13 | 313.46 | 188.32 | 49.22 | 6.88 |
| 1976 | 44.77 | 282.34 | 323.66 | 190.07 | 50.50 | 5.54 |
| 1977 | 50.78 | 290.26 | 322.49 | 190.29 | 50.35 | 5.37 |
| 1978 | 47.55 | 321.73 | 327.92 | 194.42 | 50.93 | 5.98 |
| 1979 | 50.11 | 296.46 | 325.96 | 196.77 | 50.53 | 6.21 |
| 1980 | 43.10 | 276.58 | 293.11 | 197.28 | 46.71 | 6.24 |
| 1981 | 44.34 | 264.04 | 289.35 | 203.29 | 46.10 | 6.10 |
| 1982 | 54.18 | 279.99 | 335.53 | 200.72 | 52.23 | 5.49 |
| 1983 | 36.27 | 236.15 | 296.17 | 197.40 | 47.03 | 2.79 |
| 1984 | 43.95 | 251.58 | 314.57 | 174.36 | 49.40 | 2.77 |
| 1985 | 43.05 | 254.85 | 179.98 | 174.87 | 31.53 | 2.59 |
| 1986 | 44.22 | 270.40 | 179.60 | 177.78 | 31.09 | 2.30 |
| 1987 | 44.53 | 273.96 | 182.52 | 180.85 | 31.34 | 2.06 |
| 1988 | 45.56 | 285.68 | 189.53 | 183.40 | 32.13 | 1.94 |
| 1989 | 45.82 | 287.42 | 194.01 | 181.21 | 32.75 | 1.88 |
| 1990 | 48.80 | 324.60 | 157.93 | 144.05 | 35.24 | 1.89 |
| 1991 | 43.75 | 313.57 | 163.54 | 135.70 | 39.43 | 2.00 |
| 1992 | 40.80 | 331.62 | 177.76 | 132.47 | 42.90 | 2.10 |
| 1993 | 43.14 | 330.63 | 185.00 | 152.15 | 45.64 | 2.14 |
| 1994 | 43.10 | 322.37 | 187.86 | 151.87 | 46.64 | 2.14 |
| 1995 | 43.73 | 330.00 | 188.93 | 154.17 | 49.84 | 2.07 |
| 1996 | 43.47 | 326.56 | 185.10 | 142.23 | 49.08 | 1.82 |
| 1997 | 44.52 | 318.17 | 186.32 | 148.46 | 49.64 | 1.85 |

[1]except Pb, which is in short tons.

NOTE: the combined estimates of the “NA” cells for CO emissions from SIC 20 and the Agriculture sector for 1970 to 1984 never exceed 0.26 thousand short tons in any year

*Table E-2*
**Emissions from SIC 21 (Tobacco Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 0.73 | 17.53 | 6.79 | 0.09 | 0.90 | 1.00 |
| 1971 | 0.60 | 13.65 | 5.68 | 0.08 | 0.80 | 0.61 |
| 1972 | 0.62 | 12.97 | 5.28 | 0.08 | 0.74 | 0.43 |
| 1973 | 0.59 | 12.94 | 5.37 | 0.08 | 0.75 | 0.39 |
| 1974 | 0.49 | 13.32 | 5.93 | 0.09 | 0.83 | 0.35 |
| 1975 | 0.46 | 11.87 | 4.86 | 0.07 | 0.69 | 0.30 |
| 1976 | 0.54 | 12.57 | 5.04 | 0.07 | 0.71 | 0.27 |
| 1977 | 0.59 | 15.61 | 5.91 | 0.08 | 0.84 | 0.32 |
| 1978 | 0.49 | 17.43 | 6.06 | 0.07 | 0.84 | 0.36 |
| 1979 | 0.39 | 15.98 | 6.17 | 0.07 | 0.85 | 0.38 |
| 1980 | 0.36 | 16.14 | 6.25 | 0.07 | 0.87 | 0.44 |
| 1981 | 0.35 | 16.66 | 6.52 | 0.07 | 0.91 | 0.45 |
| 1982 | 0.37 | 17.53 | 6.96 | 0.08 | 0.96 | 0.40 |
| 1983 | 0.30 | 17.99 | 7.04 | 0.08 | 0.97 | 0.23 |
| 1984 | 0.31 | 18.20 | 7.22 | 0.07 | 0.99 | 0.22 |
| 1985 | 0.64 | 14.67 | 5.35 | 0.09 | 0.78 | 0.17 |
| 1986 | 0.76 | 17.82 | 6.37 | 0.11 | 0.91 | 0.17 |
| 1987 | 0.87 | 21.58 | 7.50 | 0.12 | 1.08 | 0.18 |
| 1988 | 0.96 | 24.57 | 8.47 | 0.12 | 1.21 | 0.18 |
| 1989 | 0.92 | 23.45 | 8.33 | 0.12 | 1.20 | 0.18 |
| 1990 | 1.07 | 23.61 | 7.49 | 0.12 | 1.36 | 0.17 |
| 1991 | 0.97 | 23.50 | 7.85 | 0.11 | 1.46 | 0.18 |
| 1992 | 1.04 | 24.10 | 8.19 | 0.13 | 1.52 | 0.18 |
| 1993 | 0.84 | 19.91 | 6.98 | 0.10 | 1.27 | 0.15 |
| 1994 | 0.97 | 23.15 | 8.42 | 0.14 | 1.50 | 0.18 |
| 1995 | 1.03 | 24.40 | 8.75 | 0.12 | 1.54 | 0.19 |
| 1996 | 1.03 | 24.65 | 8.71 | 0.12 | 1.56 | 0.17 |
| 1997 | 0.97 | 22.99 | 8.34 | 0.12 | 1.48 | 0.16 |

[1]except Pb, which is in short tons.

*Table E-3*
**Emissions from SIC 22 (Textile Mill Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 8.49 | 166.43 | 97.23 | 171.52 | 13.44 | 8.26 |
| 1971 | 7.71 | 154.15 | 99.45 | 179.42 | 14.99 | 6.00 |
| 1972 | 7.83 | 143.50 | 95.53 | 203.51 | 14.47 | 4.15 |
| 1973 | 6.57 | 127.37 | 89.04 | 218.14 | 13.54 | 3.43 |
| 1974 | 4.28 | 104.85 | 78.08 | 202.67 | 11.89 | 2.55 |
| 1975 | 4.52 | 101.94 | 72.28 | 186.86 | 11.06 | 2.38 |
| 1976 | 5.52 | 116.34 | 75.44 | 207.38 | 11.40 | 2.32 |
| 1977 | 6.20 | 125.45 | 76.42 | 204.43 | 11.56 | 2.35 |
| 1978 | 5.62 | 115.74 | 75.16 | 203.02 | 11.39 | 2.18 |
| 1979 | 4.50 | 103.55 | 79.79 | 210.86 | 11.97 | 2.16 |
| 1980 | 3.96 | 91.95 | 69.79 | 197.27 | 10.77 | 2.00 |
| 1981 | 3.45 | 92.19 | 71.27 | 191.36 | 11.08 | 2.12 |
| 1982 | 3.33 | 88.67 | 71.50 | 175.99 | 10.80 | 1.78 |
| 1983 | 2.44 | 82.06 | 69.26 | 192.66 | 10.69 | 1.06 |
| 1984 | 2.48 | 86.43 | 73.52 | 197.75 | 11.23 | 1.03 |
| 1985 | 4.16 | 78.25 | 43.71 | 45.51 | 7.27 | 0.84 |
| 1986 | 4.53 | 85.55 | 45.36 | 45.49 | 7.45 | 0.79 |
| 1987 | 4.40 | 85.51 | 45.82 | 45.96 | 7.54 | 0.71 |
| 1988 | 4.37 | 84.87 | 45.81 | 46.99 | 7.49 | 0.60 |
| 1989 | 4.19 | 80.71 | 46.08 | 46.85 | 7.58 | 0.52 |
| 1990 | 4.57 | 83.63 | 37.12 | 35.96 | 7.87 | 0.47 |
| 1991 | 3.75 | 74.42 | 36.71 | 33.72 | 8.48 | 0.45 |
| 1992 | 4.14 | 81.03 | 39.32 | 36.06 | 9.12 | 0.50 |
| 1993 | 4.51 | 88.13 | 42.95 | 36.18 | 10.10 | 0.58 |
| 1994 | 4.61 | 89.58 | 43.98 | 35.39 | 10.38 | 0.62 |
| 1995 | 4.71 | 92.30 | 42.91 | 35.37 | 10.32 | 0.56 |
| 1996 | 4.61 | 90.75 | 41.74 | 33.56 | 10.11 | 0.48 |
| 1997 | 4.55 | 87.31 | 41.95 | 34.83 | 10.25 | 0.51 |

[1]except Pb, which is in short tons.

NOTE: the combined estimates of the "NA" cells for PM-10 emissions from SIC 22, 23, and 31 for 1970 to 1984 never exceed 0.01 thousand short tons in any year

NOTE: the combined estimates of the "NA" cells for $SO_2$ emissions from SIC 22, 23, and 31 for 1970 to 1984 never exceed 0.01 thousand short tons in any year

NOTE: the combined estimates of the "NA" cells for $NO_x$ emissions from SIC 22, 23, and 31 for 1970 to 1984 never exceed 0.06 thousand short tons in any year

*Table E-4*
**Emissions from SIC 23 (Apparel and Other Textile Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1.04 | 21.37 | 20.33 | 0.42 | 3.08 | 1.18 |
| 1971 | 0.91 | 18.65 | 19.93 | 0.44 | 3.27 | 0.80 |
| 1972 | 0.82 | 16.06 | 18.65 | 0.42 | 3.07 | 0.49 |
| 1973 | 0.66 | 12.23 | 16.64 | 0.39 | 2.78 | 0.33 |
| 1974 | 0.48 | 8.61 | 14.79 | 0.36 | 2.50 | 0.18 |
| 1975 | 0.55 | 9.55 | 13.76 | 0.32 | 2.25 | 0.20 |
| 1976 | 0.64 | 10.36 | 13.47 | 0.31 | 2.18 | 0.18 |
| 1977 | 0.74 | 11.83 | 15.03 | 0.35 | 2.44 | 0.19 |
| 1978 | 0.69 | 11.14 | 16.58 | 0.39 | 2.69 | 0.18 |
| 1979 | 0.56 | 9.18 | 14.37 | 0.33 | 2.31 | 0.16 |
| 1980 | 0.53 | 9.03 | 12.58 | 0.29 | 2.08 | 0.17 |
| 1981 | 0.52 | 9.90 | 13.10 | 0.29 | 2.17 | 0.20 |
| 1982 | 0.48 | 8.63 | 12.06 | 0.27 | 1.93 | 0.16 |
| 1983 | 0.38 | 7.20 | 10.54 | 0.24 | 1.72 | 0.09 |
| 1984 | 0.37 | 6.74 | 10.87 | 0.25 | 1.77 | 0.07 |
| 1985 | 0.38 | 5.24 | 4.10 | 0.17 | 0.77 | 0.05 |
| 1986 | 0.41 | 5.56 | 4.60 | 0.22 | 0.87 | 0.04 |
| 1987 | 0.50 | 6.86 | 5.75 | 0.25 | 1.06 | 0.05 |
| 1988 | 0.56 | 8.29 | 7.04 | 0.30 | 1.28 | 0.05 |
| 1989 | 0.56 | 8.36 | 6.94 | 0.28 | 1.25 | 0.05 |
| 1990 | 0.56 | 8.20 | 4.90 | 0.22 | 1.12 | 0.04 |
| 1991 | 0.52 | 7.73 | 4.77 | 0.22 | 1.20 | 0.04 |
| 1992 | 0.54 | 8.22 | 5.14 | 0.21 | 1.31 | 0.04 |
| 1993 | 0.55 | 8.29 | 5.42 | 0.21 | 1.43 | 0.05 |
| 1994 | 0.55 | 8.11 | 5.74 | 0.27 | 1.57 | 0.05 |
| 1995 | 0.58 | 8.64 | 5.64 | 0.29 | 1.59 | 0.04 |
| 1996 | 0.57 | 8.39 | 5.43 | 0.28 | 1.54 | 0.03 |
| 1997 | 0.54 | 7.66 | 5.23 | 0.28 | 1.50 | 0.04 |

[1]except Pb, which is in short tons.

NOTE: see the notes at the bottom of Table E-3

*Table E-5*
**Emissions from SIC 24 (Lumber and Wood Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 165.26 | 42.33 | 95.98 | 74.74 | 10.88 | 1.70 |
| 1971 | 166.13 | 35.56 | 90.69 | 84.39 | 10.94 | 1.07 |
| 1972 | 179.88 | 39.76 | 91.35 | 92.58 | 10.62 | 0.92 |
| 1973 | 186.05 | 41.78 | 92.62 | 92.74 | 10.70 | 0.94 |
| 1974 | 174.20 | 36.25 | 83.53 | 89.40 | 9.23 | 0.76 |
| 1975 | 158.66 | 28.86 | 78.46 | 86.28 | 8.65 | 0.49 |
| 1976 | 180.46 | 35.40 | 83.03 | 97.25 | 8.54 | 0.55 |
| 1977 | 181.57 | 29.08 | 77.09 | 100.33 | 7.47 | 0.43 |
| 1978 | 192.80 | 30.90 | 82.60 | 103.40 | 7.86 | 0.46 |
| 1979 | 190.48 | 28.96 | 82.07 | 104.94 | 7.69 | 0.44 |
| 1980 | 184.27 | 24.23 | 67.82 | 93.55 | 5.71 | 0.36 |
| 1981 | 171.79 | 19.59 | 60.98 | 80.58 | 4.83 | 0.29 |
| 1982 | 156.48 | 15.01 | 53.66 | 66.67 | 3.99 | 0.22 |
| 1983 | 164.44 | 11.82 | 54.18 | 67.66 | 3.53 | 0.15 |
| 1984 | 172.37 | 12.91 | 54.95 | 68.55 | 3.55 | 0.15 |
| 1985 | 57.89 | 18.82 | 49.65 | 17.70 | 2.97 | 0.16 |
| 1986 | 60.93 | 18.91 | 51.90 | 18.95 | 3.12 | 0.16 |
| 1987 | 62.71 | 16.70 | 52.63 | 19.05 | 3.18 | 0.13 |
| 1988 | 63.94 | 14.29 | 51.56 | 19.00 | 2.95 | 0.09 |
| 1989 | 62.65 | 14.40 | 52.69 | 18.69 | 3.12 | 0.08 |
| 1990 | 65.14 | 19.46 | 46.93 | 38.32 | 3.78 | 0.07 |
| 1991 | 55.39 | 17.31 | 44.62 | 36.29 | 3.51 | 0.06 |
| 1992 | 56.84 | 18.33 | 45.09 | 40.04 | 3.76 | 0.07 |
| 1993 | 57.87 | 21.03 | 45.75 | 43.33 | 4.48 | 0.08 |
| 1994 | 53.48 | 22.32 | 46.18 | 42.78 | 4.89 | 0.11 |
| 1995 | 54.69 | 22.95 | 46.55 | 47.99 | 5.13 | 0.11 |
| 1996 | 55.72 | 23.19 | 47.65 | 49.42 | 5.22 | 0.10 |
| 1997 | 57.76 | 23.03 | 49.05 | 51.33 | 5.32 | 0.11 |

[1]except Pb, which is in short tons.

*Table E-6*
**Emissions from SIC 25 (Furniture and Fixtures)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1.08 | 29.09 | 15.97 | 251.31 | 2.26 | 1.77 |
| 1971 | 0.80 | 20.28 | 16.88 | 314.48 | 2.63 | 0.98 |
| 1972 | 0.85 | 20.84 | 18.75 | 354.13 | 2.95 | 0.72 |
| 1973 | 0.58 | 14.04 | 16.07 | 334.81 | 2.58 | 0.43 |
| 1974 | 0.43 | 11.41 | 15.95 | 307.35 | 2.59 | 0.29 |
| 1975 | 0.39 | 10.19 | 12.68 | 277.98 | 2.04 | 0.24 |
| 1976 | 0.39 | 8.97 | 12.90 | 294.72 | 2.07 | 0.16 |
| 1977 | 0.41 | 10.54 | 14.47 | 285.71 | 2.33 | 0.19 |
| 1978 | 0.39 | 10.28 | 15.23 | 301.38 | 2.45 | 0.18 |
| 1979 | 0.35 | 9.23 | 13.73 | 316.17 | 2.22 | 0.17 |
| 1980 | 0.34 | 8.27 | 11.22 | 290.64 | 1.86 | 0.17 |
| 1981 | 0.29 | 8.15 | 10.77 | 249.37 | 1.78 | 0.18 |
| 1982 | 0.27 | 7.30 | 11.65 | 223.44 | 1.88 | 0.13 |
| 1983 | 0.18 | 5.50 | 10.27 | 246.29 | 1.69 | 0.06 |
| 1984 | 0.20 | 6.03 | 11.70 | 261.26 | 1.91 | 0.06 |
| 1985 | 1.42 | 5.77 | 7.27 | 182.52 | 1.11 | 0.05 |
| 1986 | 1.45 | 5.86 | 7.09 | 192.83 | 1.07 | 0.04 |
| 1987 | 1.56 | 7.35 | 8.23 | 195.12 | 1.27 | 0.05 |
| 1988 | 1.56 | 7.40 | 8.68 | 196.01 | 1.34 | 0.05 |
| 1989 | 2.16 | 8.80 | 9.73 | 193.26 | 1.38 | 0.05 |
| 1990 | 2.85 | 10.19 | 8.14 | 225.92 | 1.31 | 0.05 |
| 1991 | 2.92 | 9.30 | 8.38 | 219.23 | 1.29 | 0.06 |
| 1992 | 2.48 | 8.16 | 7.63 | 227.87 | 1.27 | 0.05 |
| 1993 | 2.17 | 8.16 | 7.40 | 245.52 | 1.39 | 0.05 |
| 1994 | 1.45 | 6.33 | 6.47 | 261.77 | 1.38 | 0.04 |
| 1995 | 1.47 | 6.36 | 6.53 | 256.64 | 1.42 | 0.04 |
| 1996 | 1.50 | 6.40 | 6.57 | 276.80 | 1.42 | 0.03 |
| 1997 | 1.55 | 6.47 | 6.77 | 289.22 | 1.47 | 0.03 |

[1]except Pb, which is in short tons.

*Table E-7*
**Emissions from SIC 26 (Paper and Allied Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1022.28 | 1018.59 | 532.50 | 672.33 | 668.85 | 41.67 |
| 1971 | 963.61 | 1001.03 | 545.99 | 666.61 | 671.14 | 32.32 |
| 1972 | 941.76 | 1016.50 | 526.37 | 753.76 | 714.03 | 24.61 |
| 1973 | 883.39 | 974.60 | 500.88 | 754.93 | 734.66 | 22.00 |
| 1974 | 762.59 | 1002.22 | 521.30 | 674.63 | 737.10 | 21.08 |
| 1975 | 590.56 | 869.68 | 464.54 | 568.19 | 655.67 | 17.10 |
| 1976 | 599.05 | 943.08 | 499.65 | 599.34 | 744.92 | 15.57 |
| 1977 | 614.54 | 960.77 | 499.00 | 606.45 | 752.17 | 14.97 |
| 1978 | 591.60 | 918.39 | 494.12 | 692.34 | 773.06 | 14.04 |
| 1979 | 591.86 | 897.50 | 515.18 | 695.90 | 784.19 | 14.89 |
| 1980 | 596.52 | 897.66 | 473.67 | 649.72 | 848.27 | 14.77 |
| 1981 | 547.51 | 860.03 | 484.87 | 505.11 | 845.68 | 14.87 |
| 1982 | 543.20 | 900.00 | 510.68 | 461.85 | 832.53 | 14.05 |
| 1983 | 538.08 | 859.62 | 499.58 | 529.01 | 888.96 | 8.41 |
| 1984 | 552.42 | 948.18 | 538.99 | 658.53 | 935.59 | 8.67 |
| 1985 | 137.22 | 767.79 | 402.42 | 134.00 | 670.66 | 7.18 |
| 1986 | 142.80 | 824.14 | 420.28 | 138.49 | 692.65 | 6.60 |
| 1987 | 141.48 | 812.51 | 415.38 | 138.98 | 691.06 | 5.84 |
| 1988 | 143.25 | 810.81 | 421.48 | 143.85 | 694.15 | 4.96 |
| 1989 | 142.71 | 811.77 | 428.31 | 143.68 | 701.49 | 4.42 |
| 1990 | 154.75 | 869.16 | 416.09 | 131.16 | 527.01 | 4.35 |
| 1991 | 122.36 | 823.93 | 409.89 | 119.46 | 519.57 | 4.40 |
| 1992 | 121.49 | 844.35 | 420.20 | 120.80 | 509.41 | 4.71 |
| 1993 | 123.32 | 827.76 | 422.93 | 124.69 | 515.00 | 5.00 |
| 1994 | 121.78 | 801.92 | 426.88 | 122.10 | 524.04 | 5.01 |
| 1995 | 126.85 | 852.11 | 425.78 | 123.88 | 547.74 | 4.55 |
| 1996 | 127.39 | 845.98 | 420.34 | 124.58 | 556.00 | 3.80 |
| 1997 | 131.51 | 830.10 | 432.24 | 130.61 | 579.45 | 4.22 |

[1]except Pb, which is in short tons.

*Table E-8*
**Emissions from SIC 27 (Printing and Publishing)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 0.83 | 10.19 | 25.91 | 319.57 | 3.89 | 0.26 |
| 1971 | 0.62 | 9.19 | 25.04 | 301.54 | 4.10 | 0.16 |
| 1972 | 0.65 | 9.94 | 24.43 | 344.51 | 3.99 | 0.19 |
| 1973 | 0.57 | 10.23 | 23.04 | 351.74 | 3.78 | 0.22 |
| 1974 | 0.38 | 8.70 | 18.03 | 325.61 | 2.96 | 0.19 |
| 1975 | 0.44 | 9.14 | 18.95 | 254.95 | 3.09 | 0.18 |
| 1976 | 0.35 | 7.59 | 16.27 | 280.99 | 2.64 | 0.12 |
| 1977 | 0.43 | 8.33 | 20.05 | 292.49 | 3.26 | 0.12 |
| 1978 | 0.42 | 8.15 | 19.91 | 346.78 | 3.23 | 0.12 |
| 1979 | 0.43 | 8.33 | 21.05 | 353.51 | 3.42 | 0.12 |
| 1980 | 0.42 | 7.24 | 18.36 | 373.90 | 3.10 | 0.10 |
| 1981 | 0.38 | 6.24 | 18.80 | 257.86 | 3.18 | 0.08 |
| 1982 | 0.45 | 7.13 | 22.74 | 238.26 | 3.73 | 0.09 |
| 1983 | 0.31 | 5.65 | 20.41 | 274.50 | 3.41 | 0.05 |
| 1984 | 0.31 | 6.30 | 24.17 | 360.59 | 3.99 | 0.05 |
| 1985 | 0.19 | 3.72 | 7.50 | 317.51 | 1.49 | 0.02 |
| 1986 | 0.31 | 5.55 | 8.48 | 325.33 | 1.68 | 0.03 |
| 1987 | 0.26 | 4.22 | 9.34 | 339.96 | 1.85 | 0.02 |
| 1988 | 0.28 | 4.42 | 10.80 | 362.17 | 2.12 | 0.01 |
| 1989 | 0.20 | 3.05 | 10.57 | 363.54 | 2.08 | 0.00 |
| 1990 | 0.25 | 4.95 | 7.22 | 274.92 | 1.83 | 0.00 |
| 1991 | 0.21 | 4.81 | 7.64 | 301.90 | 2.20 | 0.00 |
| 1992 | 0.22 | 4.89 | 7.64 | 308.82 | 2.24 | 0.00 |
| 1993 | 0.23 | 4.81 | 7.56 | 322.43 | 2.31 | 0.00 |
| 1994 | 0.23 | 4.59 | 7.38 | 333.28 | 2.34 | 0.01 |
| 1995 | 0.22 | 4.55 | 7.27 | 339.37 | 2.37 | 0.01 |
| 1996 | 0.22 | 4.47 | 7.17 | 389.39 | 2.34 | 0.01 |
| 1997 | 0.23 | 4.60 | 7.37 | 412.11 | 2.42 | 0.01 |

[1]except Pb, which is in short tons.

*Table E-9*
**Emissions from SIC 28 (Chemicals and Allied Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 281.15 | 1753.36 | 1386.38 | 1702.81 | 3561.66 | 172.90 |
| 1971 | 265.39 | 1664.10 | 1350.70 | 1695.21 | 3338.41 | 167.49 |
| 1972 | 259.29 | 1659.41 | 1390.62 | 1817.68 | 2756.39 | 157.26 |
| 1973 | 241.22 | 1598.19 | 1441.99 | 1923.24 | 2904.41 | 165.39 |
| 1974 | 209.04 | 1468.30 | 1516.83 | 1910.52 | 2703.36 | 173.26 |
| 1975 | 154.74 | 1216.40 | 1353.20 | 1656.87 | 2383.68 | 142.08 |
| 1976 | 164.60 | 1128.50 | 1458.21 | 1893.46 | 2551.38 | 141.74 |
| 1977 | 177.62 | 1170.70 | 1433.14 | 2011.77 | 2832.94 | 151.11 |
| 1978 | 188.84 | 1150.34 | 1384.19 | 2105.71 | 2729.51 | 157.18 |
| 1979 | 178.16 | 1129.98 | 1420.01 | 2165.38 | 2730.12 | 161.33 |
| 1980 | 174.45 | 996.58 | 1236.25 | 1996.74 | 2316.74 | 120.30 |
| 1981 | 156.04 | 1010.82 | 1241.83 | 1907.47 | 2374.99 | 144.83 |
| 1982 | 130.98 | 924.04 | 1189.79 | 1647.69 | 1865.93 | 134.40 |
| 1983 | 140.72 | 894.93 | 1090.38 | 1890.52 | 1995.51 | 146.16 |
| 1984 | 163.94 | 946.27 | 1198.28 | 2055.56 | 2246.99 | 140.63 |
| 1985 | 86.74 | 1028.16 | 700.04 | 954.02 | 1917.07 | 124.17 |
| 1986 | 88.24 | 1010.63 | 696.73 | 994.47 | 1924.22 | 113.17 |
| 1987 | 87.83 | 1013.09 | 727.38 | 1001.80 | 1875.59 | 127.16 |
| 1988 | 92.78 | 1051.55 | 779.61 | 1064.96 | 2000.59 | 139.75 |
| 1989 | 92.66 | 1017.84 | 791.54 | 1062.00 | 2010.72 | 139.34 |
| 1990 | 109.89 | 921.38 | 576.26 | 708.10 | 1263.92 | 139.09 |
| 1991 | 94.99 | 842.69 | 587.22 | 789.63 | 1220.59 | 135.52 |
| 1992 | 99.47 | 858.93 | 604.60 | 796.89 | 1212.22 | 96.69 |
| 1993 | 95.11 | 853.51 | 608.61 | 784.30 | 1199.64 | 95.40 |
| 1994 | 105.09 | 848.34 | 616.84 | 780.10 | 1282.43 | 99.42 |
| 1995 | 96.93 | 880.09 | 615.58 | 749.83 | 1335.97 | 166.28 |
| 1996 | 97.45 | 889.57 | 619.40 | 509.92 | 1337.40 | 169.94 |
| 1997 | 101.25 | 900.71 | 641.69 | 535.60 | 1405.85 | 162.09 |

[1]except Pb, which is in short tons.
NOTE: the estimates of the "NA" cells of $SO_2$ emissions for 1985 to 1991 never exceed 0.01 thousand short tons in any year
NOTE: the estimates of the "NA" cells of CO emissions for 1985 to 1989 never exceed 0.01 thousand short tons in any year

*Table E-10*
**Emissions from SIC 29 (Petroleum and Coal Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 289.98 | 985.04 | 461.94 | 2041.67 | 2183.00 | 2.15 |
| 1971 | 273.96 | 671.76 | 280.81 | 2004.65 | 2252.00 | 1.14 |
| 1972 | 260.57 | 707.58 | 287.53 | 2043.75 | 2291.71 | 0.83 |
| 1973 | 247.08 | 778.02 | 299.03 | 2037.01 | 2327.27 | 0.83 |
| 1974 | 211.38 | 774.96 | 301.02 | 1945.44 | 2245.94 | 0.72 |
| 1975 | 182.36 | 750.67 | 292.34 | 1927.22 | 2224.96 | 0.59 |
| 1976 | 157.36 | 752.08 | 302.04 | 1764.66 | 2135.36 | 0.41 |
| 1977 | 148.30 | 786.80 | 321.05 | 1822.83 | 2032.37 | 0.37 |
| 1978 | 151.97 | 782.99 | 321.77 | 1773.64 | 1930.67 | 0.42 |
| 1979 | 158.28 | 765.29 | 310.26 | 1746.59 | 1838.11 | 0.52 |
| 1980 | 141.63 | 729.26 | 292.38 | 1612.61 | 1734.47 | 0.44 |
| 1981 | 125.33 | 663.56 | 258.08 | 1471.25 | 1202.35 | 0.36 |
| 1982 | 114.74 | 640.31 | 249.68 | 1401.73 | 750.26 | 0.45 |
| 1983 | 122.46 | 627.77 | 241.23 | 1297.32 | 491.22 | 0.32 |
| 1984 | 126.69 | 635.15 | 244.00 | 1254.08 | 388.76 | 0.35 |
| 1985 | 91.81 | 579.16 | 462.00 | 953.52 | 487.56 | 1.65 |
| 1986 | 84.30 | 466.74 | 425.46 | 922.64 | 474.80 | 0.45 |
| 1987 | 82.67 | 461.49 | 407.77 | 935.18 | 477.22 | 0.49 |
| 1988 | 81.66 | 470.36 | 416.88 | 938.92 | 464.96 | 0.48 |
| 1989 | 79.10 | 453.07 | 416.57 | 937.46 | 462.43 | 0.35 |
| 1990 | 68.50 | 482.82 | 345.10 | 636.93 | 325.86 | 0.31 |
| 1991 | 54.55 | 437.78 | 369.39 | 698.00 | 365.62 | 0.27 |
| 1992 | 55.29 | 466.02 | 400.57 | 707.72 | 388.91 | 0.32 |
| 1993 | 51.17 | 427.05 | 374.50 | 718.26 | 388.61 | 0.38 |
| 1994 | 51.09 | 419.42 | 367.38 | 721.25 | 342.86 | 0.40 |
| 1995 | 53.89 | 423.36 | 359.24 | 727.68 | 354.13 | 0.33 |
| 1996 | 53.98 | 424.49 | 360.09 | 485.38 | 354.29 | 0.26 |
| 1997 | 55.82 | 433.49 | 370.83 | 507.73 | 369.90 | 0.33 |

[1]except Pb, which is in short tons.

*Table E-11*
**Emissions from SIC 30 (Rubber and Miscellaneous Plastic Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 5.91 | 110.43 | 66.11 | 77.52 | 9.41 | 6.38 |
| 1971 | 5.47 | 95.19 | 68.94 | 79.71 | 10.68 | 4.40 |
| 1972 | 7.01 | 120.93 | 80.78 | 86.74 | 12.36 | 4.13 |
| 1973 | 6.88 | 119.16 | 76.68 | 84.72 | 11.66 | 3.79 |
| 1974 | 5.51 | 104.76 | 69.62 | 81.65 | 10.56 | 2.91 |
| 1975 | 4.90 | 84.87 | 60.01 | 70.76 | 9.23 | 2.11 |
| 1976 | 5.84 | 85.81 | 61.68 | 73.91 | 9.37 | 1.73 |
| 1977 | 6.74 | 94.51 | 68.33 | 89.02 | 10.50 | 1.77 |
| 1978 | 6.15 | 79.34 | 65.67 | 88.57 | 10.16 | 1.47 |
| 1979 | 5.46 | 69.08 | 63.63 | 85.18 | 9.79 | 1.40 |
| 1980 | 4.69 | 57.56 | 51.67 | 70.27 | 8.19 | 1.22 |
| 1981 | 4.29 | 49.75 | 53.08 | 78.01 | 8.54 | 1.09 |
| 1982 | 4.31 | 44.96 | 57.39 | 74.99 | 9.04 | 0.82 |
| 1983 | 4.02 | 33.68 | 51.36 | 80.11 | 8.33 | 0.41 |
| 1984 | 4.41 | 32.50 | 55.77 | 90.63 | 9.00 | 0.36 |
| 1985 | 4.98 | 31.70 | 28.88 | 53.50 | 5.37 | 0.28 |
| 1986 | 5.12 | 32.74 | 28.11 | 55.06 | 5.19 | 0.27 |
| 1987 | 5.26 | 33.30 | 30.36 | 55.63 | 5.59 | 0.25 |
| 1988 | 5.38 | 31.52 | 30.39 | 57.86 | 5.57 | 0.19 |
| 1989 | 5.25 | 31.76 | 30.67 | 57.71 | 5.59 | 0.16 |
| 1990 | 5.52 | 36.66 | 22.60 | 85.79 | 5.19 | 0.15 |
| 1991 | 5.25 | 31.05 | 21.51 | 82.00 | 5.48 | 0.14 |
| 1992 | 5.71 | 30.60 | 21.56 | 87.18 | 5.59 | 0.14 |
| 1993 | 5.10 | 31.87 | 23.17 | 84.68 | 6.23 | 0.16 |
| 1994 | 4.85 | 29.81 | 22.97 | 84.57 | 6.45 | 0.16 |
| 1995 | 4.91 | 33.26 | 23.18 | 78.88 | 6.68 | 0.13 |
| 1996 | 4.95 | 33.99 | 23.53 | 78.80 | 6.79 | 0.11 |
| 1997 | 5.09 | 32.46 | 23.92 | 82.44 | 7.00 | 0.13 |

[1]except Pb, which is in short tons.
NOTE: the estimates of the "NA" cells of $NO_x$ emissions for 1970 to 1984 never exceed 0.04 thousand short tons in any year
NOTE: the estimates of the "NA" cells of CO emissions for 1970 to 1984 never exceed 0.07 thousand short tons in any year

*Table E-12*
**Emissions from SIC 31 (Leather and Leather Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1.07 | 19.30 | 10.70 | 0.18 | 1.51 | 0.90 |
| 1971 | 0.77 | 14.50 | 8.52 | 0.16 | 1.32 | 0.54 |
| 1972 | 0.73 | 13.19 | 7.59 | 0.14 | 1.17 | 0.38 |
| 1973 | 0.54 | 10.39 | 6.16 | 0.12 | 0.95 | 0.28 |
| 1974 | 0.39 | 8.19 | 5.24 | 0.10 | 0.81 | 0.18 |
| 1975 | 0.41 | 7.49 | 5.39 | 0.11 | 0.85 | 0.16 |
| 1976 | 0.38 | 6.68 | 5.34 | 0.11 | 0.85 | 0.12 |
| 1977 | 0.49 | 7.98 | 5.59 | 0.11 | 0.86 | 0.14 |
| 1978 | 0.41 | 7.14 | 5.28 | 0.11 | 0.82 | 0.13 |
| 1979 | 0.36 | 6.14 | 5.22 | 0.11 | 0.80 | 0.12 |
| 1980 | 0.38 | 6.14 | 4.35 | 0.09 | 0.67 | 0.11 |
| 1981 | 0.33 | 5.37 | 4.07 | 0.08 | 0.64 | 0.10 |
| 1982 | 0.36 | 5.58 | 4.45 | 0.09 | 0.68 | 0.10 |
| 1983 | 0.26 | 4.13 | 4.01 | 0.08 | 0.63 | 0.06 |
| 1984 | 0.24 | 3.96 | 3.57 | 0.08 | 0.55 | 0.06 |
| 1985 | 0.26 | 4.44 | 2.26 | 0.08 | 0.38 | 0.05 |
| 1986 | 0.37 | 6.13 | 2.70 | 0.11 | 0.43 | 0.06 |
| 1987 | 0.34 | 5.81 | 2.78 | 0.11 | 0.46 | 0.06 |
| 1988 | 0.33 | 5.58 | 2.75 | 0.11 | 0.45 | 0.04 |
| 1989 | 0.35 | 5.77 | 3.00 | 0.12 | 0.49 | 0.03 |
| 1990 | 0.31 | 5.22 | 2.19 | 0.09 | 0.52 | 0.02 |
| 1991 | 0.18 | 3.10 | 1.58 | 0.08 | 0.42 | 0.01 |
| 1992 | 0.17 | 3.00 | 1.57 | 0.08 | 0.43 | 0.01 |
| 1993 | 0.26 | 4.21 | 1.87 | 0.08 | 0.51 | 0.02 |
| 1994 | 0.22 | 3.55 | 1.62 | 0.08 | 0.46 | 0.02 |
| 1995 | 0.23 | 3.82 | 1.50 | 0.08 | 0.44 | 0.02 |
| 1996 | 0.23 | 3.82 | 1.49 | 0.08 | 0.44 | 0.01 |
| 1997 | 0.20 | 3.17 | 1.33 | 0.07 | 0.41 | 0.01 |

[1]except Pb, which is in short tons.

NOTE: see the notes at the bottom of Table E-3

*Table E-13*
**Emissions from SIC 32 (Stone, Clay, and Glass Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1737.06 | 744.97 | 339.42 | 5.63 | 35.79 | 541.69 |
| 1971 | 1596.45 | 741.66 | 350.52 | 5.90 | 54.87 | 484.63 |
| 1972 | 1514.73 | 766.06 | 364.40 | 6.10 | 56.71 | 410.28 |
| 1973 | 1361.07 | 767.87 | 367.88 | 6.09 | 62.49 | 262.31 |
| 1974 | 1067.45 | 730.84 | 344.98 | 5.70 | 56.39 | 198.58 |
| 1975 | 706.75 | 627.99 | 304.28 | 5.20 | 50.75 | 217.85 |
| 1976 | 668.43 | 699.17 | 340.71 | 5.95 | 55.59 | 200.53 |
| 1977 | 677.95 | 788.16 | 349.56 | 6.00 | 61.82 | 198.67 |
| 1978 | 689.31 | 834.16 | 364.78 | 6.23 | 64.92 | 209.43 |
| 1979 | 573.92 | 813.54 | 361.51 | 6.13 | 64.86 | 121.11 |
| 1980 | 419.72 | 735.48 | 307.16 | 5.11 | 53.56 | 93.21 |
| 1981 | 323.02 | 702.05 | 287.85 | 4.76 | 47.10 | 53.76 |
| 1982 | 249.36 | 614.08 | 260.35 | 4.47 | 41.34 | 39.98 |
| 1983 | 270.16 | 650.61 | 269.47 | 4.46 | 45.74 | 44.36 |
| 1984 | 304.13 | 703.98 | 285.11 | 4.59 | 49.19 | 47.73 |
| 1985 | 233.21 | 755.15 | 473.79 | 21.12 | 81.71 | 48.22 |
| 1986 | 233.53 | 752.47 | 472.87 | 21.69 | 83.01 | 29.40 |
| 1987 | 223.94 | 724.51 | 461.38 | 21.18 | 82.15 | 31.03 |
| 1988 | 216.51 | 719.66 | 466.35 | 21.47 | 83.85 | 25.96 |
| 1989 | 213.20 | 732.04 | 468.87 | 20.99 | 84.06 | 26.13 |
| 1990 | 213.84 | 797.01 | 481.07 | 23.95 | 97.13 | 29.09 |
| 1991 | 167.34 | 742.48 | 448.28 | 22.37 | 118.96 | 27.51 |
| 1992 | 164.49 | 711.36 | 450.06 | 31.56 | 125.72 | 29.19 |
| 1993 | 159.11 | 708.65 | 464.63 | 32.51 | 174.17 | 30.15 |
| 1994 | 157.03 | 708.36 | 481.92 | 36.15 | 174.51 | 31.13 |
| 1995 | 158.13 | 710.09 | 487.84 | 37.52 | 171.68 | 32.13 |
| 1996 | 156.39 | 738.53 | 500.50 | 38.00 | 175.56 | 32.02 |
| 1997 | 161.20 | 748.76 | 516.82 | 39.31 | 182.09 | 33.01 |

[1]except Pb, which is in short tons.

*Table E-14*
**Emissions from SIC 33 (Primary Metal Industries)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 812.08 | 5357.69 | 492.94 | 447.25 | 3701.74 | 23907.68 |
| 1971 | 720.88 | 4673.81 | 455.22 | 335.23 | 3607.62 | 22484.45 |
| 1972 | 750.64 | 5015.66 | 467.43 | 417.92 | 3753.48 | 17804.67 |
| 1973 | 787.45 | 5018.89 | 480.09 | 441.09 | 3707.86 | 14492.21 |
| 1974 | 701.76 | 4324.95 | 447.94 | 422.53 | 3482.43 | 12582.17 |
| 1975 | 512.58 | 3171.50 | 376.30 | 386.02 | 2540.81 | 9664.46 |
| 1976 | 687.18 | 2811.17 | 390.20 | 399.65 | 2692.71 | 6859.53 |
| 1977 | 613.10 | 2672.97 | 393.08 | 374.09 | 2583.28 | 4411.74 |
| 1978 | 608.65 | 2484.55 | 423.36 | 353.91 | 2662.17 | 4284.34 |
| 1979 | 562.63 | 2588.71 | 396.59 | 375.44 | 2650.08 | 3881.41 |
| 1980 | 457.81 | 2051.81 | 325.50 | 323.64 | 2284.95 | 2823.62 |
| 1981 | 450.96 | 2256.10 | 313.69 | 302.09 | 2254.41 | 2423.35 |
| 1982 | 313.62 | 1586.08 | 260.20 | 208.84 | 1550.94 | 2153.92 |
| 1983 | 274.00 | 1522.37 | 250.12 | 201.82 | 1589.59 | 1880.30 |
| 1984 | 297.80 | 1552.31 | 263.65 | 227.90 | 1764.83 | 1791.44 |
| 1985 | 227.97 | 1230.63 | 305.54 | 132.59 | 2253.65 | 1957.64 |
| 1986 | 209.30 | 1054.40 | 268.43 | 128.76 | 2105.63 | 1715.39 |
| 1987 | 200.15 | 808.51 | 273.16 | 125.21 | 2012.23 | 1704.84 |
| 1988 | 214.78 | 865.15 | 293.96 | 131.21 | 2130.52 | 1803.30 |
| 1989 | 217.66 | 847.52 | 296.13 | 130.49 | 2161.26 | 1919.82 |
| 1990 | 219.61 | 905.63 | 269.10 | 168.15 | 2632.14 | 1986.46 |
| 1991 | 181.92 | 767.49 | 244.21 | 174.45 | 2581.65 | 1777.08 |
| 1992 | 175.67 | 775.97 | 252.44 | 170.34 | 2506.53 | 1574.26 |
| 1993 | 175.54 | 772.83 | 265.94 | 171.80 | 2552.73 | 1707.93 |
| 1994 | 179.83 | 736.39 | 281.61 | 174.42 | 2494.46 | 1829.01 |
| 1995 | 206.25 | 720.56 | 290.35 | 174.00 | 2400.58 | 1866.92 |
| 1996 | 205.96 | 723.99 | 292.05 | 121.68 | 2399.25 | 1863.78 |
| 1997 | 213.91 | 740.95 | 302.09 | 127.04 | 2487.61 | 1850.88 |

[1]except Pb, which is in short tons.

*Table E-15*
**Emissions from SIC 34 (Fabricated Metal Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 12.11 | 102.54 | 152.38 | 67.97 | 22.49 | 4.78 |
| 1971 | 10.98 | 88.66 | 145.08 | 75.30 | 23.21 | 3.10 |
| 1972 | 11.63 | 86.13 | 151.10 | 80.92 | 24.15 | 2.26 |
| 1973 | 11.68 | 75.60 | 145.97 | 83.00 | 23.48 | 1.85 |
| 1974 | 10.11 | 58.20 | 125.79 | 80.41 | 20.26 | 1.21 |
| 1975 | 9.00 | 51.23 | 116.26 | 76.44 | 18.72 | 0.98 |
| 1976 | 9.87 | 52.84 | 124.61 | 86.24 | 19.89 | 0.82 |
| 1977 | 10.63 | 55.03 | 125.14 | 90.86 | 20.02 | 0.83 |
| 1978 | 10.72 | 51.68 | 129.20 | 96.93 | 20.67 | 0.75 |
| 1979 | 10.69 | 49.04 | 122.03 | 102.40 | 19.54 | 0.78 |
| 1980 | 9.84 | 41.63 | 101.14 | 95.34 | 16.76 | 0.66 |
| 1981 | 9.53 | 39.04 | 100.83 | 85.98 | 16.68 | 0.65 |
| 1982 | 8.96 | 41.51 | 113.98 | 81.71 | 18.34 | 0.63 |
| 1983 | 8.58 | 34.04 | 96.80 | 87.99 | 15.86 | 0.33 |
| 1984 | 9.24 | 33.76 | 103.11 | 87.57 | 16.75 | 0.29 |
| 1985 | 9.58 | 30.26 | 45.84 | 119.31 | 8.79 | 0.20 |
| 1986 | 9.80 | 31.56 | 44.59 | 117.50 | 8.51 | 0.20 |
| 1987 | 10.04 | 30.06 | 46.07 | 116.78 | 8.66 | 0.17 |
| 1988 | 10.38 | 31.58 | 50.48 | 118.06 | 9.40 | 0.15 |
| 1989 | 10.59 | 28.70 | 49.52 | 117.38 | 9.20 | 0.13 |
| 1990 | 10.84 | 35.77 | 35.89 | 164.91 | 8.18 | 0.12 |
| 1991 | 9.75 | 28.82 | 32.56 | 191.44 | 8.81 | 0.09 |
| 1992 | 10.28 | 30.10 | 34.87 | 197.60 | 9.42 | 0.09 |
| 1993 | 8.43 | 30.95 | 37.99 | 200.86 | 10.48 | 0.10 |
| 1994 | 8.36 | 30.69 | 43.07 | 207.23 | 11.38 | 0.10 |
| 1995 | 8.43 | 32.27 | 44.30 | 210.72 | 11.84 | 0.10 |
| 1996 | 8.46 | 32.83 | 44.94 | 215.46 | 12.04 | 0.09 |
| 1997 | 8.91 | 32.91 | 46.22 | 224.28 | 12.42 | 0.09 |

[1]except Pb, which is in short tons.
NOTE: the estimates of the "NA" cells of PM-10 emissions for 1970 to 1984 never exceed 0.11 thousand short tons in any year
NOTE: the estimates of the "NA" cells of $SO_2$ emissions for 1970 to 1984 never exceed 0.27 thousand short tons in any year

*Table E-16*
**Emissions from SIC 35 (Industrial Machinery Equipment)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 5.37 | 114.56 | 116.98 | 41.69 | 17.09 | 6.14 |
| 1971 | 4.52 | 100.76 | 115.12 | 46.59 | 18.19 | 4.32 |
| 1972 | 4.55 | 101.69 | 118.74 | 50.32 | 18.73 | 3.29 |
| 1973 | 3.91 | 92.71 | 117.13 | 52.95 | 18.62 | 2.81 |
| 1974 | 2.72 | 73.37 | 104.56 | 53.38 | 16.68 | 1.89 |
| 1975 | 2.55 | 68.40 | 93.32 | 53.12 | 14.87 | 1.63 |
| 1976 | 2.62 | 60.18 | 94.80 | 62.34 | 15.03 | 1.11 |
| 1977 | 2.62 | 62.40 | 94.42 | 64.53 | 15.02 | 1.11 |
| 1978 | 2.57 | 66.70 | 99.96 | 68.18 | 15.84 | 1.18 |
| 1979 | 2.27 | 66.39 | 97.31 | 70.50 | 15.43 | 1.33 |
| 1980 | 2.03 | 57.22 | 80.69 | 64.24 | 13.21 | 1.23 |
| 1981 | 1.91 | 53.36 | 78.42 | 55.49 | 12.83 | 1.15 |
| 1982 | 2.02 | 52.85 | 87.33 | 63.84 | 13.94 | 0.96 |
| 1983 | 1.34 | 41.58 | 68.70 | 54.96 | 11.17 | 0.48 |
| 1984 | 1.37 | 43.32 | 72.47 | 52.84 | 11.66 | 0.46 |
| 1985 | 1.91 | 39.28 | 33.46 | 38.38 | 6.22 | 0.37 |
| 1986 | 1.86 | 38.44 | 31.96 | 29.75 | 5.92 | 0.31 |
| 1987 | 1.77 | 37.92 | 34.06 | 29.84 | 6.30 | 0.27 |
| 1988 | 1.80 | 38.76 | 37.14 | 30.10 | 6.86 | 0.24 |
| 1989 | 1.71 | 35.77 | 36.67 | 29.76 | 6.73 | 0.21 |
| 1990 | 1.84 | 38.08 | 25.67 | 29.29 | 6.02 | 0.18 |
| 1991 | 1.39 | 30.97 | 23.43 | 27.27 | 6.05 | 0.16 |
| 1992 | 1.38 | 30.04 | 22.68 | 27.29 | 5.94 | 0.15 |
| 1993 | 1.40 | 29.83 | 22.88 | 27.44 | 6.19 | 0.16 |
| 1994 | 1.46 | 30.46 | 23.65 | 28.16 | 6.52 | 0.17 |
| 1995 | 1.69 | 35.73 | 26.68 | 26.75 | 7.53 | 0.18 |
| 1996 | 1.86 | 39.29 | 29.15 | 28.00 | 8.26 | 0.17 |
| 1997 | 2.02 | 41.93 | 32.22 | 29.44 | 9.19 | 0.20 |

[1]except Pb, which is in short tons.

*Table E-17*
**Emissions from SIC 36 (Electric and Electronic Equipment)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 3.90 | 80.12 | 79.37 | 80.90 | 18.43 | 4.18 |
| 1971 | 3.22 | 65.48 | 77.30 | 91.93 | 19.14 | 2.54 |
| 1972 | 3.33 | 69.69 | 79.59 | 101.93 | 20.45 | 2.16 |
| 1973 | 2.89 | 67.73 | 76.98 | 101.53 | 21.16 | 2.05 |
| 1974 | 1.87 | 52.63 | 64.23 | 91.32 | 19.08 | 1.41 |
| 1975 | 1.68 | 42.42 | 56.79 | 78.12 | 16.69 | 0.99 |
| 1976 | 1.86 | 44.42 | 61.42 | 82.48 | 18.31 | 0.84 |
| 1977 | 1.90 | 45.57 | 62.25 | 85.30 | 19.84 | 0.82 |
| 1978 | 1.89 | 45.28 | 64.38 | 90.61 | 21.23 | 0.79 |
| 1979 | 1.70 | 45.22 | 62.79 | 96.19 | 22.17 | 0.89 |
| 1980 | 1.53 | 35.54 | 53.03 | 93.57 | 21.38 | 0.70 |
| 1981 | 1.43 | 34.92 | 52.08 | 89.49 | 21.82 | 0.71 |
| 1982 | 1.59 | 36.12 | 60.65 | 87.00 | 23.14 | 0.63 |
| 1983 | 1.14 | 30.46 | 53.40 | 94.32 | 23.27 | 0.35 |
| 1984 | 1.18 | 30.63 | 56.12 | 108.64 | 26.43 | 0.32 |
| 1985 | 1.35 | 25.02 | 23.96 | 102.51 | 22.31 | 0.22 |
| 1986 | 1.39 | 25.91 | 23.31 | 99.39 | 22.29 | 0.20 |
| 1987 | 1.17 | 21.91 | 21.89 | 99.31 | 21.58 | 0.15 |
| 1988 | 1.27 | 24.01 | 25.59 | 99.56 | 17.49 | 0.14 |
| 1989 | 1.26 | 23.85 | 24.03 | 98.60 | 16.46 | 0.13 |
| 1990 | 1.43 | 27.02 | 17.70 | 101.88 | 5.56 | 0.12 |
| 1991 | 1.21 | 25.66 | 17.91 | 97.79 | 6.00 | 0.13 |
| 1992 | 1.33 | 27.83 | 18.77 | 100.48 | 6.23 | 0.15 |
| 1993 | 1.27 | 27.05 | 19.08 | 104.19 | 6.47 | 0.15 |
| 1994 | 1.36 | 28.76 | 20.39 | 109.70 | 6.87 | 0.17 |
| 1995 | 1.72 | 36.73 | 25.23 | 108.64 | 8.27 | 0.21 |
| 1996 | 2.11 | 45.10 | 30.72 | 121.75 | 9.78 | 0.22 |
| 1997 | 2.50 | 52.82 | 37.17 | 128.30 | 11.62 | 0.28 |

[1]except Pb, which is in short tons.

NOTE: the estimates of the "NA" cells of PM-10 emissions for 1970 to 1984 never exceed 0.08 thousand short tons in any year

NOTE: the estimates of the "NA" cells of $SO_2$ emissions for 1970 to 1989 never exceed 0.45 thousand short tons in any year

NOTE: the estimates of the "NA" cells of $NO_x$ emissions for 1970 to 1984 never exceed 0.07 thousand short tons in any year

*Table E-18*
**Emissions from SIC 37 (Transportation Equipment)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 8.56 | 184.46 | 118.00 | 193.63 | 16.76 | 10.97 |
| 1971 | 7.80 | 164.54 | 118.10 | 216.79 | 18.06 | 8.11 |
| 1972 | 7.98 | 169.86 | 120.73 | 232.07 | 18.39 | 6.23 |
| 1973 | 7.23 | 153.31 | 113.71 | 238.07 | 17.39 | 5.22 |
| 1974 | 5.47 | 132.27 | 105.22 | 236.81 | 16.14 | 3.94 |
| 1975 | 4.81 | 120.12 | 97.67 | 233.86 | 15.02 | 3.24 |
| 1976 | 5.33 | 119.54 | 109.54 | 261.63 | 16.81 | 2.57 |
| 1977 | 5.55 | 116.26 | 106.92 | 268.36 | 16.46 | 2.34 |
| 1978 | 5.67 | 120.07 | 111.63 | 258.56 | 17.17 | 2.34 |
| 1979 | 5.35 | 117.95 | 105.12 | 243.08 | 16.09 | 2.62 |
| 1980 | 4.87 | 99.65 | 81.92 | 197.68 | 12.82 | 2.37 |
| 1981 | 4.46 | 99.53 | 80.54 | 146.64 | 12.61 | 2.44 |
| 1982 | 4.40 | 94.84 | 83.64 | 126.25 | 12.81 | 1.95 |
| 1983 | 3.84 | 87.26 | 80.49 | 148.46 | 12.57 | 1.08 |
| 1984 | 4.14 | 92.76 | 86.00 | 169.81 | 13.29 | 1.07 |
| 1985 | 6.25 | 86.93 | 53.09 | 132.66 | 9.21 | 0.92 |
| 1986 | 6.44 | 91.46 | 54.34 | 136.55 | 9.36 | 0.82 |
| 1987 | 6.04 | 85.79 | 52.91 | 134.82 | 9.13 | 0.69 |
| 1988 | 6.08 | 83.69 | 53.58 | 139.22 | 9.20 | 0.58 |
| 1989 | 6.08 | 83.30 | 54.71 | 142.29 | 9.36 | 0.52 |
| 1990 | 6.69 | 92.01 | 43.65 | 120.70 | 9.52 | 0.50 |
| 1991 | 5.77 | 79.64 | 41.24 | 118.44 | 9.73 | 0.47 |
| 1992 | 5.67 | 75.25 | 40.82 | 121.54 | 9.80 | 0.45 |
| 1993 | 3.86 | 74.02 | 42.43 | 121.46 | 10.54 | 0.46 |
| 1994 | 3.59 | 67.29 | 41.28 | 125.54 | 10.58 | 0.43 |
| 1995 | 3.61 | 68.43 | 40.04 | 123.81 | 10.47 | 0.39 |
| 1996 | 3.62 | 68.91 | 39.95 | 148.46 | 10.50 | 0.34 |
| 1997 | 3.77 | 70.37 | 42.49 | 158.06 | 11.26 | 0.38 |

[1]except Pb, which is in short tons.
NOTE: the estimates of the "NA" cells of $NO_x$ emissions for 1970 to 1984 never exceed 0.01 thousand short tons in any year
NOTE: the estimates of the "NA" cells of CO emissions for 1970 to 1984 never exceed 0.01 thousand short tons in any year

*Table E-19*
**Emissions from SIC 38 (Instruments and Related Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1.87 | 46.19 | 21.73 | 0.33 | 2.99 | 2.69 |
| 1971 | 1.92 | 48.18 | 22.87 | 0.36 | 3.32 | 2.35 |
| 1972 | 2.08 | 52.86 | 24.03 | 0.37 | 3.46 | 1.94 |
| 1973 | 1.63 | 43.78 | 20.65 | 0.32 | 2.97 | 1.48 |
| 1974 | 1.31 | 42.67 | 20.10 | 0.31 | 2.86 | 1.26 |
| 1975 | 1.13 | 35.82 | 18.40 | 0.29 | 2.68 | 0.96 |
| 1976 | 1.10 | 33.45 | 20.25 | 0.35 | 3.00 | 0.73 |
| 1977 | 1.11 | 22.92 | 18.71 | 0.38 | 2.87 | 0.42 |
| 1978 | 1.01 | 25.56 | 18.52 | 0.35 | 2.81 | 0.49 |
| 1979 | 0.96 | 41.51 | 22.77 | 0.36 | 3.32 | 0.98 |
| 1980 | 0.91 | 37.16 | 20.34 | 0.32 | 3.04 | 0.97 |
| 1981 | 0.84 | 35.20 | 20.00 | 0.32 | 3.00 | 0.92 |
| 1982 | 0.94 | 38.44 | 23.17 | 0.38 | 3.41 | 0.84 |
| 1983 | 0.71 | 36.78 | 22.12 | 0.36 | 3.30 | 0.46 |
| 1984 | 0.76 | 38.96 | 24.37 | 0.39 | 3.61 | 0.46 |
| 1985 | 1.61 | 35.92 | 15.78 | 0.38 | 2.47 | 0.41 |
| 1986 | 1.62 | 36.33 | 15.86 | 0.40 | 2.47 | 0.34 |
| 1987 | 1.62 | 37.57 | 17.61 | 0.48 | 2.84 | 0.30 |
| 1988 | 1.63 | 38.15 | 17.49 | 0.46 | 2.77 | 0.28 |
| 1989 | 1.71 | 39.42 | 18.95 | 0.50 | 3.02 | 0.27 |
| 1990 | 2.00 | 42.15 | 15.87 | 0.43 | 3.19 | 0.27 |
| 1991 | 1.72 | 40.26 | 15.70 | 0.38 | 3.26 | 0.29 |
| 1992 | 1.82 | 41.21 | 16.55 | 0.41 | 3.47 | 0.29 |
| 1993 | 1.85 | 41.83 | 17.14 | 0.38 | 3.58 | 0.30 |
| 1994 | 1.74 | 39.26 | 16.72 | 0.44 | 3.49 | 0.29 |
| 1995 | 1.82 | 40.93 | 16.93 | 0.45 | 3.56 | 0.29 |
| 1996 | 1.86 | 42.31 | 17.27 | 0.45 | 3.67 | 0.26 |
| 1997 | 1.84 | 41.01 | 17.31 | 0.46 | 3.68 | 0.27 |

[1]except Pb, which is in short tons.

*Table E-20*
**Emissions from SIC 39 (Miscellaneous Manufacturing Products)**
**(thousand short tons)[1]**

| Year | PM-10 | SO2 | NOx | VOC | CO | Pb |
|---|---|---|---|---|---|---|
| 1970 | 1.02 | 15.91 | 14.67 | 0.30 | 2.13 | 0.61 |
| 1971 | 0.94 | 16.01 | 15.27 | 0.33 | 2.42 | 0.46 |
| 1972 | 1.08 | 17.36 | 16.96 | 0.37 | 2.69 | 0.41 |
| 1973 | 0.83 | 14.30 | 14.90 | 0.33 | 2.37 | 0.32 |
| 1974 | 0.53 | 10.99 | 13.18 | 0.30 | 2.11 | 0.22 |
| 1975 | 0.51 | 8.32 | 11.23 | 0.26 | 1.81 | 0.15 |
| 1976 | 0.59 | 10.02 | 11.63 | 0.26 | 1.84 | 0.17 |
| 1977 | 0.51 | 8.83 | 11.46 | 0.26 | 1.84 | 0.14 |
| 1978 | 0.48 | 8.45 | 12.00 | 0.28 | 1.92 | 0.14 |
| 1979 | 0.39 | 7.57 | 11.53 | 0.27 | 1.86 | 0.13 |
| 1980 | 0.36 | 7.14 | 10.01 | 0.23 | 1.66 | 0.13 |
| 1981 | 0.31 | 6.88 | 9.75 | 0.22 | 1.61 | 0.13 |
| 1982 | 0.30 | 6.20 | 9.69 | 0.22 | 1.55 | 0.11 |
| 1983 | 0.23 | 5.78 | 8.84 | 0.20 | 1.43 | 0.07 |
| 1984 | 0.24 | 5.54 | 9.44 | 0.22 | 1.52 | 0.06 |
| 1985 | 0.28 | 5.10 | 4.39 | 0.18 | 0.81 | 0.05 |
| 1986 | 0.30 | 5.45 | 4.67 | 0.21 | 0.86 | 0.05 |
| 1987 | 0.34 | 6.52 | 5.28 | 0.21 | 0.95 | 0.05 |
| 1988 | 0.28 | 5.59 | 5.80 | 0.26 | 1.09 | 0.03 |
| 1989 | 0.28 | 5.57 | 5.64 | 0.25 | 1.05 | 0.03 |
| 1990 | 0.27 | 5.33 | 3.56 | 0.19 | 0.90 | 0.02 |
| 1991 | 0.24 | 4.92 | 3.42 | 0.18 | 0.93 | 0.02 |
| 1992 | 0.24 | 5.06 | 3.66 | 0.17 | 1.00 | 0.02 |
| 1993 | 0.25 | 5.01 | 3.90 | 0.17 | 1.10 | 0.02 |
| 1994 | 0.24 | 4.64 | 3.84 | 0.20 | 1.11 | 0.02 |
| 1995 | 0.25 | 5.00 | 3.88 | 0.22 | 1.15 | 0.02 |
| 1996 | 0.25 | 5.10 | 3.94 | 0.23 | 1.17 | 0.02 |
| 1997 | 0.25 | 4.89 | 3.95 | 0.23 | 1.19 | 0.02 |

[1]except Pb, which is in short tons.

# APPENDIX F
# ORGANIZATION OF SPREADSHEET

*Contents of Spreadsheet SIC7097.WK3*

| **SIC7097.WK3** | **Description of contents of Sheet** |
|---|---|
| Sheet A | Contents of spreadsheet |
| Sheet B | CO emissions (original spreadsheet) |
| Sheet C | $NO_x$ emissions (original spreadsheet) |
| Sheet D | VOC emissions (original spreadsheet) |
| Sheet E | $SO_2$ emissions (original spreadsheet) |
| Sheet F | PM-10 emissions (original spreadsheet) |
| Sheet G | PM-2.5 emissions (original spreadsheet) |
| Sheet H | Ammonia emissions (original spreadsheet) |
| Sheet I | Pb emissions (original spreadsheet) |
| Sheet J | Process emissions (agriculture, 4 mining industries, construction, and 20 manufacturing industries) (sum of sheets B through F, and sheet I) - assigned by Allocation Rules 1 and 2 |
| Sheet K | Adjusted CO emissions (assign values to "NA" cells) |
| Sheet L | Adjusted $NO_x$ emissions (assign values to "NA" cells) |
| Sheet M | Adjusted VOC emissions (assign values to "NA" cells) |
| Sheet N | Adjusted $SO_2$ emissions (assign values to "NA" cells) |
| Sheet O | Adjusted PM-10 emissions (assign values to "NA" cells) |
| Sheet P | Adjusted Pb emissions (assign values to "NA" cells) |
| Sheet Q | Output indexes : 1970 -1997 (agriculture, 4 mining industries, construction, and 20 manufacturing industries) |
| Sheet R | Federal Reserve Board, value added, 1992, 1987, 1982 |
| Sheet S | Federal Reserve Board, production indexes, 1919-1985 |
| Sheet T | Federal Reserve Board, production indexes, 1986-1999 |
| Sheet U | Process emissions (agriculture, 4 mining industries, construction, and manufacturing industries) (sum of sheets K through P) |

| **SIC7097.WK3** | **Description of contents of Sheet** |
|---|---|
| Sheet V | BEA, gross output (1947-1987) : agriculture and construction |
| Sheet W | BEA, gross output (1987-1997) : agriculture and construction |
| Sheet X | Coal consumption (1982-1997) : agriculture, 4 mining industries, and construction) |
| Sheet Y | Natural Gas consumption (1982-1997) : agriculture, 4 mining industries, and construction |
| Sheet Z | Distillate Fuel Oil consumption (1982-1997) : agriculture, 4 mining industries, and construction |
| Sheet AA | Residual Fuel Oil consumption (1982-1997) : agriculture, 4 mining industries, and construction |
| Sheet AB | Share of Coal consumption of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AC | Share of Residual Fuel Oil consumption of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AD | Share of Distillate Fuel Oil consumption of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AE | Share of Fuel Oil consumption (aggregate - assign CO emissions) of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AF | Share of Fuel Oil consumption (aggregate - assign VOC emissions) of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AG | Share of Gas (natural, processed, and other) consumption of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AH | Share of Wood consumption of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AI | Share of Coke Oven Gas and Still Gas consumption (PM-10) of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |

| **SIC7097.WK3** | **Description of contents of Sheet** |
|---|---|
| Sheet AJ | Share of Coke Oven Gas and Still Gas consumption ($NO_x$) of agriculture, mining, construction, and 20 manufacturing industries (1970-1997) |
| Sheet AK | Emissions from coal combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AL | Emissions from residual fuel oil combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AM | Emissions from distillate fuel oil combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AN | Emissions (VOC and CO) from fuel oil combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AO | Emissions from natural gas combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AP | Emissions from wood combustion (agriculture, mining, construction, and 20 manufacturing industries) |
| Sheet AQ | Fuel combustion emissions (agriculture, mining, construction, and 20 manufacturing industries) (sum of sheets AK through AP) |
| Sheet AR | Process and Fuel combustion emissions (agriculture, mining, construction, and 20 manufacturing industries) (sum of sheets U through AQ) |
| Sheet AS | Process and Fuel combustion emissions (agriculture, mining, construction, and 20 manufacturing industries) (linked to Appendix E) |

# APPENDIX G
# PREPARATION OF REPORT AND PEER REVIEW PROCESS

## G.1. PREPARING THE REPORT

This report was prepared by Carl A. Pasurka, Jr. in the EPA's National Center for Environmental Economics, Office of Policy, Economics and Innovation.

Dwight French, Christy Hall, Alice Lipert, and Mark Schipper of the U.S. Department of Energy provided information on the availability of energy consumption data for the industrial sector.

Chris Perrien of the U.S. Bureau of the Census provided information on thermal conversion factors used in the *Census of Mineral Industries*.

Wiley Barbour (Office of Air and Radiation, U.S. EPA) and Anton Steurer (Eurostat) provided encouragement and insights throughout the process of writing this report.

Bill Barnard of E.H. Pechan and Associates provided useful insights concerning the estimates of emissions. Douglas Solomon and David Misenheimer (U.S. EPA, Office of Air and Radiation) also provided assistance. Special thanks go to Sharon Nizich (Office of Air and Radiation, U.S. EPA) and Tom McMullen (Office of Air and Radiation, U.S. EPA) for providing information on the procedures employed to estimate air emissions. It would have been impossible to complete this project without their assistance.

## G.2. DESCRIPTION OF THE REVIEW PROCESS

The draft of what has emerged as *Statistical Methodology for Assigning Emissions to Industries in the United States, Revised Estimates: 1970 to 1997* was subjected to both inter- and intra-agency review. In addition to a representative of the Statistical Office of the European Communities, representatives from the Office of Air and Radiation of the U.S. EPA were contacted for comment.

The following individuals (in alphabetical order) provided helpful comments on the draft of this report:

Wiley Barbour (U.S. EPA, Office of Air and Radiation)
Tom McMullen (U.S. EPA, Office of Air and Radiation)
Sharon Nizich (U.S. EPA, Office of Air and Radiation)
Anton Steurer (Statistical Office of the European Communities)

In addition to making numerous suggestions for changes in style, the reviews also made the following suggestions regarding the content of the report. Upon receipt of the comments, Carl Pasurka attempted to address and incorporate all comments to the maximum extent possible. The comments listed in this section do not always represent the exact wording of the original comments and may reflect a combination of more than one comment. Specific comments and responses are listed below.

G.3. SPECIFIC COMMENTS AND RESPONSES

Comment: Report should highlight the fact that emissions from motor vehicles are not assigned to various industries.

Response: Section 1.1. now mentions that emissions from motor vehicles are not assigned to industries.

Comment: The use of fuel consumption data to assign emissions from result from fuel combustion ignores differences in control efficiencies, age of boilers, and variation in standards across industries.

Response: The first paragraph of Section 3 acknowledges this assumption. Section 4 (Overview) points out that this same assumption has been employed by the statistical agencies of other governments that have developed inventories of emissions by industry.

Comment: There should be some explanation of why certain source categories are not assigned to industries.

Response: Portions of Sections 1.1, 2.1.13, 3.6, and 4 discuss which source categories are excluded and explain why some of the categories are excluded.

Comment: The report should provide a list of Acronyms and Abbreviations.

Response: The report now includes a list of relevant Acronyms and Abbreviations.

Comment: The report should define “industrial sector.”

Response: The report provides a definition of “industrial sector” in footnote 4 on page 2.

Comment: There should be a discussion of the potential uses of the data developed in the report.

Response: Within the Introduction section, the “Purpose of the Project” now contains an overview of some of the proposed uses of these data.

Comment: Will it be fairly easy to revise the data in this study from an SIC basis to the NAICS codes?

Response: Footnotes 46 and 47 discuss some of the problems associated with maintaining a consistent time series using data collected by the SIC and NAICS systems. This is an important issue confronting the statistical agencies of the United States. It appears there will be efforts to maintain consistent time series for at least some data. However, it will be several years before it becomes apparent which data and which years will be included in such a time series. If the change from SIC to

NAICS codes makes it difficult to assign the Tier I, II, and III categories of process emissions, it would be possible to use the estimates of emissions by SCC codes and develop a consist set process emissions for the years starting with 1985.

Comment: The "Allocation Rules" in Section 2.1 of need to be clarified.

Response: The discussion of the "Allocation Rules" in Section 2.1 has been revised.

Comment: The study should clarify how emissions from the co-generation of electricity are treated.

Response: Footnote 17 discusses this issue

Comment: How significant is the discrepancy between the NEA and DAEMEC estimates of fuel consumption?

Response: The shares of coal, residual fuel oil, distillate fuel oil, and natural gas consumption assigned to industries in Sheets AB, AC, AD, and AG of SIC7097.WK3 do not appear to experience a dramatic change between 1984 (NEA data) and 1985 (DAEMEC data). This is mentioned in footnote 21. Section 3.3.3. discusses the discrepancies that exist between the NEA and DAEMEC estimates of consumption of wood for heat and power. Sheets AH of SIC7097.WK3 presents the distribution of wood consumption among industries. Section 3.3.4. discusses the discrepancies that exist between the NEA and DAEMEC estimates of consumption of blast furnace / coke oven and still gases heat and power. Sheets AI of SIC7097.WK3 presents the distribution of blast furnace / coke oven and still gases consumption among industries. In addition, Section 4 contains two paragraphs illustrating that most of the substantial declines in VOC and PM-10 emissions between 1984 and 1985 are the consequence of factors other the switch from the NEA and DAEMEC estimates of fuel consumption.

Comment: Since *Statistical Methodology for Assigning Emissions to Industries in the United States, Revised Estimates: 1970 to 1997* assigns values to some cells listed as "NA" in the *1970-1997 NAPET*, the reader should be told which values are affected by these estimates.

Response: In Appendix E, all estimates of emissions affected by estimates of "NA" cells are highlighted.

Comment: Is it possible to develop more disaggregated estimates of emissions than the two-digit SIC level?

Response: Estimates of process emissions are available by SCC for 1985 to the present. It would be necessary to develop a concordance between the SCCs and the SIC or NAICS codes. Since fuel consumption by industry is used to assign emissions

from the combustion of fuel in the industrial sector, the only other constraint on developing more disaggregated estimates of emissions is the availability of information on fuel consumption by industry.

Comment: What share of total emissions are assigned to industries in this report?

Response: Table 6 has been added and shows the quantity of emissions included in this report, and the share of total emissions assigned to the electric utility sector and industries in the industrial sector.