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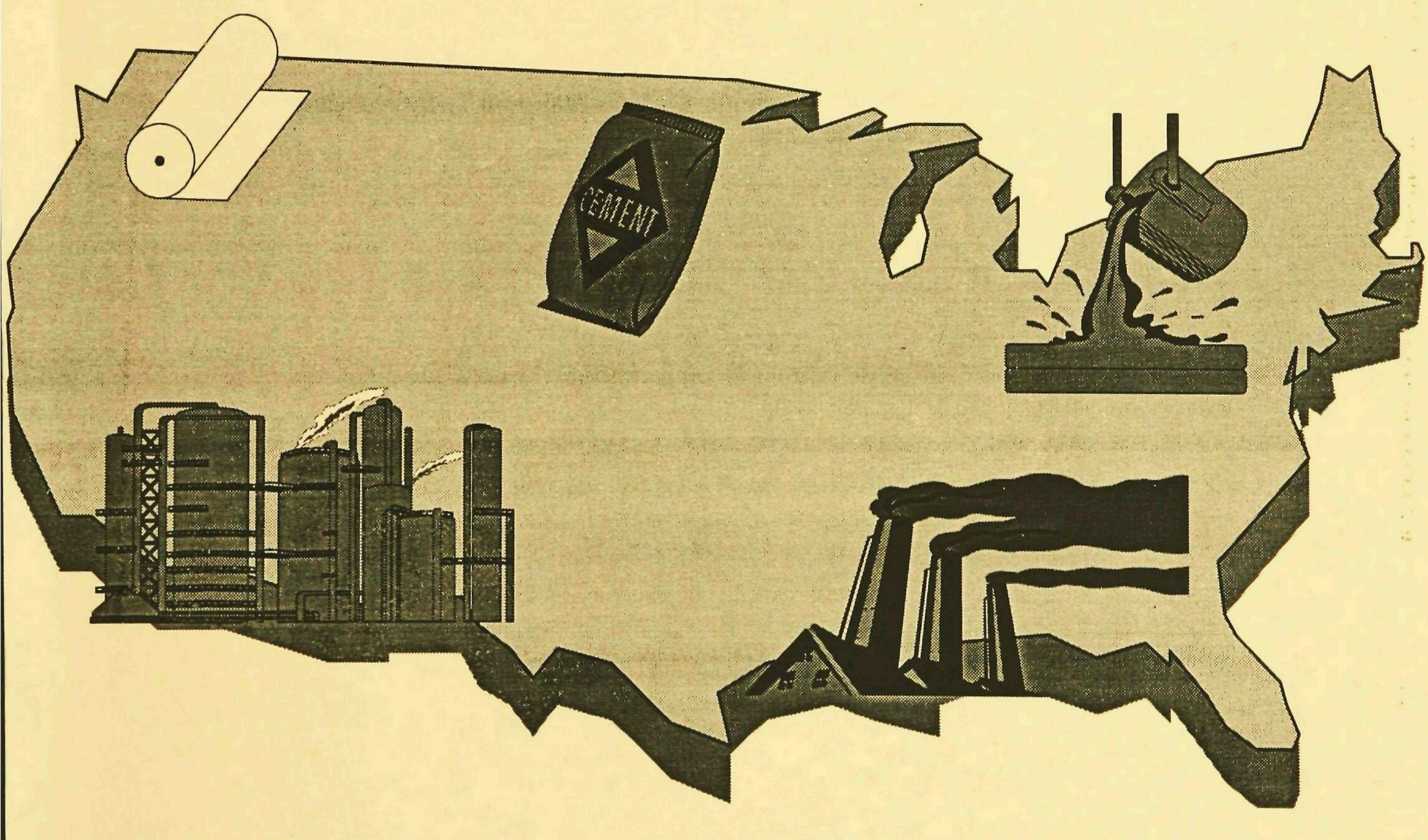
EPA Comparison of the 1985 NAPAP Emissions Inventory with the 1985 EPA TRENDS Estimate for Industrial SO_2 Sources



Joint **E**missions **I**nventory **O**versight **G**roup

EPA REVIEW NOTICE

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Comparison of the 1985 NAPAP Emissions Inventory with the 1985 EPA TRENDS Estimate for Industrial SO_2 Sources

Final Report

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FOREWORD

This document compares results from 1985 EPA Emission TRENDS methodology with 1985 NAPAP Emission Inventory methodology. Due to findings in this report as well as other factors, the TRENDS methodology has been revised as of 1993; thus, references to TRENDS in this report will no longer be valid for years 1985 and beyond, effective with the 1993 edition of the TRENDS report. The new TRENDS methodology uses the 1985 NAPAP Emission Inventory as a base. Further changes will be seen in the TRENDS reports published in 1994 and thereafter. Thus, the reader is cautioned that comments on the EPA TRENDS report in this document are valid for editions prior to 1993, but are not valid for the editions 1993 and thereafter.

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EXECUTIVE SUMMARY

Section 406 of the 1990 Clean Air Act Amendments (CAAA) requires that the Administrator of the Environmental Protection Agency transmit to Congress a report containing a national inventory of annual sulfur dioxide (SO_2) emissions from industrial sources not later than January 1, 1995 for all years for which data are available, as well as the likely trend in SO_2 emissions over the following twenty year period (1995 to 2015). Under the Act as amended, 1985 served as the baseline for the 5.6 million ton industrial SO_2 emission estimate. To provide the 1995 analysis mandated by Congress, the 1985 baseline data must first be examined to identify strengths and weaknesses in the available emission and supporting data. This report presents the initial analysis of two major sources of baseline industrial data available at this time: the 1985 National Acid Precipitation Assessment Program (NAPAP) emission inventory and the 1985 national emission estimates, referred to as the TRENDS emission estimates.

The 1985 NAPAP emission inventory effort supported acid precipitation deposition research, including atmospheric modeling, through comprehensive, detailed source emission estimates provided by local and state agencies. It is a "bottom-up" inventory and a 1985 snapshot. The SO_2 emission data for significant (>100 tons per year) sources were systematically quality assured, with greater effort expended on larger sources. The inventory included a unique confirmation step, allowing individual plants emitting at least 2500 tons per year to review their emission estimates prior to finalization. The resulting inventory is widely regarded as the most comprehensive and accurate national inventory compiled to date.

The TRENDS estimates represent both current and historic emissions (1940 to present) and are compiled annually. Industrial emission estimates are derived from national, published activity data and standard emission factors; historic estimates are altered based on the most recent activity data and emission factors to better represent the most current understanding of emission processes. It is essentially a "top-down" approach and not a true inventory. It presents a consistently derived national emission estimate at the emission category level (*e.g.*, industrial oil combustion) rather than the source (*e.g.*, boiler) level.

The aim of this document is to analyze the derivation of individual industrial category estimates from NAPAP and TRENDS. Such analyses are complicated by several factors:

- NAPAP is comprehensive and includes all reported industrial emission categories; TRENDS is limited to categories thought to emit at least 10,000 metric tons of a criteria pollutant per year.

- NAPAP is source and plant specific; TRENDS is national and category-specific. There is no opportunity to match individual data values between the inventories; in fact, category definitions differ between the two inventories.

- The 1985 NAPAP inventory is a single year inventory and is not updated; TRENDS adjusts historical data based on the most current information.

- A complete understanding of a NAPAP emission category could entail plant by plant, source by source review of throughput data, control information, fuel parameters, etc. Such an effort was not possible within the framework of this project. The TRENDS methods were reviewed, but still represent a large and complicated set of data, methods and assumptions.

It is unavoidable but in a number of cases it is difficult if not impossible to compare TRENDS and NAPAP on an even basis.

This document presents a highly detailed view of the two inventories on a category basis, principally relying on emission and activity (throughput) data. Methods, data sources, emissions and assumptions are documented and analyzed in as much detail as possible so that this information need not be recompiled for future examination. The authors have attempted to reproduce the 1985 TRENDS emissions estimates and noted any irregularities in the calculated and published data. The analyses proved complex, especially when disaggregating data to create comparable categories between NAPAP and TRENDS datasets, and raised a number of questions. (In particular, categories with significant inprocess fuel emissions such as cement proved difficult to assess because the process and fuel emissions were treated differently in each dataset.) As such, most of the document is technical in nature and is meant to be a reference tool as individual category methods and emissions are compared during the development of the 1995 Report to Congress. Supporting data are consolidated and provided in Appendix A.

Overall, the two 1985 estimates (NAPAP and TRENDS) compare favorably: NAPAP estimates 5.6 million tons SO_2 (as reflected in the Act as amended) and TRENDS estimates 6.0 million tons. When broken down, however, the two estimates show greater divergence for individual categories. The TRENDS estimate is larger than the 1985 NAPAP estimate and does not include as many source categories. The TRENDS estimate systematically overestimates emissions, relative to the NAPAP inventory, and therefore on aggregate the estimates are very similar. The primary reason for the overestimation in the TRENDS method is the exclusion of SO_2 control technology that has come into being over the years. SO_2 control technology has been applied to the majority of the large industrial SO_2 categories through the promulgation of New Source Performance Standards (NSPS), issuance of operating permits, and New Source Review Permits. Several categories exceeding 100,000 tons of SO_2 differ by more than 50 percent between the two datasets:

- Primary lead and zinc
- Iron and steel
- Oil and natural gas production
- Pulp and paper
- Cement

In general terms, the authors drew the following conclusions from the analyses of the two datasets. These conclusions are based on an analysis of the 1985 NAPAP SAS® data files (annual files) and the published TRENDS methods and emissions data.

NAPAP

- The 1985 NAPAP inventory still represents the most comprehensive and accurate *emissions* estimates for 1985 because of its unprecedentedly rigorous quality assurance of emissions and bottom-up nature. The inventory accounts for individual source operating characteristics, controls and emission factors.

- Activity data in the 1985 NAPAP inventory were not subject to the same standard of quality assurance or completeness. Some data were unreported due to confidentiality restrictions and activity data for small sources (*i.e.*, <100 tons per year) passed only the grossest quality assurance checks. There are known reporting problems among miscellaneous fuels and other categories. The accuracy and representativeness of activity data in the NAPAP inventory are best evaluated source by source; category-level summaries are unreliable without adjustments.

- It is still very possible to locate questionable data values in the 1985 NAPAP emission inventory when examined on a source by source basis, especially for smaller emitters.

TRENDS

- Some industrial emission categories, notably processes within oil and natural gas production, are missing from the TRENDS method.

- As a top-down approach, broad assumptions of emission factors and controls are used across a category. Frequently, estimates make no adjustment for controls and accommodation for individual operating characteristics, including emission factors, is impossible.

- For the most part, the underlying industrial activity data are reliable and probably far superior to the corresponding NAPAP estimates at the category level. Any method for 1995 and beyond should take advantage of the underlying data sources.

- Based on the TRENDS documentation, the actual TRENDS execution contains minor to moderate errors in calculation of activity and emissions. As such, some sections of this report related to the calculation of the TRENDS emission estimate are internally inconsistent. TRENDS could also benefit from recently revised standard emission factors and updated sources of activity data.

Due to findings in this report as well as other factors, the TRENDS methodology has been revised as of 1993; thus, references to TRENDS in this report will no longer be valid for years 1985 and beyond, effective with the 1993 edition of the TRENDS report. The new TRENDS methodology uses the 1985 NAPAP Emission Inventory as a base. Further changes will be seen in the TRENDS reports published in 1994 and thereafter. Thus, the reader is cautioned that comments on the EPA TRENDS report in this document are valid for editions prior to 1993, but are not valid for the editions for 1993 and thereafter.

SECTION 1
INTRODUCTION

Section 406 of the 1990 Clean Air Act Amendments (CAAA) requires that not later than January 1, 1995, the Administrator of the Environmental Protection Agency (EPA) transmit to Congress a report containing an inventory of national annual sulfur dioxide (SO_2) emissions from industrial sources for all years for which data are available, as well as the likely trend in such emissions over the following twenty-year period.

To support the development of the report to Congress, the Air and Energy Engineering Research Laboratory (AEERL) conducted an analysis of the differences in the 1985 National Acid Precipitation Assessment Program (NAPAP) Emission Inventory and the 1985 EPA TRENDS Emission Estimates for industrial SO_2 emission sources. This document presents the initial findings of this analysis.

The 1985 NAPAP emission inventory is the most comprehensive national inventory of industrial SO_2 emissions that has been compiled to date. The NAPAP inventory was used by Congress in the development of the 1990 CAAA. In section 406 of the 1990 CAAA, Congress cites a limit for industrial SO_2 emissions of 5.6 million tons. This value was derived from the 1985 NAPAP emission inventory.[1]

The majority of industrial SO_2 emissions as reported in the 1985 NAPAP Emission Inventory are reported as point sources. Over 4,000 industrial facilities were listed as emitting SO_2, one third of these facilities emitted a small amount of SO_2 (<100 tons of SO_2). Figure 1 shows that relatively few sources (about 130) account for approximately 50 percent of the total industrial SO_2 emissions. Based on data from the 1985 NAPAP inventory, only 500 facilities account for 80 percent of the industrial SO_2 emissions.

Every year the Office of Air Quality Planning and Standards (OAQPS) prepares annual estimates to determine emission TRENDS.[2] The emission estimates are updated as necessary to account for changes in the activity data or the emission estimation method.

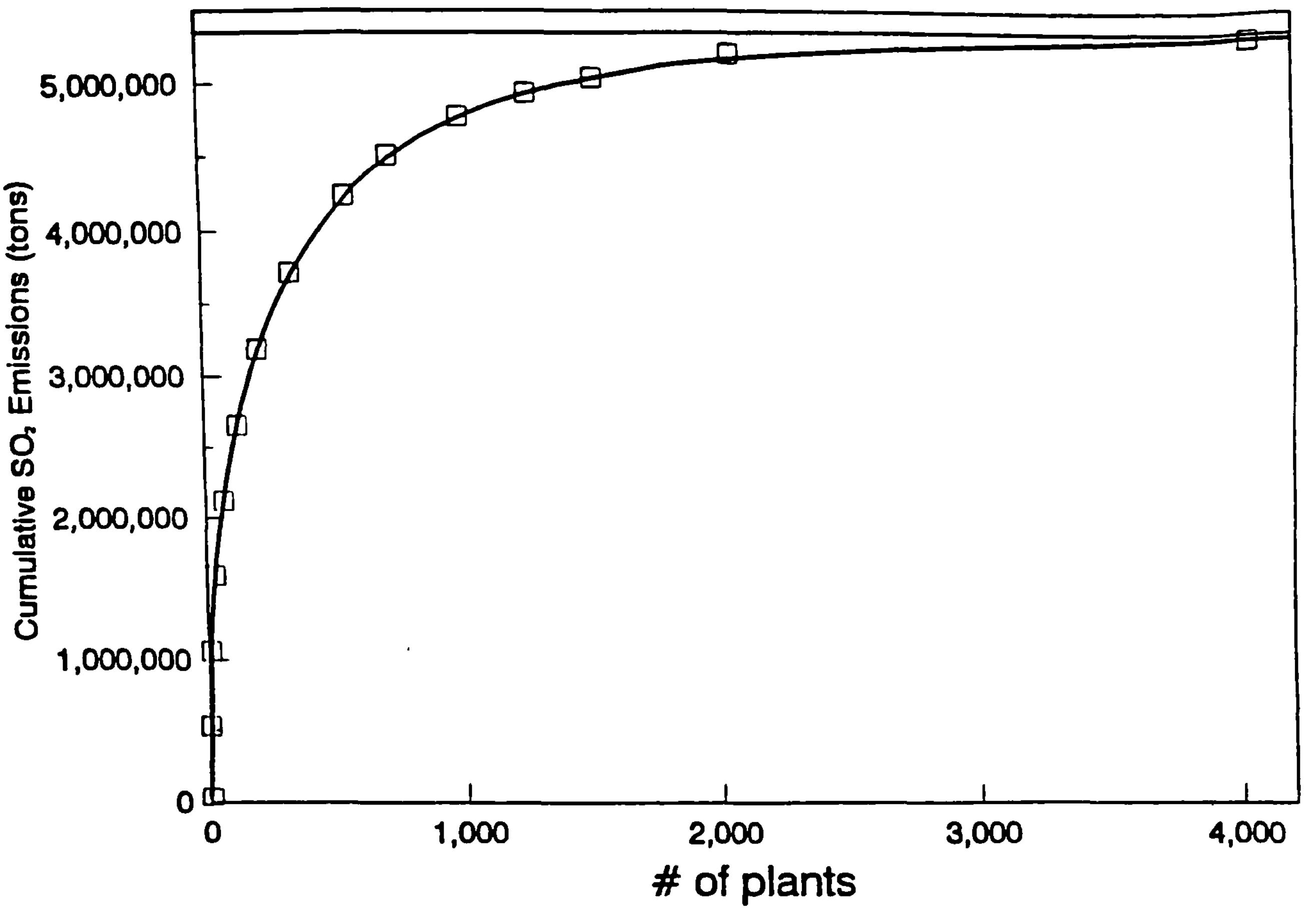

Figure 1. Cumulative sulfur dioxide emissions in the 1985 NAPAP inventory versus number of plants

Historically, the EPA TRENDS estimates have only included source categories that exceeded 10,000 metric tons of a criteria pollutant.

The calculation of the EPA TRENDS emission estimates is accomplished by following a documented procedure. The procedure that pertains to industrial SO_2 emission source categories is included as Appendix A. The procedures manual is supplemented with two extensive spreadsheets that are utilized in the TRENDS calculation procedure. The emissions calculations spreadsheet includes all of the emission factors, fuel sulfur assumptions, and control assumptions and is utilized in the calculation of current emissions. The second spreadsheet contains historic activity data and is used to project emissions for the study year. Data are entered into the spreadsheets and are used in other areas of the spreadsheet as necessary. The only documentation of the 1985 TRENDS estimates is the procedures manual and the accompanying spreadsheets. In several instances, following the documented procedures resulted in values that were inconsistent with the values in these spreadsheets. This occasionally resulted in two sets of 1985 TRENDS SO_2 emission estimates, the published TRENDS value and the calculated TRENDS value. These inconsistencies are documented throughout this report.

In 1991, a scoping study was undertaken to determine the feasibility of different approaches for developing an updated industrial SO_2 emission estimate for the report to Congress. This scoping study revealed large differences in the NAPAP and TRENDS emission estimates. Table 1-1 summarizes the differences between the NAPAP and TRENDS estimates.

The annual EPA TRENDS estimate is a logical source of industrial SO_2 emissions trends data. Prior to using the EPA TRENDS estimate in the 1995 Report to Congress, a detailed analysis of the differences that exist in the 1985 NAPAP and TRENDS estimates was undertaken. The results of that analysis are presented in this report.

This report includes three sections. Section 2 presents the results of the detailed analysis. Section 3 summarizes the conclusions for each source category covered in the detailed analysis.

TABLE 1-1. MAGNITUDE DIFFERENCES BETWEEN 1985 TRENDS AND NAPAP SO_2 EMISSION ESTIMATES

Source Category[a]	TRENDS (tons)	NAPAP (tons)	Delta (tons)	Delta (percent)
Coal[b]	1,840,000	1,721,000	119,000	6.9
Oil[c]	540,000	713,000	-173,000	-24.3
Natural Gas[d]	0	33,000	-33,000	-100.0
Wood	10,000	42,000	-32,000	-76.2
Miscellaneous Fuel	80,000	14,000	66,000	471.4
Other Fuel Combustion Emissions Reported through NAPAP		74,000	-74,000	-100.0
1° Copper	650,000	655,000	-5,000	-0.8
1° Lead and Zinc	240,000	106,000	134,000	126.4
2° Lead	30,000	21,000	9,000	42.9
1° Aluminum	70,000	58,000	12,000	20.7
Other Primary and Secondary Metals Emissions Reported through NAPAP		42,000	-42,000	-100.0
Iron and Steel	360,000	204,000	156,000	76.5
Iron and Steel Foundries		16,000	-16,000	-100.0
Oil and Natural Gas Production	160,000	332,000	-172,000	-51.8
Pulp and Paper	250,000	130,000	120,000	92.3
Cement	620,000	291,000	329,000	113.1
Glass	30,000	23,000	7,000	30.4
Lime	30,000	32,000	-2,000	-6.3
Sulfuric Acid	210,000	217,000	-7,000	-3.2
Carbon Black	10,000	28,000	-18,000	-64.3
Petroleum Refineries	830,000	640,000	190,000	29.7
Other Industrial Process Emissions Reported through NAPAP		220,000	-220,000	-100.0
Total	5,960,000	5,612,000	348,000	6.2

[a]Except where noted, the emissions for a source category represent process level emissions only and do not include emissions from the combustion of fuel.
[b]Excludes bituminous coal and lignite consumed at cement and lime manufacturing facilities.
[c]Excludes both distillate and residual oil consumed at cement plants and petroleum refineries and residual oil consumed at iron and steel mills.
[d]Excludes natural gas consumed in cement manufacturing, petroleum refining, the iron and steel industry, glass manufacture, and at crude petroleum and natural gas production facilities.

SECTION 2

ANALYSIS OF 1985 TRENDS AND NAPAP ESTIMATES

A detailed analysis of the differences and a determination of the validity of emission estimates presented by both sources is provided in this section. The analysis of the differences is limited to the source categories which appear in the TRENDS method. This section is divided into three subsections: combustion, non-ferrous smelting, and other industrial categories. Combustion includes coal, oil, natural gas, and miscellaneous fuels from all industrial processes except the largest fuel-consuming industries (specifically cement manufacturing, petroleum refining, iron and steel processing, glass manufacturing, and lime manufacturing). Non-ferrous smelting includes primary copper, primary zinc, primary lead, primary aluminum, and secondary lead. Other industrial processes include the pulp and paper industry, chemical manufacturing (sulfuric acid and carbon black production), petroleum refining, the iron and steel industry, and the minerals processing industries (cement, glass, and lime manufacturing).

A table summarizing the emission estimates for the source categories is presented at the beginning of each subsection. The summary table lists the applicable Source Classification Codes (SCC) and Standard Industrial Classification (SIC) codes for each source category. In addition, the emissions are broken down to illustrate the differences between the NAPAP and TRENDS estimate. Except for fuel combustion, these industrial categories are wholly represented in the stationary point source NAPAP categories.

Each subsection holds to a standard format for comparison of the TRENDS and NAPAP emission estimates by industrial category. Each of the source category discussions begins with a comparison of the overall estimate for the subcategory. Following this comparison, the remaining discussion is divided into six parts:

- TRENDS Activity
- TRENDS Emission Factor
- TRENDS Emissions
- NAPAP Activity

- NAPAP Emissions
- Conclusion

Within the first three divisions covering TRENDS, the TRENDS estimate is recreated and discussions of the derivation of the activity data, the emission factor, and the final emission estimate are provided. Many of the TRENDS emission estimates do not include all of the emission sources within the source category. For example, there may be three types of furnaces in a metallurgical operation and the TRENDS method may only provide emissions estimates from two of the three furnace types.

The next two divisions provide the NAPAP activity and emission estimate for the corresponding emissions categories. It is important to note that the NAPAP emissions are reported emissions and have probably been derived using source tests, mass balance and both AP-42 and State emission factors, along with source-specific control information. Additional emissions (not included explicitly in TRENDS) for the source category which are included in NAPAP are discussed. For the above metallurgical example, the NAPAP emission estimate for the third type of furnace is also listed.

Finally, conclusions on the validity of the estimates are made. The conclusions section includes a "revised" TRENDS estimate where potential errors or gaps in the TRENDS method are discovered.

2.1 COMBUSTION SOURCES

The TRENDS combustion categories are separated into coal, oil, natural gas, miscellaneous fuels, and wood. Coal combustion is developed from two numbers, one for anthracite coal and one for bituminous and lignite. Oil combustion emissions are calculated for distillate and residual oil. Miscellaneous fuels include coke, coke oven gas, kerosene, and liquified petroleum gas (LPG). NAPAP emissions are source emissions derived from a national fuel balance step which compares published fuel use from several DOE publications to fuel use reported among point sources. Any fuel unaccounted in point sources is assigned to the relevant area source category. Emissions are estimated using standard emission factors and DOE point source data on fuel sulfur. A summary of the differences in the emission estimates for these combustion categories is presented in Table 2-1.

2.1.1 Oil Combustion

The 1985 TRENDS emission value for industrial oil combustion was 540,000 tons SO_2. The TRENDS estimate includes residual and distillate oil and excludes oil consumed from cement plants and petroleum refineries, and residual oil consumed by steel mills. The emission estimates for these industry-specific uses are included in the specific-industry estimates.

The 1985 NAPAP value for distillate and residual oil, including external combustion boilers and in-process fuel use, and excluding cement plants, petroleum refineries, and residual oil consumed by steel mills, is 107,385 + 605,200 = 712,600 tons SO_2.

The apparent difference between the two inventories is 117,600 tons of SO_2 (26 percent). Table 2-2 summarizes the fuel consumption and emission estimates for the 1985 TRENDS and NAPAP inventories.

2.1.1.1 *Distillate Oil*

TRENDS activity

Distillate oil consumption is calculated in the TRENDS method by subtracting the quantity of distillate oil consumed by cement plants and petroleum refineries from the "adjusted" quantity of distillate oil sales to industrial and oil companies.

The "adjusted" quantity of distillate oil sales to industrial and oil companies in 1985 is obtained from Table 13 "Adjusted Sales of Distillate Fuel Oil by End Use in the United States: 1985-1989" of *Fuel Oil and Kerosene Sales*.[3] For 1985, the value is:

TABLE 2-1. EMISSIONS FROM COMBUSTION TRENDS VERSUS NAPAP

Industrial Combustion	SCC	1985 TRENDS (tons)[a]	1985 NAPAP (tons)[b]
Anthracite			
External combustion	1-02-001		10,998
In-process fuel	3-90-001		177
Anthracite (total)		*900*	*11,200*
Bituminous Subbituminous			
External combustion	1-02-002		1,272,795
In-process fuel	3-90-002		3,137
	Area		356,000
Lignite			
External combustion	1-02-003		78,417
In-Process fuel	3-90-003		72
Bituminous and Lignite (total)[c]		*1,687,400*	*1,710,000*
Coal (total)		**1,840,000**	**1,721,000**
Residual Oil			
External Combustion	1-02-004 1-02-014-04		349,932
Internal Combustion	2-02-005-01		96
	Area		242,000
In-process fuel use	3-01-900-12 3-05-900-02 3-90-004		13,132
Residual Oil (total)[d]		*460,000*	*618,226*
Distillate Oil			
External Combustion	1-02-005 1-02-014-03		47,557
Internal Combustion	2-02-001		727
	Area		55,000
Space Heaters	1-05-001-05		578
In-process fuel	3-04-900-01 3-90-005[f]		3,512
Distillate Oil (total)[e]		*72,500*	*107,400*
Oil (total)		**540,000**	**712,600**

(continued)

TABLE 2-1. EMISSIONS FROM COMBUSTION TRENDS VERSUS NAPAP (Continued)

Industrial Combustion	SCC	1985 TRENDS (tons)[a]	1985 NAPAP (tons)[b]
Natural Gas (Boilers)			
External Combustion	1-02-006 1-02-014-01		19,085
	Area		1,000
Space Heaters	1-05-001-06		11
Internal Combustion	2-02-002		1,501
In-process fuel	3-01-900-03 3-01-900-13 3-03-900-03 3-04-900-03 3-07-900-03 3-07-900-13 3-90-006 3-99-900-03 3-99-900-13		11,223
Natural Gas Boilers (total)[f]		**1,400**	**32,800**
Natural Gas Production (total)	3-10-900-04 3-10-900-14 Other[g]	**400**	**7,660**
Miscellaneous Fuels			
Coke			
External Combustion	1-02-008		11,253
Coke (total)[h]		*36,000*	*11,253*
Coke-oven Gas			
External Combustion	1-02-007-07		2
In-process fuel	3-90-007-01 3-90-007-02 3-90-007-89		2,687
Coke-oven Gas (total)[i]		*43,258*	*2,689*
Kerosene			
Internal Combustion	2-02-009		421
Kerosene (total)		*2,491*	*421*

(continued)

TABLE 2-1. EMISSIONS FROM COMBUSTION TRENDS VERSUS NAPAP (Continued)

Industrial Combustion	SCC	1985 TRENDS (tons)[a]	1985 NAPAP (tons)[b]
Liquified Petroleum Gas			
External Combustion	1-02-010		27
Space Heaters	1-05-001-10		18
In-process fuel	3-90-009-89 3-90-010-89		7
Liquified Petroleum Gas (total)		*109*	*52*
Miscellaneous Fuels (total)		**80,000**	**14,400**
Wood			
Wood/Bark Waste	1-02-009		15,141
	Area		17,000
In-process fuel	3-90-008-89 3-90-009-99		9,568
Wood (total)		**10,000**	**41,700**
Other NAPAP Industrial Fuel Combustion Categories			
External Combustion			
Process Gas	1-02-007-02 1-02-007-10 1-02-007-99 1-02-014-02		44,804
Bagasse	1-02-011		170
Solid Waste	1-02-012		2,753
	5-03		10,686
	Area		1,000
Liquid Waste	1-02-013		12,199
Internal Combustion			
Gasoline and Diesel	2-02-003 2-02-004		135
In-Process Fuel Use			
Process Gas	3-03-900-24 3-90-007-97 3-90-007-99 3-99-900-24		1,233

(continued)

TABLE 2-1. EMISSIONS FROM COMBUSTION TRENDS VERSUS NAPAP (Continued)

Industrial Combustion	**SCC**	**1985 TRENDS (tons)[a]**	**1985 NAPAP (tons)[b]**
Liquid Waste	3-90-013		166
Miscellaneous Processes	3-99-999		717
Other NAPAP Industrial Fuel Combustion Categories			**74,500**
Total		2,470,000	2,597,000

[a] *National Air Pollutant Emission Estimates, 1900 - 1991*, EPA-454/R-92-013, October 1992.

[b] The 1985 NAPAP Emissions Inventory (version 2): Development of the Annual Data and Modelers' Tapes, EPA-600/7-89-012a, November 1989.

[c] Excludes bituminous and lignite burned in cement and lime kilns.

[d] Excludes residual oil burned in cement plants, petroleum refineries and iron and steel mills.

[e] Excludes distillate oil burned in cement plants and petroleum refineries.

[f] Excludes natural gas burned in cement plants, petroleum refineries, iron and steel mills, glass manufacture, and oil and natural gas production.

[g] Other includes all natural gas combustion emissions with an SIC code of 1311 or 1321.

[h] Excludes iron and steel industry.

[i] Excludes iron and steel industry.

TABLE 2-2. COMPARISON OF OIL COMBUSTION VALUES FOR 1985 TRENDS AND NAPAP

Category	Trends Published	Trends Calculated	NAPAP Published
Distillate Oil			
Emissions (tons)		72,500	107,400
Fuel Consumed (10^6 gallons)	3,426.8	3,429.8	1,902
Residual Oil			
Emissions (tons)		460,000	605,200
Fuel Consumed (10^6 gallons)	3,562	3,555	5,615
Total Oil Combustion Emissions (tons)	540,000	532,500	712,600

2,592,678,000 + 876,505,000 = 3,469,183,000 gallons.

The quantity of oil consumed by cement plants is obtained from Table 7, "Clinker Produced in the United States, by Fuel" of *Minerals Yearbook 1986 "Cement"*.[4] The quantity for 1985 is 755,000 barrels (31,710,000 gallons). TRENDS assumes that one-third of the oil consumed is distillate oil (10,570,000 gallons).

The quantity of distillate oil consumed by petroleum refineries is obtained from Table 43, "Fuels Consumed at Refineries by PAD District, 1985" of the *Petroleum Supply Annual*.[5] The figure for 1985 is 758,000 barrels (31,836,000 gallons).

Therefore the TRENDS activity number for industrial distillate oil consumption is:

3,469,183,000 - 10,570,000 31,836,000 = 3,426,777,000 gallons.

The value in the current TRENDS activity data file is 3,426,800,000 for 1985.

TRENDS emission factors

The emission factors cited in the TRENDS procedure are for external combustion of grades 1 and 2 oil (combined) and grade 4 oil. The emission factors listed in the TRENDS procedure are provided below.

SCC	Description	Emission Factor	Units
1-02-005-01	External Combustion Industrial: Distillate grades 1 and 2 oil	143.6S	$lbs/10^3$ gallons burned
1-02-005-04	External Combustion - Industrial: Distillate grade 4 oil	150.0S	$lbs/10^3$ gallons burned

The 1985 sulfur content for distillate oil is obtained from Table 1 "Summary of Grade 1 Fuels" and Table 2 "Summary of Grade 2 Fuels" of *Heating Oils*[6] which reports average sulfur contents for five regions of the country for both grade 1 and 2 oil. This report does not include an average sulfur content for grade 4 oil due to a lack of data. The average sulfur content for grade 1 oil ranged from 0.042 to 0.123 weight percent. The average sulfur content for grade 2 oil ranged from 0.228 to 0.267 weight percent. The average sulfur contents were averaged across grade and region based on the number of samples, and the average grades 1 and 2 sulfur content was determined to be 0.206 weight percent. By contrast, the average sulfur contents reported through NAPAP (weighted on the number of records reporting fuel sulfur content) are 0.36 for grades 1 and 2 oil and 0.85 for grade 4 oil. The cement procedure (see Section 2.3.7) cites a distillate oil sulfur content of 0.3 percent.

The TRENDS procedure requires that the emission factors be weighted based on AIRS data and provides a table to assist in the weighing. Table 2-3 illustrates the values used to produce a weighted emission factor for distillate oil combustion. Table 2-3 requires the emission factor for internal combustion engines burning distillate oil. For turbines, the emission factor is 140.0S $lbs/10^3$ gallon burned and for reciprocating engines, the emission factor is 31.22 $lbs/10^3$ gallon burned.[7] Table 2-3 also requires activity data obtained from the 1985 NAPAP emission inventory. Average sulfur content for grades 1 and 2 oil are from

Heating Oils as derived above and, for the other SCCs, the average NAPAP sulfur contents were used.

TABLE 2-3. WEIGHTED AVERAGE EMISSION FACTOR FOR DISTILLATE OIL COMBUSTION

Combustion Category	NAPAP Consumption (10^3 gallons)	AP-42 SO_2 Emission Factors ($lb/10^3$ gal)	Average sulfur content (weight percent)
Boilers burning grade 1 or 2	843,851[a]	143.6S	0.206
Boilers burning grade 4	125,949[b]	150.0S	0.85
Turbines	352[b]	140.0S	0.27
Internal Combustion Engines	399	31.2	
Weighted Average ($lb/10^3$ gal)		42.3	

[a] Heating Oils, 1985
[b] NAPAP

The weighted average emission factor was calculated by multiplying the activity number (consumption) by the emission factor (and the sulfur content as needed) and dividing by the total activity. The average emission factor for 1985 was calculated as 42.3 $lb/10^3$ gallon. This value is higher than the emission factors that were used in the 1990 (39.2 $lb/10^3$ gallon) and the 1991 (38.5 $lb/10^3$ gallon) TRENDS estimates.

The TRENDS procedure calls for an SO_2 control efficiency, which is obtained from EIA 767 data. If a control efficiency is applied, the TRENDS value is not documented and the control efficiency does not appear in the TRENDS spreadsheets. In addition, the EIA-767 data pertains to utility boilers and the suitability of transferring control data from the utility sector to the industrial sector has not been investigated or documented.

TRENDS emissions

The TRENDS emission estimate for distillate oil in 1985 is:

3,426,777 * 42.3 / 2000 = 72,476 tons of SO_2.

NAPAP activity

The overall NAPAP activity should match the TRENDS number. During the development of the NAPAP inventory, the same national industrial distillate oil consumption value was used to produce a "fuel balance" among point and area sources. In NAPAP, the oil consumed by point sources [as reported through the National Emissions Data System (NEDS)] is subtracted from the national number and any remaining balance is allocated to the area source inventory. As shown in Table 2-1, there are more emissions reported among area sources than for external combustion point sources. This may be due to the under reporting of fuel usage by point sources. The reporting of fuel usage was a secondary priority in NAPAP and many sources consider throughput data confidential and did not report it. In addition, the entire State of Texas did not report industrial fuel usage by plant, instead fuel usage was reported at the county level.

The distillate oil activity data reported through NAPAP include external combustion boilers, space heaters, internal combustion engines, and in-process fuel use. To better compare the TRENDS and NAPAP combustion estimates, the fuel used in the cement and petroleum refining industries must be subtracted from the total NAPAP estimate. Unfortunately, for the NAPAP inventory development effort, fuel usage was not a priority data element and facilities were not required to report their fuel usage. Therefore, subtracting the fuel used by these industries as reported in NAPAP will still not provide a reliable value for comparing the fuel combustion and will in fact make the two estimates more dissimilar.

The emission factors for industrial distillate oil combustion range from 31.2 for internal combustion reciprocating engines to 143.6S for the majority of the boiler descriptions.

In addition, the emission factor for distillate in-process fuel use (general) is 0.0, and it is intended that this emission factor be used to report fuel usage for industries where the process emission factor accounts for the fuel sulfur emissions. Both cement and lime kilns have substantially lower emission factors (98S and 72S respectively), due to the affinity for sulfur of both lime and cement.

NAPAP emissions

The NAPAP industrial distillate oil emissions are reported as follows:

SCC	Description	Tons SO_2 Emitted
1-02-005-01	External combustion boilers - Industrial: Distillate oil, grade 1 and 2	39,359
1-02-005-02	External combustion boilers - Industrial: Distillate oil	2,071
1-02-005-03	External combustion boilers - Industrial: Distillate oil	800
1-02-005-04	External combustion boilers - Industrial: Distillate oil, grade 4	3,625
1-02-014-03	External combustion boilers - Industrial: Distillate oil, cogeneration	3,836
1-05-001-05	External combustion boilers - Space heaters, Industrial, Distillate oil	578
2-02-001-01	Internal combustion engines - Industrial, Distillate (Diesel) oil, turbine	284
2-02-001-02	Internal combustion engines - Industrial, Distillate (Diesel) oil, reciprocating	399
2-02-001-03	Internal combustion engines - Industrial, Distillate (Diesel) oil, turbine cogeneration	68
3-04-900-01	Secondary metal, Process heaters, distillate oil	8
3-90-005-01	In process fuel use, Distillate oil	59
3-90-005-02	In process fuel use - Distillate Oil: Cement kiln/dryer	2,404
3-90-005-03	In process fuel use - Distillate Oil: Lime kiln	12
3-90-005-89	In process fuel use, Distillate oil, General	1,624
3-90-005-99	In process fuel use, Distillate oil, General	1,827
Total		56,954

In addition, NAPAP reports area source emissions for distillate oil of 55,000 tons. This results in total NAPAP distillate oil emissions of 111,954 tons of SO_2.

To compare the NAPAP estimate with the TRENDS estimate, emissions for cement kilns/dryers and petroleum refineries must be subtracted from this total. For the above listed SCCs, NAPAP reports that 2,450 tons are emitted from cement manufacturing (SIC 3241) and 2,119 tons are emitted at petroleum refineries (SIC 2911). This results in 107,385 tons of SO_2 being emitted through distillate oil combustion excluding cement manufacturing and petroleum refineries.

Conclusion

The distillate oil estimates are 72,480 tons for TRENDS versus 107,358 tons for NAPAP. The NAPAP point source estimate and the TRENDS estimate are quite similar, although no conclusion can be drawn from this similarity. This may indicate that area source emissions were overestimated due to an underestimate of fuel use in the point source inventory.

There is a huge discrepancy in the reported quantity of oil burned in the TRENDS estimate versus the NAPAP inventory. TRENDS reports 3,426 x 10^6 gallons and NAPAP reports approximately 2,000 x 10^6 gallons. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] reports 31,684,000 barrels (bbls) consumed (1,330.7 x 10^6 gallons). This survey reports an activity that is approximately one third the value reported in TRENDS. If the value used in TRENDS was also used to compute an area source activity in NAPAP, this could have resulted in a large overestimation in distillate oil consumed and resulting emissions reported in NAPAP through the area source category.

The development of an average sulfur content for distillate oil is not well documented in the TRENDS procedure. The sulfur content assumptions have a large impact on the overall emission factor. Additional effort should be expended to determine a reasonable average sulfur content, to determine if industrial distillate oil consumers are electing to use lower sulfur content oil, and if so, the overall effects on emissions from this category.

2.1.1.2 *Residual Oil*

TRENDS activity

The residual oil consumption is calculated by subtracting the quantity of oil consumed by cement plants, petroleum refineries, and steel mills from the "adjusted" quantity of residual oil sales to industrial and oil companies.

The adjusted quantity of residual oil sales to industrial and oil companies in 1985 is obtained from Table 14 "Adjusted Sales of Residual Fuel Oil by End Use in the United States: 1985-1989" of *Fuel Oil and Kerosene Sales 1989.*[3] For 1985, the value is:

4,011,361,000 + 776,019,000 = 4,787,380,000 gallons.

The quantity of oil consumed by cement plants is obtained from Table 7 "Clinker produced in the United States, by fuel" of *Minerals Yearbook 1986 "Cement".*[4] The quantity for 1985 is 755,000 barrels (31,710,000 gallons). TRENDS assumes that two thirds of the oil consumed is residual oil (21,140,000 gallons).

The quantity of residual oil consumed by petroleum refineries is obtained from Table 43 "Fuels Consumed at Refineries by PAD District, 1985" in the *Petroleum Supply Annual.*[5] The figure for 1985 is 13,326,000 barrels (559,692,000 gallons).

The quantity of residual oil consumed by steel mills was calculated by multiplying the quantity in tons of raw steel produced in 1985 by a conversion factor for the value of residual oil consumed per ton of raw steel produced. The conversion factor used is 7.38 gal/ton raw steel. The quantity of raw steel produced is obtained from the Bureau of Economic Analysis, Survey of Current Business. The quantity of raw steel produced is more readily available from Table 1 "Salient Iron and Steel Statistics" of *Minerals Yearbook 1986 "Iron and Steel."*[5] The value for 1985, in both references, is 88,259,000 short tons. The quantity of residual oil consumed by steel mills is calculated as:

88,259,000 * 7.38 gal/ton raw steel = 651,350,000 gallons.

Therefore the TRENDS activity value for residual oil consumed by industrial sources is:

4,787,380 - 21,140 - 559,692 - 651,350 = 3,555,198 x 10^3 gallons.

The value in the TRENDS activity table is 3,562.300 x 10^3 gallons.

TRENDS emission factors

The emission factor cited in TRENDS is for grade 6 oil, SCC 1-02-004-01, and the value is:

158.6S lbs/10^3 gallons burned.

This emission factor matches the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document. The average sulfur content of grade 6 Fuel Oil is obtained from *Heating Oils, 1985*.[6] Again, this reference provides averages for each of five regions. The average sulfur contents range from 1.20 to 1.75 percent in a total of 44 samples. The average national figure based on the number of samples is 1.63 percent. The average sulfur content for residual oil can also be obtained from Table 11 "Receipts of No. 6 Fuel Oil at Electric Utilities" of *Cost and Quality of Fuels for Electric Utility Plants 1985*.[9] For 1985, the average sulfur content of grade 6 fuel oil was 1.09 percent by weight. The emission factor for residual oil (based on the *Heating Oils, 1985*[6] data) is:

158.6 * 1.63 = 258.5 lb/10^3 gallons burned.

TRENDS emissions

The emissions are calculated as:

258.5 * 3,555,198 / 2000 = 459,510 tons of SO_2.

NAPAP activity

The residual oil activity data reported through NAPAP include external combustion boilers, space heaters, internal combustion engines, and in-process fuel use. Collection and quality assurance of all throughput data were not a priority item in the NAPAP inventory. The NAPAP inventory also includes approximately 932,000 x 10^6 gallons of crude oil burned during production in the total residual oil throughput value. This oil was placed in the residual oil category because no other category existed in NAPAP.

NAPAP emissions

The estimated emissions reported through NAPAP for residual oil combustion are listed below:

SCC	Description	Tons SO_2 Emitted
1-02-004-01	External combustion boilers - Industrial: Residual oil, grade 6 oil	349,348
1-02-004-02	External combustion boilers - Industrial: Residual oil, 10-100 MMBTU/hr	39,304
1-02-004-03	External combustion boilers - Industrial: Residual oil, <10 MMBTU/hr	2,676
1-02-004-04	External combustion boilers - Industrial: Residual oil, grade 5	5,836
1-02-004-05	External combustion boilers - Industrial: Residual oil, Cogeneration	1,655
1-02-004-06	External combustion boilers - Industrial: Residual oil	4
1-02-014-04	External combustion boilers Industrial: CO Boiler, Residual oil	376

SCC	Description	Tons SO_2 Emitted
2-02-005-01	Internal combustion engines - Industrial, Residual/ Crude oil, reciprocating	96
3-01-900-12	Chemical Manufacturing, Incinerators, Residual oil	657
3-05-900-02	Mineral Products, Process Heater, Residual oil	134
3-90-004-02	In-process fuel use, Residual oil, Cement Kiln/dryer	3,574
3-90-004-03	In-process fuel use, Residual oil, Lime Kiln	738
3-90-004-89	In-process fuel use, Residual oil, General	19,451
3-90-004-99	In-process fuel use, Residual oil, General	1,644
Total		425,493

In addition, the NAPAP estimate includes 242,000 tons of SO_2 from the combustion of residual fuel oil by area sources, bringing the NAPAP total for residual oil combustion to 667,493 tons of SO_2.

To compare the NAPAP and TRENDS estimates, it is necessary to exclude the residual oil emissions from cement manufacturing, petroleum refineries, and steel mills. The emission estimates for the above listed SCCs are 3,807 tons for cement manufacturing (SIC 3241); 44,208 tons for petroleum refining (SIC 2911); and 14,318 tons for iron and steel mills and foundries (SIC 3312 and 3325). Subtracting these emissions results in a NAPAP estimate of 605,160 tons of SO_2.

Conclusion

The TRENDS estimate is 459,510 tons for residual oil excluding cement plants, petroleum refineries and steel mills. The NAPAP estimate for the same category of emissions is 605,160 tons of SO_2. The two estimates would be much closer if the area source component of the NAPAP total were not included.

There is a huge discrepancy in the reported quantity of residual oil burned in the TRENDS estimate versus the NAPAP inventory. TRENDS reports 3,555 x 10^6 gallons and NAPAP reports approximately 6,000 x 10^6 gallons. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] reports 80,252,000 bbls consumed (3,370.6 x 10^6 gallons).

2.1.2 Coal Combustion

The 1985 TRENDS SO_2 emission value for coal is comprised of two separate categories; anthracite, and bituminous coal and lignite. The published TRENDS emission estimate of 1,840,000 tons of SO_2 excludes emissions from bituminous coal and lignite consumed at cement and lime manufacturing facilities. The 1985 NAPAP value, excluding bituminous coal and lignite consumed at cement and lime manufacturing facilities, was 1,721,000 tons of SO_2. The apparent difference between the two inventories is 119,000 tons of SO_2 (7 percent). Table 2-4 illustrates the differences in the coal consumption and emission estimates for the 1985 TRENDS and NAPAP inventories.

TABLE 2-4. COMPARISON OF COAL COMBUSTION VALUES FOR 1985 TRENDS AND NAPAP

Category	TRENDS Published	TRENDS Calculated	NAPAP Published
Anthracite			
Emissions (tons)		10,900	11,000
Fuel Consumed (10^3 tons)	658.8	800	522
Bituminous & Lignite			
Emissions		1,687,000	1,710,000
Fuel Consumed (10^6 tons)	61.6	62.131	74.535
Total Coal Combustion Emissions (tons)	1,840,000	1,698,000	1,721,000

The total published TRENDS estimate is 1.84 x 10^6 tons SO_2. In following the TRENDS procedure, the emission estimates for anthracite as a category and bituminous and lignite as a category are 10,900 and 1,687,000 tons of SO_2, respectively. The total of 1,698,000 tons SO_2 differs from the published TRENDS estimate by 152,000 tons SO_2.

The sulfur contents and resulting emission factors that were actually used in 1985 are not documented and may explain the difference. In addition, the TRENDS procedure manual refers to the use of control assumptions as documented in the EIA-767 data. If control assumptions have been applied (EIA-767 data pertain to utilities and should not be used to estimate controls on the industrial sector), they are not documented.

2.1.3 Anthracite Coal

2.1.3.1 *1985 TRENDS Activity*

Anthracite combustion activity obtained from the distribution of anthracite coal from District 24 (District 24 is the anthracite-producing district of Pennsylvania) to industrial users except coke plants. The value for 1985 is obtained from Table 6 "Distribution of U.S. Coal by Origin, Destination, and Consumer" of *Coal Distribution.*[10] The value for 1985 is 800,000 short tons.

The TRENDS activity data spreadsheet has a 1985 activity value of 658,800 tons. The wording in the TRENDS procedure document is "obtain the distribution of anthracite from Pennsylvania to industrial less coke plants." This could be interpreted as direction to subtract the coke coal (29,000 short tons), but this would be an error (because the coal coke is already excluded from the value) and it does not resolve the difference between the two values.

2.1.3.2 *TRENDS Emission Factors*

Emission factors for three types of boilers, pulverized, traveling grate stoker, and hand-fired, that burn anthracite coal are 39.0S lbs/ton burned. The TRENDS method assumes a sulfur content of 0.7 percent. This provides an emission factor of:

39.0 * 0.7 = 27.3 lb/ton burned.

2.1.3.3 *TRENDS Emissions*

TRENDS emissions were calculated using the activity value found in the TRENDS spreadsheet.

658,800 * 27.3 / 2000 = 8,990 tons of SO_2

Emissions calculated using the activity value derived following the TRENDS procedure manual results in emissions of:

800,000 tons * 27.3 / 2000 = 10,920 tons of SO_2.

2.1.3.4 *NAPAP Activity*

The NAPAP activity value for anthracite coal combustion is based on the SCC codes for industrial external combustion and in-process fuel use. However, collection and quality assurance of all throughput data were not priority items.

2.1.3.5 *NAPAP Emissions*

SCC	Description	Tons SO_2 Emitted
1-02-001-01	External combustion boilers - Industrial: Anthracite coal, Pulverized coal	9,099
1-02-001-02	External combustion boilers - Industrial: Anthracite coal	17
1-02-001-04	External combustion boilers - Industrial: Anthracite coal, Traveling grate, (overfeed) stoker	1,872
1-02-001-07	External combustion boilers - Industrial: Anthracite coal, Hand-fired	10
3-90-001-89	In process fuel use, Anthracite coal, General	99
3-90-001-99	In process fuel use, Anthracite coal, General	78
Total		11,175

2.1.3.6 *Conclusion*

The emission estimates are in agreement, 11,000 tons of SO_2 in both NAPAP and TRENDS. The NAPAP inventory does not report all of the anthracite coal that is consumed, and it is unclear what fraction of the anthracite coal combustion is represented by the emissions that are reported through NAPAP. The NAPAP estimates result in an overall emission factor of 42.8 lbs/ton of coal burned. This translates into an average sulfur content of 1.1 percent. The reported sulfur content for anthracite coal varies in the NAPAP inventory. The average reported for pulverized coal is 1.15 percent (3 records reporting). The average reported for traveling grate (overfeed) stoker and the majority of records reporting is 0.7 (24 records). The assumptions on sulfur content have a large influence on the emission estimate.

The activity value that is published in the TRENDS activity spreadsheet could not be replicated. The NAPAP inventory may overestimate SO_2 emissions relative to the reported quantity of coal burned but anthracite coal is a relatively minor category. Additional research into a reasonable average sulfur content for anthracite coal is warranted.

2.1.4 Bituminous Coal and Lignite

2.1.4.1 *TRENDS Activity*

The 1985 TRENDS activity for bituminous coal and lignite is calculated by subtracting coal consumed in lime and cement plants from the national total for industrial users. The national value is obtained from Table 23 "Coal Consumption by End-use Sector" of *Quarterly Coal Report.*[11] The 1985 value for "other industrial" is 75,317,000 tons.

The consumption by cement plants is obtained from Table 7 "Clinker produced in the United States, by fuel" of *Minerals Yearbook 1986 "Cement."*[4] In 1985, 11,606,000 tons of coal were consumed by cement plants.

National annual lime production is obtained from "Facts and Figures for the Chemical Industry" published in *Chemical & Engineering News*.[12] The 1985 primary production figure was 15,800,000 short tons. Coal consumption is estimated using a multiplier of 0.1 ton coal/ton lime produced. Therefore, the estimated coal consumption by lime plants is:

15,800,000 * 0.1 = 1,580,000 tons.

The TRENDS bituminous coal and lignite consumption is:

75,317,000 - 11,606,000 - 1,580,000 = 62,131,000 tons.

The TRENDS activity spreadsheet has a value of 61,600,000 tons of coal consumed.

2.1.4.2 *TRENDS Emission Factors*

The documented procedure for determining an overall emission factor for this category is complex and the documentation states that the procedure has not been applied. The primary complexity is in the development of an average sulfur content. The TRENDS procedure uses an overall emission factor of 38.1S lb SO_2/ton coal burned. In the complex procedure, an average sulfur content is developed from each coal production district and these average sulfur contents are weighted based on shipments data listed in *Coal Distribution*.[10]

Recent TRENDS procedures for developing an emission factor for this category are unclear. The emission factor for 1990 was 54.3 lb/ton burned and the emission factor for 1991 was 51.5 lb/ton burned. Why and how these factors were changed is unclear. To back calculate the 1990 sulfur content using the emission factor of 38.1S lb/ton burned results in an overall sulfur content of 1.4 percent:

54.3 / 38.1 = 1.4 percent sulfur.

2.1.4.3 *TRENDS Emissions*

TRENDS emissions, using the 1990 emission factor and the activity value in the TRENDS spreadsheet, are calculated as follows:

61,600,000 * 54.3 / 2000 = 1,672,440 tons of SO_2.

Emissions calculated using the activity data derived following the TRENDS procedure manual results in emissions of:

62,131,000 * 54.3 / 2000 = 1,686,900 tons of SO_2.

2.1.4.4 *NAPAP Activity*

Activity data were not priority items for collection and quality assurance for the entire NAPAP inventory. Activity data are not reproduced here by SCC.

2.1.4.5 *NAPAP Emissions*

The following emission estimates were reported for bituminous coal and lignite combustion.

SCC	Description	Tons SO_2 Emitted
Bituminous:		
1-02-002-01	External combustion boilers - Industrial: Bituminous coal, Pulverized coal: wet bottom	101.735
1-02-002-02	External combustion boilers - Industrial: Bituminous coal, Pulverized coal: dry bottom	571.457
1-02-002-03	External combustion boilers - Industrial: Bituminous coal, Cyclone furnace	81.758
1-02-002-04	External combustion boilers - Industrial: Bituminous coal, Spreader stoker	330.099
1-02-002-05	External combustion boilers - Industrial: Bituminous coal, Overfeed stoker	102.120

SCC	Description	Tons SO_2 Emitted
1-02-002-06	External combustion boilers - Industrial: Bituminous coal, Underfeed stoker	18,088
1-02-002-10	External combustion boilers - Industrial: Bituminous coal, Overfeed stoker	1,518
1-02-002-12	External combustion boilers - Industrial: Bituminous coal, Pulverized coal: Dry bottom (Tangential)	20,286
1-02-002-17	External combustion boilers Industrial: Bituminous coal, Atmospheric Fluidized bed	5,438
1-02-002-19	External combustion boilers - Industrial: Bituminous coal, Cogeneration	12,128
Subbituminous:		
1-02-002-21	External combustion boilers - Industrial: Subbituminous coal, Pulverized coal: wet bottom	83
1-02-002-22	External combustion boilers - Industrial: Subbituminous coal, Pulverized coal: dry bottom	8,547
1-02-002-24	External combustion boilers - Industrial: Subbituminous coal, Spreader stoker	11,195
1-02-002-25	External combustion boilers - Industrial: Subbituminous coal, Traveling grate (overfeed) stoker	8,396
Lignite:		
1-02-003-01	External combustion boilers - Industrial: Lignite, Pulverized coal	45,759
1-02-003-03	External combustion boilers - Industrial: Lignite, Cyclone furnace	341
1-02-003-04	External combustion boilers - Industrial: Lignite, Traveling grate (overfeed) stoker	29,905
1-02-003-06	External combustion boilers - Industrial: Lignite, Spreader stoker	2,412
In-process fuel use:		
3-90-002-01	In process fuel use, Bituminous coal, Cement kiln/dryer	77,859
3-90-002-03	In process fuel use, Bituminous coal, Lime kiln	6,384
3-90-002-89	In process fuel use, Bituminous coal, General	6,828
3-90-002-99	In process fuel use, Bituminous coal, General	10,925
3-90-003-89	In process fuel use, Lignite, General	72
Total		1,453,333

In addition, NAPAP reports area source emissions of 356,000 tons of SO_2 from coal combustion. This brings the total combustion from bituminous coal, subbituminous coal and lignite to 1,809,333 tons. In order to compare the NAPAP and TRENDS estimates, emissions from cement and lime kilns must be excluded from the NAPAP estimate. For the above listed SCCs, 92,524 tons are for cement manufacturing (SIC 3241) and 6,386 tons are for lime manufacturing (SIC 3274). The adjusted NAPAP emissions for bituminous and lignite combustion are 1,710,423 tons of SO_2.

2.1.4.6 *Conclusions*

The total estimates for both emissions and coal burned for this category are very close. The total initial activity value, including coal burned in lime manufacturing and cement plants, is 75.3 x 10^6 tons of coal in TRENDS versus 74.5 x 10^6 tons of coal in NAPAP. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* reports 59.195 x 10^6 tons of coal burned in the industrial sector. This activity is consistent with both the TRENDS and NAPAP totals. The emissions, excluding lime and cement-related emissions, are 1.69 x 10^6 tons of SO_2 versus 1.71 x 10^6 tons of SO_2. Again, the NAPAP inventory relies on a total fuel balance to determine the area source emissions for this category. For this category, the addition of the area source emissions brings the NAPAP and TRENDS estimate closer together.

The TRENDS method utilizes a factor of 0.1 tons of coal consumed/ton of lime produced. This factor should be verified. The *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] and subsequent available editions do not separate lime from other mineral products industries. The survey for 1991 is expected to provide additional resolution and the preliminary numbers should be available in late summer of 1993.

The three types of coal that constitute this category each have a slightly different emission factor. The emission factors for external combustion in industrial boilers are generally as follows.

Bituminous	1-02-002-01,19	39.0S
Subbituminous	1-02-002-21,29	35.0S
Lignite	1-02-003	30.0S

There are smaller emission factors for some types of bituminous coal combustion (for example fluidized bed), but these constitute a very small amount of the coal combustion activity.

Sulfur contents reported in the NAPAP inventory for these SCCs range as follows.

1-02-002-01,19	1.0 to 1.9 percent
1-02-002-21,29	0.4 to 1.5 percent
1-02-003	0.5 to 0.9 percent

Average sulfur contents for the types of coal are estimated based on emissions, and reported coal consumption are as follows.

1-02-002-01,19	1.4 percent
1-02-002-21,29	0.7 percent
1-02-003	0.7 percent

Use of these sulfur contents results in the following average emission factors.

Bituminous	1-02-002-01,19	54.6 lb/ton burned
Subbituminous	1-02-002-21,29	24.5 lb/ton burned
Lignite	1-02-003	21.0 lb/ton burned

The TRENDS emission factor of 54.3 is probably an overestimation. In addition, there are probably some emission controls that are not reflected in the TRENDS method.

2.1.5 Natural Gas

The 1985 TRENDS does not publish emission estimates for categories if the total estimated emissions are less than 10,000 tons. The emissions from natural gas combustion are adjusted to exclude natural gas consumed by cement plants, petroleum refineries, the iron and steel industry, glass manufacturing, and crude petroleum and natural gas production. Once the TRENDS estimates are adjusted to exclude the above mentioned categories, the emission estimate is less than 10,000 tons and therefore there is no published SO_2 estimate for natural gas combustion. The adjusted NAPAP emissions are 32,800 tons SO_2.

The TRENDS procedure includes a subsection adjustment to estimate the emissions from natural gas combustion during crude petroleum and natural gas production. The combustion emissions estimated in this section are combined with sulfur recovery emissions (estimated in Section 2.3.3) and reported in Section 2.3.5. Table 2-5 summarizes the information for natural gas combustion and natural gas plants and pipelines for the 1985 TRENDS and NAPAP inventories.

TABLE 2-5. COMPARISON OF NATURAL GAS VALUES FOR 1985 TRENDS AND NAPAP

Category	Trends Published	Trends Recreated	NAPAP Published
Natural Gas Combustion			
Emissions (tons)		1,400	32,800
Fuel Consumed (10^9 ft^3)	4,764.8	4,852.3	6,700
Natural Gas Plants and Pipelines			
Emissions (tons)		400	7,660
Fuel Consumed (10^9 ft^3)	1,469.8	1,469.8	15

2.1.5.1 *TRENDS Activity*

TRENDS separates the natural gas emissions into combustion in boilers and emissions from gas pipelines and plants. The emissions from the combustion of natural gas at natural gas pipelines and plants are reported in Section 2.3.5.

Boilers

The total industrial consumption of natural gas consumed in industrial boilers is obtained from Table 26 "Natural Gas Consumption in the U.S. 1930-1985" of *Natural Gas Annual, 1985.*[13] For 1985, this value is 5,901,288 million cubic feet (10^6 ft^3). The TRENDS procedure subtracts consumption by cements plants, petroleum refineries, the iron and steel industry, and the glass manufacture industry from the total.

Natural gas consumption for cement plants is provided in Table 7 "Clinker produced in the United States, by fuel" of *Minerals Yearbook 1986 "Cement."*[4] The value for 1985 is 10,644.314 10^6 ft^3.

The total natural gas consumption by petroleum refineries is obtained from Table 43 "Fuels Consumed at Refineries" of *Petroleum Supply Annual 1985.*[5] The 1985 value is listed as 487,830 10^6 ft^3.

Natural gas consumption by the iron and steel industry is estimated from the annual production of raw steel and a conversion factor of 4.25 x 10^6 $ft^3/10^3$ ton raw steel produced. Annual raw steel production is obtained from Table 1 "Salient Iron and Steel Statistics" of *Minerals Yearbook 1986 "Iron and Steel."*[4] The 1985 production was 88,259,000 tons. Therefore natural gas consumption for the iron and steel industry is calculated as:

$$4.25 * 88{,}259 = 375{,}100 \times 10^6 \ ft^3.$$

Natural gas consumption by the glass manufacture industry is also estimated using the annual glass production and a conversion factor of 10.8 x 10^6 $ft^3/10^3$ tons glass produced. Annual glass consumption is computed as the sum of production of flat glass, container glass, and miscellaneous glass products. The procedure for calculating annual glass production is described in Section 2.3.8. Flat glass production in 1985 was obtained from Table 1A "Summary of Flat Glass Production, Shipments, and Inventories: 1986 and 1985" of *Current Industrial Reports Flat Glass Summary for 1986.*[14] Container glass production was obtained from Table 5 "Shipments, Production and Stocks of Glass Containers: 1985" from *Current Industrial Reports Glass Containers Summary for 1986.*[15] Miscellaneous glass products are assumed to be an additional 10 percent of the production of flat glass and glass containers. Annual glass production in 1985 was 16,245,837 tons. Therefore, the amount of natural gas consumed by the glass manufacture industry for 1985 is:

$$10.8 * 16,246 = 175,457 \times 10^6 \ ft^3.$$

The resulting TRENDS consumption in boilers is calculated as:

$$5,901,288 - 10,644 - 487,830 - 375,100 - 175,457 = 4,852,257 \times 10^6 \ ft^3.$$

The value reported in the TRENDS activity spreadsheet is 4,764,800 x 10^6 ft^3.

Gas pipelines and plants

The natural gas consumption for gas pipelines and plants is the sum of pipelines fuel and lease and plant fuel. These values are obtained from Table 13 "Consumption of Natural Gas" of *Natural Gas Annual, 1985.*[13] The value for 1985 for lease and plant fuel is 966,047 x 10^6 ft^3 and the 1985 value for pipelines fuel is 503,766 x 10^6 ft^3. Therefore, the total pipelines and plants natural gas combustion rate is:

$$966,047 + 503,766 = 1,469,813 \times 10^6 \ ft^3.$$

2.1.5.2 *TRENDS Emission Factor*

The TRENDS emissions factor is 0.6 lb $SO_2/10^6$ ft^3 burned. This emission factor is consistent with all of the natural gas combustion emission factors listed in *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*.[7]

2.1.5.3 *TRENDS Emissions*

TRENDS emissions for industrial boilers using the activity rate in the TRENDS spreadsheet are:

0.6 * 4,764,800 / 2000 = 1,429 tons of SO_2.

TRENDS emissions for natural gas pipelines are calculated as:

0.6 * 1,469,813 / 2000 = 441 tons of SO_2.

Because TRENDS does not report emissions of fewer than 10,000 tons from a source category, the published TRENDS estimate is zero tons for 1985.

2.1.5.4 *NAPAP Activity*

Boilers

Activity data collection and quality assurance were not priority items for all sources. Activity data for natural gas combustion in boilers are not itemized here.

Natural gas production

The TRENDS activity for natural gas production is the amount burned during the development of the natural gas (extraction, transportation, etc.). In NAPAP, the following two SCCs appear to correspond to the combustion of natural gas in natural gas production as reported through TRENDS.

SCC	Description		10^6 ft^3 Burned
3-10-004-04	Oil and Gas Production	Process Heaters: Natural gas	12,187
3-10-004-14	Oil and Gas Production	Steam generators: Natural gas	2,852
Total			15,039

Additional combustion of natural gas at natural gas pipelines and plants is reported through boilers, engines, as in-process fuel, and in flares.

2.1.5.5 *NAPAP Emissions*

Industrial natural gas consumption is listed for external combustion boilers, process heaters, internal combustion boilers, and in-process fuel. The emissions at the 8-digit SCC level are as follows.

Boilers

SCC	Description	Tons SO_2 Emitted
1-02-006-01	External combustion boilers - Industrial: Natural gas, Over 100 MMBtu/Hr	23,655
1-02-006-02	External combustion boilers - Industrial: Natural gas, 10-100 MMBtu/Hr	10,733
1-02-006-03	External combustion boilers - Industrial: Less than 10 MMBtu/Hr	267
1-02-006-04	External combustion boilers - Industrial: Natural gas, Cogeneration	315
1-02-014-01	External combustion boilers - Industrial: CO Boiler, Natural gas	9

SCC	Description	Tons SO_2 Emitted
1-05-001-06	External combustion boilers - Space heaters - Industrial, Natural gas	14
2-02-002-01	Internal combustion engines- Industrial: Natural gas, Turbine	1,523
2-02-002-02	Internal combustion engines- Industrial: Natural gas, Reciprocating	4,198
2-02-002-03	Internal combustion engines- Industrial: Natural gas, Turbine: Cogeneration	211
2-02-002-04	Internal combustion engines- Industrial: Natural gas, Reciprocating: Cogeneration	4
3-01-900-03	Chemical manufacturing - Process heaters: Natural gas	1,908
3-01-900-13	Chemical manufacturing Incinerators: Natural gas	2,016
3-03-900-03	Primary metal production Process heaters: Natural gas	1,370
3-04-900-03	Secondary metal production - Process heaters: Natural gas	25
3-07-900-03	Pulp & Paper and Wood products - Process heaters: Natural gas	39
3-07-900-13	Pulp & Paper and Wood products - Incinerators: Natural gas	13
3-90-006-02	In process fuel use: Natural gas, Cement kiln/dryer	0
3-90-006-03	In process fuel use: Natural gas, Lime kiln	0
3-90-006-05	In process fuel use: Natural gas, Metal melting	0
3-90-006-89	In process fuel use: Natural gas, general	12,700
3-90-006-99	In process fuel use: Natural gas, general	993
3-99-900-03	Miscellaneous Manufacturing Industries - Process heaters: Natural gas	3
3-99-900-13	Miscellaneous Manufacturing Industries - Incinerators: Natural gas	37
Total		60,033

In addition, NAPAP reports area source emissions of 1,000 tons of SO_2 from natural gas combustion. This brings the total combustion from natural gas to 61,033 tons of SO_2. In order to compare the NAPAP and TRENDS estimates, emissions from cement plants, petroleum refineries, the iron and steel industry, and the glass manufacture industry must be excluded from the NAPAP estimate. For the above listed SCCs, 5 tons are from cement manufacturing (SIC 3241), 9,377 tons are from petroleum refineries (SIC 2911), 10,044 tons are from the iron and steel industry (SIC 3312, & 3325), and 1,582 tons are from glass manufacture (SIC 3211, 3221, & 3229). In addition, NAPAP reports 6,797 tons of SO_2 from combustion during crude petroleum and natural gas production (SIC 1311) and 404 tons of SO_2 from natural gas liquids production (SIC 1321) for the above listed SCCs. The adjusted NAPAP emissions for natural gas combustion in boilers are 32,824 tons of SO_2.

Natural gas pipelines and plants

Emissions from combustion of natural gas at natural gas pipelines and plants are reported in NAPAP under as follow.

SCC	Description	Tons SO_2 Emitted
3-10-004-04	Oil and Gas Production - Process heaters: Natural gas	442
3-10-004-14	Oil and Gas Production - Steam generators: Natural gas	18
Total		460

In addition, emissions of 6,797 tons of SO_2 from crude petroleum and natural gas (SIC 1311) and 404 tons of SO_2 from natural gas liquids production (SIC 1321) are included in the category Natural Gas Pipelines and Plants. This brings the total for this category to 7,661 tons of SO_2.

2.1.5.6 *Conclusions*

The activity rates for natural gas combustion that are reported in the NAPAP inventory are not consistent with the emissions. The emissions appear to be overestimated by less than an order of magnitude and, given the relatively small amount of SO_2 emitted, were not closely reviewed in the NAPAP inventory. The total natural gas reportedly consumed is about 7,000 x 10^9 ft^3 in NAPAP versus 5,901 x 10^9 ft^3 in TRENDS (unadjusted). The TRENDS value is fairly consistent with the 4,512 x 10^9 ft^3 reported through the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*.[8]

The TRENDS conversion factors for both the iron and steel industry and the glass manufacturing industry are to be periodically updated. The value for the steel industry that is currently used is 4.25 x 10^6 ft^3 of natural gas/10^3 tons of raw steel. The value for the iron and steel industry can be updated with information provided in Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group, and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1988*.[16] Natural gas consumed by blast furnaces and steel mills was 400 billion cubic feet (TRENDS calculated 375 billion cubic feet for raw steel). Based on a 1985 raw steel production of 88,259,000, a revised factor for iron and steel would be:

400,000 / 88,259 = 4.53 x 10^6 ft^3/1000 ton raw steel.

The value for glass cannot be recalculated at this time because the reference cited combines stone, clay, and glass products.

2.1.6 Miscellaneous Fuel

TRENDS includes industrial SO_2 emission estimates for four categories of fuel. The estimate is published for all four of the fuels combined. The TRENDS estimate for miscellaneous fuels is 80,000 tons of SO_2. NAPAP reports emissions of 14,400 tons of SO_2 for those same four fuels. The apparent difference in the emission estimates is 65,600 tons (455 percent). Table 2-6 compares the NAPAP and TRENDS values for these four fuels.

2.1.6.1 *TRENDS Activity*

In TRENDS, there are four subcategories for miscellaneous fuel SO_2 emissions: coke, coke oven gas, kerosene, and LPG. Both the coke and coke oven gas categories exclude fuel burned in the iron and steel industry. Each of these subcategories is discussed separately below.

TABLE 2-6. COMPARISON OF MISCELLANEOUS FUELS VALUES FOR 1985 TRENDS AND NAPAP

Category	TRENDS Published	TRENDS Calculated	NAPAP Published
Coke Combustion			
Emissions (tons)	36,000	26,645	11,000
Fuel Consumed (10^3 tons)	1,343	1,621.2	1,656
Coke oven Gas Combustion			
Emissions (tons)	43,000	1,075	2,700
Fuel Consumed (10^9 ft^3)	79	85	4
Kerosene Combustion			
Emissions (tons)	2,000	1,434	421
Fuel Consumed (10^6 gallons)	463	463	0.656[a]
LPG Combustion			
Emissions (tons)	0	63	52
Fuel Consumed (10^6 gallons)	1,979	5,756	286[b]
Total Miscellaneous Fuels Emissions (tons)	80,000	29,200	14,400

[a]Excludes activity assigned to area sources as part of distillate oil.
[b]Excludes activity assigned to area sources as natural gas equivalents.

Coke

Industrial coke consumption outside the iron and steel industry is an adjusted sum of coke from coal and petroleum coke. Coke from coal is obtained from Table A5 "Coke and Breeze Production at Coke Plants" of the *Quarterly Coal Report*.[11] Total breeze production at coke plants in 1985 was 2,155,000 short tons. TRENDS assumes that 24 percent is sold for use as boiler fuel. Therefore, industrial breeze consumption is:

2,155,000 * 0.24 = 517,200 short tons.

Coke sales to "other industrial plants" are obtained from Table A6 "Coke and Breeze Distributed from Coke Plants" in the *Quarterly Coal Report.*[11] The 1985 value was 873,000 short tons. Therefore, total industrial coke, produced from coal, consumed outside the iron and steel industry in 1985 was:

517,200 + 873,000 = 1,390,200 short tons.

TRENDS provides two sources for petroleum coke. The first reference is Table 12 "Receipts of Petroleum Coke at Electric Utilities for Steam Plants of 50-Megawatt Installed Nameplate Capacity or Larger, 1985" of *Cost and Quality of Fuels for Electric Utility Plants 1985*[9] which lists 279,900 short tons of petroleum coke received at electric utilities. The second reference is a footnote to Table 7 "Consumption of Coal, Petroleum, and Gas by Electric Utilities, 1984-1985" of the *Electric Power Annual 1985*[17] which states that petroleum coke consumption in 1985 was 231,000 short tons by the electric utility industry.

The total coke consumed is calculated by adding the total amount of coke produced from coal, and the amount of petroleum coke consumed by power plants. For 1985, the total is:

1,390,200 + 231,000 = 1,621,200 short tons.

This value differs from the value in the TRENDS activity spreadsheet which was 1,343,000 short tons. It is unclear why the petroleum coke consumed at electric utilities should be included in the industrial fuel combustion category. Assuming this is an error in the TRENDS procedure document would bring the values closer together (1,390,000 short tons here versus 1,343,000 short tons in activity spreadsheet).

Coke oven gas

The TRENDS procedure is to obtain coke oven gas production from *Quarterly Coal Report,*[11] however, coke oven gas production is not provided in that report. Table 23 "Coal Consumption by End-Use Sector" of *Quarterly Coal Report*[11] provides coal consumption by coke plants in 1985 of 41,056,000 short tons. Figure 15 "Production of Coke and Coal Chemicals" of *Coal Data: A Reference*[18] indicates that 11,000 ft^3 of coke oven gas are produced per ton of metallurgical (coking) coal. This is consistent with the value used in the Iron and Steel section of the TRENDS procedure. This results in 1985 coke oven gas production of:

$$41,056,000 * 11,000 / 1,000,000 = 451,616 \times 10^6 \text{ ft}^3.$$

The TRENDS method assumes that 18.8 percent of the coke oven gas is consumed outside of the iron and steel industry. Therefore the coke oven gas consumption is:

$$451,616 * 0.188 = 84,903 \times 10^6 \text{ ft}^3.$$

The value in the TRENDS activity spreadsheet is 79,300 x 10^6 ft^3.

Kerosene

Kerosene consumption is obtained from Table 15 "Adjusted Sales of Kerosene by End Use in the United States 1985-1989" of *Fuel Oil and Kerosene Sales 1989*.[3] The 1985 value is 254,491,000 gallons for industrial use and 208,139,000 for all other. Therefore the TRENDS activity value for industrial kerosene is:

$$254,491,000 + 208,139,000 = 462,630,000 \text{ gallons.}$$

LPG

Most (88 percent) of the LPG is used as a feed stock. The TRENDS procedure attempts to account for this using an ad hoc procedure to determine consumption for use as a fuel. LPG consumption by industrial sources is calculated by multiplying the 1985 production with the ratio of 1982 sales of LPG to the 1982 product supplied (the last available data).

In 1982 the total sales were 5,397,000,000 gallons. The 1982 products supplied were 1,499,000 barrels/day. Therefore the ratio is:

5,397,000,000 / 1,499,000 = 3,600 gallons/bbl/day.

The 1985 product supplied is obtained from Table S7 "Liquified Petroleum Gases Supply and Disposition" of *Petroleum Supply Annual 1985*.[5] In 1985 the products supplied were 1,599,000 barrels/day, therefore, the 1985 industrial LPG activity figure is:

1,599,000 * 3,600 = 5,756,000,000 gallons.

The value listed in the TRENDS activity spreadsheet is 1,979 x 10^6 gallons. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group, and Selected Industries, 1985" of the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* lists the industrial LPG consumption as 1,116 x 10^6 gallons.

2.1.6.2 *TRENDS Emission Factors*

Coke

The TRENDS method recommends the development of a weighted emission factor for coal coke and petroleum coke. The emission factor listed for petroleum coke is 38.8 and TRENDS multiplies this value by 3.25 percent sulfur content for petroleum coke. There is no emission factor in the *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] or in *Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources. Fourth Edition. AP-42*[19] for combustion of petroleum coke.

The TRENDS procedure document lists an emission factor of 30.3 lb/ton burned for coal coke. The emission factor listed in the *AIRS Facility Subsystem SCC and Emission*

Factor Listing for Criteria Pollutants[7] for industrial coke combustion is 39.0S lb/ton burned (SCC 1-02-008-02). This implies that TRENDS is using 0.77 percent sulfur for coal coke.

The TRENDS procedure requires that the emission factors be weighted based on AIRS data and provides a table to assist in the weighing. Table 2-7 illustrates the values used to produce the weighted emission factor of 43.9 lbs/ton coke burned. The TRENDS spreadsheet lists an emission factor of 53 lb/ton for both the 1990 and 1991 study years.

TABLE 2-7. WEIGHTED AVERAGE EMISSION FACTOR FOR COKE COMBUSTION

Coke Type	Trends Activity (10^3 tons)	SO_x Emission Factor (lb/ton)
Petroleum Coke	231	126*
Coal Coke**	1,390.2	30.3
Weighted Average (lb/10^3 ton burned)		43.9

* Assumes a constant sulfur content value of 3.25 percent for petroleum coke.
** Total of breeze production plus coke industrial boilers.

Coke oven gas

The emission factor for coke oven gas is 680.0S lb $SO_2/10^6$ ft^3. This is consistent with the *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] document for SCC 1-02-007-007. The TRENDS procedure document assumes a sulfur content of 1.605 percent. Therefore the emission factor is:

$$680.0 * 1.605 = 1{,}091 \text{ lb } SO_2/10^6 \text{ ft}^3.$$

Kerosene

TRENDS lists the kerosene emission factor for SCC 1-02-005-01 as 143.6S lbs $SO_2/10^3$ gallons burned. TRENDS also lists an average sulfur content of 0.075 percent for kerosene. This results in an overall emission factor for kerosene combustion of:

$143.6 * 0.075 = 10.77\ lb/10^3$ gallons burned.

The SCC 1-02-005-01 is for grades 1 and 2 distillate oil. An appropriate SCC for kerosene would be 2-02-009-01. All of the emission factors listed in *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] for SO_2 from kerosene combustion are 6.2 $lb/10^3$ gallons burned.

LPG

TRENDS lists the LPG emission factor for SCC 1-02-010-02 as 86.5S lbs $SO_2/10^3$ gallons burned. This matches the emission factor in the *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] for both butane and propane. TRENDS also lists an average sulfur content of 0.0013 percent for LPG and results in the following overall emission factor:

$86.5 * 0.0013 = 0.11\ lb/10^3$ gallons burned.

2.1.6.3 ***TRENDS Emissions***

The estimates presented below utilize the activity rates found in the TRENDS activity spreadsheet and emission factors found in the TRENDS procedure document. Differences between these numbers and TRENDS estimates are discussed under conclusions.

Coke

Emissions from industrial coke combustion are calculated using the activity value and emission factor found in the TRENDS spreadsheets.

1,343,000 * 53.0 / 2000 = 35,589 tons of SO_2

Coke oven gas

Emissions are calculated using the activity value found in the TRENDS activity spreadsheet.

79,300 * 1,091 / 2000 = 43,258 tons of SO_2

Kerosene

Emissions are calculated using the emission factor listed in the TRENDS procedure document.

462,600 * 10.77 / 2000 = 2,491 tons of SO_2

LPG

Emissions are calculated using the activity value found in the TRENDS activity spreadsheet.

1,979,000 * 0.11 / 2000 = 109 tons of SO_2

Total miscellaneous fuels

The total emissions are the sum of coke, coke oven gas, kerosene and LPG:

35,589 + 43,258 + 2,491 + 109 = 81,447 tons SO_2

2.1.6.4 *NAPAP Activity*

Although these data were not priority NAPAP items, the data are presented here for comparison.

Coke

The NAPAP activity for coke combustion include industrial external boilers and in-process fuel use. The NAPAP inventory reports 55 percent of the activity in SIC codes 1011, 3312 and 3321 (all iron and steel). The remainder includes petroleum refining, electric utilities, chemical manufacturing and mineral products.

SCC	Description	Tons burned
1-02-008-02	External combustion boilers - Industrial: Coke, all boiler sizes	392,652
1-02-008-04	External combustion boilers Industrial: Coke, cogeneration	834,218
3-90-008-99	In process fuel use, Coke, general	2,414,424
Total		3,641,294

Coke oven gas

The NAPAP activity for coke oven gas include external combustion boilers and in-process fuel use. The inventory reports 99 percent of the activity in SIC codes 1011, 3312 and 3321, with the remainder in chemical manufacturing, carbon black and petroleum refining.

SCC	Description	10^6 ft^3 Burned
1-02-007-07	External combustion boilers - Industrial: Process gas, coke oven gas	111,686
3-90-007-01	In process fuel use, Process gas, Coke oven or blast furnace	423,091
3-90-007-02	In process fuel use, Process gas, Coke oven gas	193,971
3-90-007-89	In process fuel use, Process gas, Coke oven gas	65,119
Total		793,867

Kerosene

The NAPAP activity for kerosene include internal combustion boilers. No adjustment for area source activity could be made because kerosene is combined into the distillate oil category.

SCC	Description	10^3 Gallons Burned
2-02-009-01	Internal combustion engines Industrial: Kerosene/Naphtha (Jet fuel), Turbine	656
Total		656

LPG

The NAPAP activity for LPG include external combustion boilers, space heat, internal combustion boilers, and in-process fuel use. No adjustment for area source activity could be made because LPG is combined as natural gas equivalents in the natural gas category.

SCC	Description	10^3 Gallons Burned
1-02-010-01	External combustion boilers - Industrial: LPG - Butane	714
1-02-010-02	External combustion boilers - Industrial: LPG - Propane	100,060
1-05-001-10	External combustion boilers - Space heaters: Industrial - LPG	47
2-02-010-01	Internal combustion engines - Industrial: LPG, propane: reciprocating	1,854
2-02-010-02	Internal combustion engines - Industrial: LPG, butane: reciprocating	3
3-90-009-89	In process fuel use, LPG, general	91,944[a]
3-90-010-89	In process fuel use, LPG, general	9,702
3-90-010-99	In process fuel use, LPG, general	81,864
Total		286,188

[a] Tons burned.

2.1.6.5 *NAPAP Emissions*

Coke

The NAPAP emission estimates for coke combustion include industrial external boilers and in-process fuel use.

SCC	Description	Tons SO_2 Emitted
1-02-008-02	External combustion boilers Industrial: Coke, all boiler sizes	2,246
1-02-008-04	External combustion boilers - Industrial: Coke, cogeneration	9,665
3-90-008-99	In process fuel use, Coke, general	89
Total		12,000

The NAPAP inventory reports 747 tons SO_2 in these three SCCs among SICs 1011, 3312 and 3321 within the iron and steel industry. The remaining 11,252 tons are categorized with miscellaneous fuel.

Coke oven gas

The NAPAP emission estimates for coke oven gas include external combustion boilers and in-process fuel use.

SCC	Description	Tons SO_2 Emitted
1-02-007-07	External combustion boilers Industrial: Process gas, coke oven gas	17,637
3-90-007-01	In-process fuel use, Process gas, Coke oven or blast furnace	6
3-90-007-02	In-process fuel use, Process gas, Coke oven gas	4,331
3-90-007-89	In-process fuel use, Process gas, Coke oven gas	4,796
Total		26,770

The NAPAP inventory reports 24,081 tons SO_2 in these SCCs among SICs 1011, 3312 and 3321 (iron and steel). The remaining 2,689 tons are categorized within miscellaneous fuel.

Kerosene

The NAPAP emission estimates for kerosene include internal combustion boilers.

SCC	Description	Tons SO_2 Emitted
2-02-009-01	Internal combustion engines - Industrial: Kerosene/Naphtha (Jet fuel), Turbine	421
Total		421

LPG

The NAPAP emission estimates for LPG include external combustion boilers, space heat, internal combustion boilers, and in-process fuel use.

SCC	Description	Tons SO_2 Emitted
1-02-010-01	External combustion boilers - Industrial: LPG - Butane	0
1-02-010-02	External combustion boilers - Industrial: LPG Propane	27
1-05-001-10	External combustion boilers - Space heaters: Industrial - LPG	18
2-02-010-01	Internal combustion engines - Industrial: LPG, propane: reciprocating	0
2-02-010-02	Internal combustion engines - Industrial: LPG, butane: reciprocating	0
3-90-009-89	In process fuel use, LPG, general	2
3-90-010-89	In process fuel use, LPG, general	5
3-90-010-99	In process fuel use, LPG, general	0
Total		52

2.1.6.6 *Conclusions*

There are many numbers in this category that are not well justified in the TRENDS method. The categories are discussed separately.

Coke

The coke emissions, excluding iron and steel, are 11,300 tons in NAPAP, and 36,000 tons in TRENDS. The coke emissions are probably underestimated in the NAPAP inventory.

There are discrepancies in the TRENDS activity data. First, it is unclear why the petroleum coke that is delivered to electric utilities should be included in this category. (The NAPAP total for this petroleum coke is 3,111 tons.) Second, the activity value in the TRENDS spreadsheet could not be reproduced by following the TRENDS procedure. TRENDS lists 1,343,000 tons in the activity spreadsheet. Following the TRENDS procedure resulted in a value of 1,621,000 tons. The *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] lists 1,952,000 tons of coke and breeze for industries outside of blast furnaces and steel mills. Therefore, the activity value used to estimate the 1985 coke combustion emissions is probably too low in the TRENDS procedure.

The emission factor which is used for coke combustion may overestimate the TRENDS emission estimate. TRENDS uses an emission factor of 53.0 lb/ton burned. The *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] has an emission factor of 39.0S lb/ton burned. The NAPAP inventory lists an average coke sulfur content of 0.7 percent which results in an overall emission factor of 27.3 lb/ton burned. If the petroleum coke delivered to electric utilities is not included and the value from the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] is used and the revised emission factor is utilized, the following TRENDS coke emission estimate would result.

$$1,952,000 * 27.3 / 2000 = 26,645 \text{ tons of } SO_2$$

Coke oven gas

The coke oven gas emissions, excluding iron and steel, are 2,700 tons in NAPAP, and 43,000 tons in TRENDS. It appears as though TRENDS overestimates SO_2 emissions for combustion of coke oven gas outside the iron and steel industry. TRENDS assumes 18.8 percent of the coke oven gas produced is burned in boilers outside the iron and steel industry. The 18.8 percent is not documented. In addition, the TRENDS iron and steel section assumes that 40 percent of coke oven gas is used in the iron and steel process equipment (see Roll and Finish subsection of iron and steel). The remaining 40 percent of the coke oven gas being consumed in the TRENDS procedure is not accounted for. Table 12 "Production and Disposal of Coke Oven Gas in the United States by Producing State: 1980" of *Coke and Coal Chemicals in 1980*[20] reports that in 1980 coke gas use was 39 percent by producers in heating ovens, 58 percent other use by producers, 1.4 percent commercial sales, and 1.5 percent wasted. These statistics are consistent with the NAPAP distribution of coke oven gas combustion.

TRENDS lists a coke oven gas average sulfur value of 1.605 percent. The NAPAP inventory lists an average sulfur content for coke oven gas of 0.5 percent. Using a factor of 1.4 percent of coke oven gas burned in industrial boilers outside the iron and steel industry and using the NAPAP average sulfur content, results in the following emissions.

$$451{,}616 * 0.014 * 680 * 0.5 / 2000 = 1{,}075 \text{ tons of } SO_2$$

Kerosene

The kerosene emissions are 421 tons in NAPAP and 2,491 tons in TRENDS. The kerosene emissions are probably overestimated in the TRENDS document. The emission factor used in the TRENDS procedure to estimate kerosene emissions is actually an emission factor for distillate oil. The emission factor cited is 10.77 lb/10^3 gallon burned. Using a kerosene emission factor of 6.2 lb/10^3 gallons burned results in the following emissions.

462,630 * 6.2 / 2000 = 1,434 tons of SO_2

LPG

The LPG emissions are 52 tons in NAPAP and 109 tons in TRENDS. The LPG emissions are probably overestimated in the TRENDS document. Following the TRENDS procedure manual did not result in the same activity value for LPG combustion as is published in the TRENDS activity spreadsheet. The LPG activity value used in the 1985 TRENDS estimate is higher (1,979 million gallons versus 1,116 million gallons) than the value reported through the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*.[8] Using the value reported through the survey results in the following emissions.

1,116,000 * 86.5 * 0.0013 / 2000 = 63 tons of SO_2

The TRENDS procedure for determining LPG combustion activity is difficult to understand. A preferred approach may be to hold the value constant and update it every three years with a new *Manufacturing Energy Consumption Survey*.

Total TRENDS emissions for the miscellaneous fuel category would then be:

26,645 + 1,075 + 1,434 + 63 = 29,217 tons of SO_2

2.1.7 Wood

The published TRENDS emission estimate for wood combustion is 10,000 tons of SO_2. The NAPAP estimate is 41,700 tons of SO_2. The apparent difference in the emission estimates is 31,700 tons (76 percent).

2.1.7.1 *TRENDS Activity*

The TRENDS procedure for determining the activity value for wood combustion is poorly documented and difficult to follow. The total industrial combustion of wood for both the 1984 and the 1989 study years is available from Table 1 "U.S. Consumption of Wood Energy by Sector, 1949-1990" of *Estimates of U.S. Biofuels Consumption 1990.*[21] The value for 1984 is 1,679 trillion Btu. The TRENDS procedure document provides a conversion factor of 17.2 million Btu per oven-dried short ton. Therefore the 1984 wood consumption is:

$(1{,}679 \times 10^{12}) / (17.2 \times 10^{6}) = 97.616 \times 10^{6}$ oven-dried short tons.

The TRENDS procedure initially instructs the user to obtain the consumption figures, in tons, for the previous year and to assume that 15 percent of the heating value is lost to moisture on a typical basis. The TRENDS procedure further states that as of 1990, wood consumption was published in therms of Btu's and an average Btu content per oven-dried short ton is provided. TRENDS then states "No adjustment to the calculated tonnage is necessary." This last statement is interpreted as instruction not to apply the 85 percent factor to account for lost moisture.

TRENDS assumes that 75 percent of the industrial wood is consumed by the pulp and paper industry and 25 percent is used in lumber and wood products. TRENDS requires that the converted (from Btu to oven-dried ton) consumption figure be projected to the update year following a procedure, outlined in the LPG section, for paper and wood separately. Therefore the portion of the industrial wood combustion from pulp is:

$0.75 * 97{,}616{,}300 = 73{,}212{,}000$ oven-dried tons.

The portion of the industrial wood combustion from the lumber industry is:

$0.25 * 97{,}616{,}300 = 24{,}404{,}000$ oven-dried tons.

The production of sulfite (kraft) and sulfite is found in Table 4 "Production and Shipments of Woodpulp, by Type of Pulp: 1986 and 1985" of *Current Industrial Reports, Pulp, Paper, and Board.*[22] The 1985 production figure for sulfate was 42,563,831 short tons and for sulfite was 1,620,084 short tons. Therefore, the total 1985 pulp production value was 44,183,915 short tons. The 1984 value is obtained from the TRENDS activity spreadsheet and was 42,758,800 short tons. Therefore the projection for the paper portion of the wood combustion is as follows:

$$\text{'85 wood}_{paper} = \text{'84 wood}_{paper} * [1 + (\text{'85 paper - '84 paper}) / \text{'84 paper}]$$
$$= 73{,}212{,}000 * [1 + (44{,}183.9 - 42{,}758.8)/ 42{,}758.8]$$
$$= 75{,}652{,}388 \text{ oven-dried tons}$$

The lumber production is found in Table 1 "Lumber Production: 1980 to 1991" of *Current Industrial Reports, Lumber Production and Mill Stocks.*[23] The 1985 total production was 36,445 million board feet. The 1984 total production, as documented in the TRENDS activity spreadsheet, was 37,065 million board feet. Therefore the projection for the lumber portion of the wood combustion is as follows:

$$\text{'85 wood}_{lumber} = \text{'84 wood}_{lumber} * [1 + (\text{'85 lumber} \quad \text{'84 lumber}) / \text{'84 lumber}]$$
$$= 24{,}404{,}000 * [1 + (36{,}445 \quad 37{,}065)/ 37{,}065]$$
$$= 23{,}995{,}795 \text{ oven-dried tons}$$

Total industrial wood combustion is the sum of these two figures:

75,652,388 + 23,995,795 = 99,648,183 oven-dried tons.

The value in the TRENDS activity spreadsheet is 113,380,000 oven-dried tons.

2.1.7.2 *TRENDS Emission Factors*

TRENDS lists the emission factor for wood combustion as 0.15 lb/ton burned. This is consistent with the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document which lists the emission factors for industrial external combustion of wood as 0.15 lb/ton burned for all types of boilers.

2.1.7.3 *TRENDS Emissions*

Using the activity value in the TRENDS activity spreadsheet results in emissions of:

113,380,000 * 0.15 / 2000 = 8,504 tons of SO_2.

2.1.7.4 *NAPAP Activity*

Collection and quality assurance of the activity data were not priority elements for all sources in the inventory. The data are not presented here.

2.1.7.5 *NAPAP Emissions*

The emissions from wood combustion reported in NAPAP include wood and bark waste burned in external boilers, wood burned as in-process fuel, and area source wood combustion. Because the collection and quality assurance of the activity data were not high priority items for all sources, these data are not presented here.

SCC	Description	Tons SO_2 Emitted
1-02-009-01	External combustion boilers - Industrial: Wood/Bark waste, Bark-fired boiler (>50,000 lb steam)	6,863
1-02-009-02	External combustion boilers - Industrial: Wood/Bark waste, Wood/Bark-fired boiler (>50,000 lb steam)	5,664
1-02-009-03	External combustion boilers - Industrial: Wood/Bark waste, Wood-fired boiler (>50,000 lb steam)	1,102
1-02-009-04	External combustion boilers - Industrial: Wood/Bark waste, Bark-fired boiler (<50,000 lb steam)	4

SCC	Description	Tons SO_2 Emitted
1-02-009-05	External combustion boilers - Industrial: Wood/Bark waste, Wood/Bark-fired boiler (<50,000 lb steam)	45
1-02-009-06	External combustion boilers - Industrial: Wood/Bark waste, Wood-fired boiler (<50,000 lb steam)	16
1-02-009-07	External combustion boilers Industrial: Wood/Bark waste, Wood cogeneration	1,446
3-90-008-89	In process fuel, Wood, general	9,567
3-90-009-99	In process fuel, Wood, general	1
Total		24,708

In addition, NAPAP reports 17,000 tons as area source emissions. Therefore, the total NAPAP wood combustion emission estimate is 41,700 tons SO_2.

2.1.7.6 *Conclusions*

The TRENDS emission estimate for wood combustion is 8,504 tons of SO_2. The NAPAP estimate is 41,700 tons of SO_2. Nearly half of the point source emissions in the NAPAP inventory are from a general in-process wood combustion category. The emission factor for this SCC (3-90-008-89) is 38.0S lbs/ton burned. NAPAP also reports an average sulfur content of 1.5 percent for the SCC. This emission factor is substantially higher than the emission factor used in TRENDS and the rest of the NAPAP categories (0.15 lb/ton burned). As a result, this category is responsible for a disproportionate share of the wood combustion point source emissions reported in NAPAP. Due to the high emissions for this one category of wood combustion, the NAPAP inventory probably overestimates the wood combustion emissions.

Following the TRENDS procedure did not recreate the activity value that was used in the calculation of the 1985 emission estimate for wood combustion. Even when rounding the emission estimate to the nearest 10,000 tons, the difference is not insubstantial. Table 3 "Industrial Woodfuel Consumption by Sector, 1990" of *Estimates of U.S. Biofuels Consumption 1990*[22] states that paper and allied product consume 79 percent of the industrial wood fuel, lumber and wood products consume 18 percent and other industries consume the remaining 3 percent. Using these breakdowns by industry results in a 1985 wood consumption value of 99,892,644 oven-dried tons. This results in emissions of:

$$99{,}892{,}644 * 0.15 / 2000 = 7{,}492 \text{ tons of } SO_2.$$

2.1.8 Other NAPAP Combustion Categories

Additional emissions are reported in the NAPAP inventory as combustion emissions for sources not discussed in this section (because they have no corresponding TRENDS estimate). These emissions include liquid waste, waste oil, solid waste, bagasse, and process gas, and amount to an additional 74,477 tons of SO_2.

2.2 NON-FERROUS SMELTING

The TRENDS nonferrous smelting category includes primary copper, primary lead, primary zinc, primary aluminum and secondary lead. Additional categories are included in TRENDS for other criteria pollutants (especially particulate) and other non-ferrous smelting categories are included in the NAPAP inventory. Table 2-8 presents the comparison of the NAPAP and TRENDS non-ferrous smelting SO_2 emission estimates.

The non-ferrous smelting source categories contribute significantly to the industrial SO_2 emissions. The majority of the smelters recover sulfur that is emitted from the ores being processed. Due to the increasing environmental pressures exerted on smelters and global competition, smelters in this country are continuing to close, dramatically affecting the trends in emissions from these categories. This discussion begins with the reporting of sulfur recovered as H_2SO_4 from non-ferrous smelters.

Byproduct 1985 sulfuric acid production was reported in Table 7 "Byproduct Sulfuric Acid Produced in the United States" of *Minerals Yearbook 1989 "Sulfur"* and in Table 22 "Byproduct Sulfuric Acid (100% Basis) Produced in the United States" of *Minerals Yearbook 1989 "Copper"*. Values are converted to SO_2 based on molecular weights of sulfur (32), SO_2

TABLE 2-8. COMPARISON OF NON-FERROUS SMELTING VALUES FOR 1985 TRENDS AND NAPAP

Category (SIC)	TRENDS Published	TRENDS Calculated	NAPAP Published
Primary Copper (3331)			
Emissions (tons)	650,000		655,300
Activity			
Primary Zinc (3339)			
Emissions (tons)	67,400[a]	93,864	7,600
10^3 Tons of concentrate	686.2	734.3	
Primary Lead (3339)			
Emissions (tons)	34,500[a]	98,775	98,800
Lead processing (10^3 tons)	759.3	975.4	
Primary Aluminum (3334)			
Emissions (tons)	70,000	71,039	58,400
Aluminum produced (10^3 tons)	3,850	3,855.6	
Secondary Lead (3341, 3364)			
Emissions (tons)	30,000	27,147	20,700
Reverberatory furnace (10^3 tons)	394.0	393.6	216.6
Blast furnace (10^3 tons)	391.3	430.4	332.8
Total Emissions (tons)	990,000[b]	940,825	840,800

[a]Published together as one value of 240,000 tons of SO_2. The discrepancy between the total and individual sum (67,400 + 34,500) could not be resolved.
[b]Includes 240,000 tons of SO_2 for primary lead and zinc.

(64), and sulfuric acid (98). Table 2-9 lists the 1985 sulfur recovery breakdown.[4]

The TRENDS activity spreadsheet lists sulfur recovered as H_2SO_4 as 327,900 tons of SO_2 for primary lead and zinc versus 501,000 tons published in *Mineral Yearbook, 1989*.[4]

2.2.1 Primary Copper

NAPAP and TRENDS report essentially identical SO_2 emissions for this category (655,000 tons vs. 650,000 tons). Because these smelters are large and few in number, it is understood that TRENDS actually tracks individual primary copper smelter emissions, as does NAPAP No further analysis of the category is warranted.

TABLE 2-9. RECOVERY OF SULFUR AS H_2SO_4

	As Sulfur[a] (metric tons)	As SO_2[a] (short tons)	As H_2SO_4[b] (metric tons)	As SO_2[b] (short tons)
Copper	729,000	1,604,000	2,230,257	1,602,240
Lead & Molybdenum	87,000	191,400	267,159	191,930
Zinc	141,000	310,200	430,946	309,600
Total	957,000	2,105,600	2,928,362	2,103,770

[a]Reported in Table 7 *Minerals Yearbook 1989 "Sulfur."*
[b]Reported in Table 22 *Minerals Yearbook 1989 "Copper."*

2.2.2 Combined Primary Lead and Primary Zinc

The 1985 TRENDS value is 240,000 tons SO_2 for primary lead and zinc, which are reported together as one category. As described below, this total could not be reproduced. The 1985 NAPAP value is 98,775 for primary lead and 7,642 for primary zinc. The discrepancy between the two inventories is 133,600 tons (126 percent).

2.2.3 Primary Zinc

2.2.3.1 *TRENDS Activity*

National zinc production is obtained from Table 1 "Salient Zinc Statistics" of *Minerals Yearbook 1989 "Zinc."*[4] The 1985 total slab U.S. zinc production was 333,772 metric tons (367,149 short tons). This value is multiplied by 2 because there are 2 units of concentrate per ton slab zinc. This provides a value of 734,298 tons of concentrate.

The value listed in the TRENDS activity spreadsheet is 686,200 tons for 1985.

2.2.3.2 *TRENDS Emission Factor*

The emission factor for zinc roasting cited in the TRENDS method is as follows.

SCC	Description	Emission Factor	Units
3-03-030-02	Primary Metal Zinc Production: Multiple hearth roaster	1,100	lb/ton concentrated ore processed

2.2.3.3 *TRENDS Emissions*

TRENDS accounts for the recovery of sulfur at primary zinc smelters. The 1985 recovery as shown in Table 2-9 is 310,000 tons of SO_2. Therefore, 1985 emissions are calculated as follows (using the activity value found in the TRENDS spreadsheet):

1,100 * 686,200 / 2000 - 310,000 = 67,410 tons of SO_2.

In contrast, the 1985 emissions using the zinc activity published in *Minerals Yearbook*[4] are:

1,100 * 734,298 / 2000 - 310,000 = 93,864 tons of SO_2.

2.2.3.4 *NAPAP Activity*

The NAPAP activity is listed below. The units for most processing with associated SO_2 emissions are tons of concentrated ore processed. Recall that these activity data were not high priority for all sources in the inventory.

SCC	Description	Tons of Concentrated Ore Processed
3-03-030-02	Primary Metal Zinc Production: Multiple hearth roaster	35,082
3-03-030-03	Primary Metal Zinc Production: Sinter strand	472,552

SCC	Description	Tons of Concentrated Ore Processed
3-03-030-05	Primary Metal - Zinc Production: Vertical retort/ electrothermal furnace	1,954,037
3-03-030-06	Primary Metal - Zinc Production: Electrolytic processor	3,407,830
3-03-030-07	Primary Metal Zinc Production: Flash roaster	0
3-03-030-11	Primary Metal Zinc Production: Zinc casting	79,410[a]
3-03-030-14	Primary Metal - Zinc Production: Crushing/ screening	2,376
3-03-030-15	Primary Metal Zinc Production: Zinc melting	26,208[b]
3-03-030-99	Primary Metal Zinc Production: Not classified	5,682,107

[a] Tons zinc produced
[b] Tons processed

As shown above, one record lists 79,410 tons of zinc cast (3-03-030-11), however, it is doubtful that this represents all of the zinc produced in 1985. The largest value for concentrated ore processed is 3,407,830 tons. Neither the total zinc cast nor the concentrated ore processed in the electrolytic processor are consistent with the TRENDS activity value.

2.2.3.5 *NAPAP Emissions*

SCC	Description	Tons SO_2 Emitted
3-03-030-02	Primary Metal - Zinc Production: Multiple hearth roaster	849
3-03-030-03	Primary Metal - Zinc Production: Sinter strand	5,175
3-03-030-05	Primary Metal - Zinc Production: Vertical retort/ electrothermal furnace	1,104
3-03-030-06	Primary Metal - Zinc Production: Electrolytic processor	0
3-03-030-07	Primary Metal - Zinc Production: Flash roaster	258
3-03-030-11	Primary Metal - Zinc Production: Zinc casting	0
3-03-030-14	Primary Metal - Zinc Production: Crushing/ screening	0
3-03-030-15	Primary Metal - Zinc Production: Zinc melting	0
3-03-030-99	Primary Metal - Zinc Production: Not classified	256

SCC	Description	Tons SO_2 Emitted
Total		7,642

Only 849 tons are reported in NAPAP for zinc roasting in the multiple hearth roaster and this process is not the largest source of SO_2 emissions in the NAPAP inventory (although it does have the largest emission factor).

2.2.3.6 *Conclusion*

The NAPAP and TRENDS estimates for emissions from primary zinc production are very different. NAPAP reported emissions of 7,642 tons of SO_2 and the TRENDS method resulted in an emission estimate of 93,864 tons of SO_2.

The TRENDS published estimate for primary zinc production is combined with the primary lead estimate and the published total of 240,000 tons of SO_2 from both industries could not be recreated. In the TRENDS method, sulfur recovered as H_2SO_4 is used in the development of both the zinc and lead emission estimate. The value in the TRENDS spreadsheet for recovered sulfur for this section also could not be reproduced. The TRENDS activity spreadsheet stated that 327,900 tons of SO_2 were produced at primary lead and primary zinc facilities in 1985. The references for these data are sections in the *Minerals Yearbook*[4] and the values published are 501,500 tons of SO_2. The difference in the recovered sulfur could account for the inability to recreate the published TRENDS value.

The TRENDS method needs to be updated. TRENDS assumes all roasting is done in a multiple hearth roaster; two additional SCCs for roasting exist, flash roaster (3-03-030-07) and fluid bed roaster (3-03-030-08). Both have a smaller emission factor (404.4 and 223.5 lbs/ton of concentrated ore processed, respectively) than the multiple hearth roaster (1,100 lbs/ton of concentrated ore processed).

The NAPAP inventory did not report the majority of emissions through the multiple hearth roaster. The NAPAP inventory may have overestimated SO_2 emissions from some of the other processes in zinc production (specifically the sinter strand and the vertical retort/electrothermal furnace SCC 3-03-030-03/05). The discrepancy in NAPAP where the majority of emissions were not reported through the roasting process needs to be investigated, but could be an artifact of the NEDS software as well as misreporting of emissions.

2.2.4 Primary Lead

2.2.4.1 *TRENDS Activity*

The TRENDS procedure has a complicated method to determine "Lead Processing" as opposed to primary lead production. Primary lead production can be obtained from Table 1 "Salient Lead Statistics" of *Minerals Yearbook 1989 "Lead."*[4] The 1985 production value is the sum from domestic ore and base bullion and from foreign ores and base bullion and was:

422,650 + 71,353 = 494,003 metric tons = 543,403 short tons.

According to the TRENDS procedure manual, lead processing is calculated in four steps. First, total copper and zinc SO_2 emissions are calculated. Second, byproduct sulfuric acid recovered from copper, zinc, and lead smelters is estimated. Third, total SO_2 lead emissions are calculated using the following equation:

$$\text{Total } SO_2 = SO_2\text{ (lead+zinc)} - SO_2\text{(zinc)} + \text{AFS Lead Emissions.}$$

Fourth, the lead processing value is backcalculated using the following equation.

$$\text{Lead Processing} = \frac{\text{Total } SO_2 \text{ Lead Emissions} * 2000}{595}$$

The derivation and reasoning behind this procedure are not documented. In addition, this procedure includes steps to calculate values that are not used in the remaining steps.

Following the TRENDS procedure for determining lead production leads to the following value for 1985.

Step 1, copper and zinc SO_2 emissions (based on the previous sections) are:

650,000 + 67,410 = 717,410 tons of SO_2.

Step 2, byproduct sulfuric acid for copper, lead and zinc are listed in Table 2-9 as 2,100,000 tons of SO_2. Byproduct sulfuric acid for lead and zinc are 501,600 tons of SO_2. (It is unclear why the TRENDS procedure references the sulfur recovered from copper smelting).

Step 3, NAPAP lists the 1985 SO_2 emissions (SCC 3-03-010-XX) as 98,775 short tons.

Total SO_2 = SO_2 (lead+zinc) - SO_2(zinc) + AFS Lead Emissions

= 501,600 - 310,200 + 98,775 = 290,175 tons of SO_2

Step 4,

$$\text{Lead Processing} = \frac{290{,}175 * 2000}{595} = 975{,}378 \text{ short tons}$$

The TRENDS spreadsheet lists a lead processing value for 1985 as 759,300 tons. There is probably an error in the TRENDS procedure manual. It is unclear why the lead sulfur recovery would be added to the zinc sulfur recovery only to subtract the zinc value. The copper sulfur recovery value is referenced, but does not appear to enter into the equation.

2.2.4.2 *TRENDS Emission Factor*

The emission factors cited in the TRENDS method are as follows.

SCC	Description	Emission Factor	Units
3-03-010-01	Primary Metals - Lead production: Sintering, single stream	550	lb/ton lead produced
3-03-010-02	Primary Metals - Lead Production: Blast furnace operation	45	lb/ton lead produced
Total		595	lb/ton lead produced

These emission factors are twice those listed in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document but are consistent with AP-42. The units are different: AP-42 units are tons of lead produced, the SCC emission factor units are tons of concentrated ore processed. In addition, the SCC emission factor document lists 3-03-010-06 as a major source (sintering dual stream versus single stream above) but this appears to be a new SCC as there are no values in the NAPAP inventory.

2.2.4.3 *TRENDS Emissions*

Using the TRENDS emission factor and activity rate published in the TRENDS spreadsheet and subtracting the recovered sulfur results in the following emissions.

759,300 * 595 / 2000 - 191,400 = 34,500 tons of SO_2.

Using the activity data derived following the TRENDS procedure manual and subtracting the recovered sulfur results in emissions of:

975,382 * 595 / 2000 - 191,400 = 98,775 tons of SO_2.

2.2.4.4 *NAPAP Activity*

The following activity data were published in the NAPAP inventory.

SCC	Description	Tons of Concentrated Ore Processed
3-03-010-01	Primary metal - Lead production: Sintering single stream	1,062,662
3-03-010-02	Primary metal Lead production: Blast furnace operation	1,006,182
3-03-010-09	Primary metal - Lead production: Lead drossing	275,599
3-03-010-23	Primary metal Lead production: Lead casting	131,601

2.2.4.5 *NAPAP Emissions*

There are 21 SCCs or processes listed for lead production. Of these 21 SCCs only four have associated SO_2 emissions and they are listed below.

SCC	Description	Tons SO_2 Emitted
3-03-010-01	Primary metal - Lead production: Sintering single stream	78,496
3-03-010-02	Primary metal Lead production: Blast furnace operation	20,109
3-03-010-09	Primary metal - Lead production: Lead drossing	1
3-03-010-23	Primary metal - Lead production: Lead casting	169
Total		98,775

2.2.4.6 ***Conclusion***

The NAPAP and TRENDS estimates for emissions from primary lead production are also very different. NAPAP reported emissions of 98,775 tons of SO_2 and the TRENDS method resulted in an emission estimate of 34,500 tons of SO_2. (The TRENDS published estimate for primary lead production is combined with the primary zinc estimate and the published total of 240,000 tons of SO_2 from both industries could not be recreated.)

In the TRENDS method, sulfur recovered as H_2SO_4 is used in the development of both the zinc and lead emission estimate. The value in the TRENDS spreadsheet for recovered sulfur could not be reproduced. The TRENDS activity spreadsheet stated that 327,900 tons of SO_2 were produced at primary lead and primary zinc facilities in 1985. The reference for these data are sections in the

Minerals Yearbook[4] and the values published are 501,500 tons of SO_2. The difference in the recovered sulfur could account for the inability to recreate the published TRENDS value for primary lead and primary zinc emissions.

The TRENDS method is outdated relative to the data that are currently provided in the *Minerals Yearbook, 1989*.[4] It is unclear why such a complicated procedure is introduced to determine lead processing activity. The TRENDS method includes four steps to determine lead processing, however, many of the steps do not seem logical. After following the four steps, the result was a lead processing value of 975,378 short tons, which did not match the value of 759,300 tons in the TRENDS activity spreadsheet. After analyzing the four steps that currently comprise the TRENDS emission estimation procedure for primary lead, it appears that the final number is a simple sum of the emissions reported through NEDS (now AFS) and the sulfur recovered as sulfuric acid. The recovered sulfur is then subtracted from the emission estimate. Therefore, there should be complete agreement between NAPAP and TRENDS for this category. If the TRENDS method is intended to be different from the simple sum, there are errors in the TRENDS procedure manual that need to be addressed.

The NAPAP activity for this category is fairly close to the activity published in the *Minerals Yearbook*.[4] The *Minerals Yearbook* cites a 1985 production of 543,403 short tons. TRENDS includes the assumption that there is a 2:1 ratio of concentrated ore processed to lead produced. NAPAP reports 1,006,182 tons of concentrated ore processed in the blast furnace which would correspond to a lead production rate of 503,000 tons of lead.

2.2.5 Primary Aluminum

The 1985 TRENDS emission value is 70,000 tons of SO_2 for primary aluminum. The 1985 NAPAP value is 58,400 tons of SO_2 for primary aluminum. The discrepancy between the two inventories is 11,600 tons (20 percent).

2.2.5.1 *TRENDS Activity*

In TRENDS, the primary aluminum production is obtained from Table 20 "Salient Aluminum Statistics" of *Minerals Yearbook 1989 "Bauxite, Alumina, and Aluminum."*[4] In 1985 the U.S primary production was reported as 3,500,000 metric tons (3,850,000 short tons). The TRENDS activity spreadsheet reports 3,855,600 tons of aluminum produced.

2.2.5.2 TRENDS Emission Factor

SO_2 emissions are calculated using an emission factor of 33.5 lbs/metric ton (reported in the TRENDS spreadsheet). This factor converts to 36.85 lbs/ton. The emission factor is documented as an average emission factor based on NEDS data from Washington State (February 1980).

2.2.5.3 *TRENDS Emission Estimate*

Emissions using TRENDS method and activity data confirm the reported TRENDS estimate:

36.85 * 3,855,600 / 2,000 = 71,039 tons SO_2.

2.2.5.4 *NAPAP Activity*

NAPAP activity data were not a high priority for collection or quality assurance for all sources. The activity data reported through the NAPAP inventory are as follows for comparison.

SCC	Description	Tons of Molten Aluminum Produced
3-03-001-01	Primary metal - Aluminum Ore: Electro-Reduction: Prebaked reduction cell	2,996,007
3-03-001-02	Primary metal - Aluminum Ore: Electro-Reduction: Horizontal stud soderberg cell (MSS)	307,880
3-03-001-03	Primary metal Aluminum Ore: Electro-Reduction: Vertical stud soderberg cell (VSS)	575,497
3-03-001-04	Primary metal Aluminum Ore: Electro-Reduction: Materials handling	5,371,185

SCC	Description	Tons of Molten Aluminum Produced
3-03-001-05	Primary metal - Aluminum Ore: Electro-Reduction: Anode baking furnace	1,950,248
3-03-001-06	Primary metal - Aluminum Ore: Electro-Reduction: Degassing	290,785
3-03-001-07	Primary metal - Aluminum Ore: Electro-Reduction: Roof vents	677,601
3-03-001-99	Primary metal Aluminum Ore: Electro-Reduction: Other not classified	7,861,822
3-03-002-01	Primary metal - Aluminum Hydroxide Calcining: Overall process	4,893,410[a]

[a]Tons of Alumina Produced

2.2.5.5 *NAPAP Emissions*

The emissions from primary aluminum production reported through the NAPAP inventory are as follows.

SCC	Description	Tons SO_2 Emitted
3-03-001-01	Primary metal - Aluminum Ore: Electro-Reduction: Prebaked reduction cell	31,178
3-03-001-02	Primary metal - Aluminum Ore: Electro-Reduction: Horizontal stud soderberg cell	1,976
3-03-001-03	Primary metal - Aluminum Ore: Electro-Reduction: Vertical stud soderberg cell	4,909
3-03-001-04	Primary metal - Aluminum Ore: Electro-Reduction: Materials handling	3,448
3-03-001-05	Primary metal - Aluminum Ore: Electro-Reduction: Anode baking furnace	3,230
3-03-001-07	Primary metal - Aluminum Ore: Electro-Reduction: Roof vents	741
3-03-001-99	Primary metal - Aluminum Ore: Electro-Reduction: Other not classified	750
3-03-002-01	Primary metal - Aluminum Hydroxide Calcing: Overall process	12,154
Total		58,386

2.2.5.6 *Conclusion*

The validity of the TRENDS emission factor for primary aluminum could not be confirmed and appears suspect for two reasons. First, it relies on one set of old emissions (not test) data. Second, there is no documentation of an adjustment due to controls. There are three emission factors in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document. Prebake (3-03-001-01) has an emission factor of 57.3 lbs/ton, HSS (3-03-001-02) has an emission factor of 10.0 lbs/ton, and VSS (3-03-001-03) has an emission factor of 17.0 lbs/ton. (None of these emission factors was derived from AP-42. In fact, AP-42 does suggest a method for calculating SO_2 emissions based on other process parameters, but reports no emission factor.) Many of the particulate controls on primary aluminum would be effective controls for SO_2. An investigation into the distribution of the three types of electro-reduction processes and their controls and how they dominate the primary aluminum industry should be undertaken to develop an appropriately weighted emission factor.

Further, the emission factor used by TRENDS is not consistent with the TRENDS indicators for industrial processes for the primary metals industry production process breakdown (as listed in the TRENDS procedure document as provided in Appendix A).

Prebake:	71.0 percent of production
HSS:	18.5 percent of production
VSS:	10.5 percent of production

AP-42 confirms that Prebake is the most common.[19] However, this is not the weighing used in the SO_2 emission factor for primary aluminum. Using this weighing would provide an emission factor of:

$$57.3(0.71) + 10.0(0.105) + 17.0(0.105) = 43.5 \text{ lbs/ton}.$$

Using the 43.5 lbs/ton of aluminum produced emission factor results in a total emission estimate of 84,000 tons of SO_2, exceeding the current TRENDS estimate by 14,000 tons. (Other weightings used in TRENDS for the emission categories other than primary aluminum may also be suspect.)

The NAPAP reported production for materials handling 3-03-001-04 (which should in theory represent the sum of the three process types) is 5,371,185 tons of molten aluminum produced. However, this SCC represents particulate emissions and no priority was placed on collecting or quality assuring particulate data under the 1985 NAPAP effort. This materials handling value does exceed the sum of the three aluminum processes listed above (3,879,384 short tons of aluminum processed). Note that the sum of the three NAPAP aluminum process SCCs approximates the production reported in *Minerals Yearbook*[4] (3,850,000 short tons of aluminum).

Using the 1985 NAPAP production estimates would result in a breakdown between the three process types as follows:

Prebake:	77.2 percent of production
HSS:	7.9 percent of production
VSS:	14.8 percent of production

Using this weighing instead of the TRENDS weighing would result in an even larger emission factor:

$$57.3(.772) + 10.0(.079) + 17.0(.148) = 47.5 \text{ lbs/ton.}$$

If the 1985 NAPAP primary aluminum emission estimate is used to develop a revised emission factor, an overall factor of 38,063 tons SO_2 / 3,850,000 short tons Al = 19.8 lbs/ton Al produced. The absolute factor is lower because reported NAPAP emissions from these processes is only 38,063 tons, but presumably accounts for the effect of SO_2 controls.

In the NAPAP inventory, only 38,063 tons of SO_2 are attributable to the three processes covered by the TRENDS method. Of the processes that are not included in TRENDS, aluminum hydroxide calcining is the most important. TRENDS includes the aluminum hydroxide calcining process in the estimation of TSP and PM-10 emissions but not in the SO_2 estimate.

2.2.6 Secondary Lead

The published 1985 TRENDS value is 30,000 tons SO_2 from secondary lead processing. The 1985 NAPAP value is 20,720 for secondary lead. The discrepancy between the two inventories is 9,300 tons (45 percent).

2.2.6.1 *TRENDS Activity*

In TRENDS, the secondary lead production is obtained from Table 1 "Salient Lead Statistics" of *Minerals Yearbook, 1989 "Lead."*[4] The 1985 production of secondary lead (based on lead content) was 615,695 metric tons (677,264 short tons). The consumption of lead scrap is obtained from Table 8 "Stocks and Consumption of New and Old Lead Scrap in the United States, by Type of Scrap" of *Minerals Yearbook, 1986 "Lead."*[4] The total 1985 consumption of scrap is 804,832 metric tons (885,315 short tons). SO_2 emissions are only calculated for reverberatory and blast furnaces. There are no emission estimates or emission factors for SO_2 from pot furnaces.

For reverberatory furnaces the TRENDS activity is the fraction of lead recovered as soft lead to total lead recovered multiplied by the consumption of scrap. The amount recovered as soft lead is obtained from Table 11 "Lead Recovered from Scrap Processed in The United States, by Kind of Scrap and Form of Recovery" of *Minerals Yearbook, 1986 "Lead"*[4] and the value was 273,698 metric tons (301,068 short tons). The 1985 production from reverberatory furnaces is calculated as follows:

301,068 / 677,264 * 885,315 = 393,554 tons.

This value matches the TRENDS activity spreadsheet.

For blast furnaces the activity is the fraction of lead recovered as antimonial lead to total lead recovered multiplied by the total consumption of lead scrap. The amount recovered as antimonial lead is also obtained from Table 11 and was 299,307 metric tons (329,238 short tons). The 1985 production from blast furnaces is calculated as follows:

329,238 / 677,264 * 885,315 = 430,377 tons.

The TRENDS activity spreadsheet has a value of 391,300 tons for the secondary lead blast furnaces. It appears as though the value in the TRENDS activity spreadsheet was not converted from metric tons to short tons.

2.2.6.2 *TRENDS Emission Factors*

The emission factors cited in the TRENDS method are as follows.

SCC	Description	Emission Factor	Units
3-04-004-02	Secondary metal - Secondary lead production: Reverberatory furnace	80	lbs/ton lead produced
3-04-004-03	Secondary metal - Secondary lead production: Blast furnace (Cupola)	53	lbs/ton lead produced

These emission factors match the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants* document.[7]

2.2.6.3 *TRENDS Emissions*

Using the activity data published in the TRENDS activity spreadsheet and the TRENDS emission factor results in the following 1985 emissions:

(394,000 * 80 + 391,300 * 53)/ 2000 = 26,129 tons of SO_2.

Using the activity data derived following the TRENDS procedure manual (to correct the failure to convert units to short tons) results in increased emissions.

(393,554 * 80 + 430,377 * 53)/ 2000 = 27,147 tons of SO_2

2.2.6.4 *NAPAP Activity*

The secondary lead production reported in NAPAP is 216,554 tons of metal charged to the reverberatory furnace and 332,773 tons of metal charged to the blast furnace (cupola).

2.2.6.5 *NAPAP Emissions*

There are ten SCCs or processes listed for secondary lead production. Of these ten SCCs only five have associated SO_2 emissions. These are listed below.

SCC	Description	Tons SO_2 Emitted
3-04-004-01	Secondary metal - Secondary lead: Pot furnace	2
3-04-004-02	Secondary metal - Secondary lead: Reverberatory furnace	10,258
3-04-004-03	Secondary metal - Secondary lead: Blast furnace (Cupola)	10,185
3-04-004-07	Secondary metal - Secondary lead: Pot furnace heater natural gas	3
3-04-004-99	Secondary metal - Secondary lead: Other not classified	272
Total		20,720

2.2.6.6 *Conclusion*

There is an apparent error in the TRENDS estimate because the activity value for the blast furnace was not converted to english units. Following the TRENDS published procedure and converting the activity data results in emissions of 27,147 tons of SO_2. This is not a significant difference in the published TRENDS estimate, because the values that are published are rounded to the nearest 10,000 tons.

The TRENDS and NAPAP emission values are somewhat similar, however, the TRENDS value is 30 percent higher than the NAPAP emissions. TRENDS does not account for SO_2 controls such as baghouses and wet scrubbers.

There is a new SCC, with an SO_2 emission factor of 144.0S lbs $SO_2/10^3$ gallons burned. for this category. The SCC is 3-04-004-07 for pot furnace heater burning distillate oil. This SCC is not in the TRENDS method and it is not in the NAPAP inventory.

2.2.7 Other NAPAP Non-ferrous Emission Categories

In addition to the categories discussed above, NAPAP reports additional non-ferrous emissions of 41,511 tons of SO_2. The categories and the NAPAP emission estimates are summarized in Table 2-10.

2.3 OTHER INDUSTRIAL PROCESSES

TRENDS estimates SO_2 emissions from other industrial processes including pulp and paper, chemical manufacturing, petroleum refining, iron and steel, and mineral products. Within the chemical manufacturing group, TRENDS provides SO_2 estimates for sulfuric acid and carbon black manufacture. Within the mineral products group, TRENDS estimates SO_2 emissions for cement, glass, and lime manufacturing. Table 2-11 summarizes the 1985 TRENDS and NAPAP emission estimates for these industrial processes.

The 1985 NAPAP emission inventory is a detailed database with emission estimates reported in a record format. The total emissions reported for a source category is dependent upon the way in which the emissions are summed. For industrial sources, the inclusion or exclusion of SO_2 emissions from fuel combustion as opposed to process emissions can dramatically effect the emissions associated with a particular source category. The NAPAP emission estimates reported in Table 2-11 were summed to allow comparison with the TRENDS source category estimates. For some source categories fuel combustion emissions are included and for some source categories they are not included.

TABLE 2-10. OTHER NON-FERROUS EMISSIONS REPORTED IN NAPAP

Primary and Secondary Metals Source Category (SIC)	SCC	1985 NAPAP (tons)[a]
Ferroalloy (3313)	3-03-006 3-03-007	10,016
Molybdenum Ore Mining (1061)	3-03-011	986
Barium Ore Processing (3295)	3-03-014	2,514
Taconite Iron Ore Processing (1011)	3-03-023	1,547
Secondary Aluminum Production (3341, 3353, 3354, 3355, 3363, 3365)	3-04-001	3,768
Secondary Copper Production (3341, 3364, 3366)	3-04-002	8
Lead Battery Manufacture (3691)	3-04-005	1,347
Magnesium (3341)	3-04-006	27
Secondary Zinc Production (3341)	3-04-008	3,094
Furnace Electrode Manufacture (3624)	3-04-020	3,979
Fugitive Emissions (1000, 3300)	3-03-888	12,060
Process Heaters, Incinerators, and Miscellaneous Not Classified	3-03-900 3-03-999 3-04-999	2,165
Total		41,511

[a]*The 1985 NAPAP Emissions Inventory (version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a, November 1989.

2.3.1 Kraft Pulp Production

The 1985 TRENDS emission value is 250,000 tons SO_2. The 1985 NAPAP value is 130,400 tons for both Kraft and sulfite pulp products.[a] The discrepancy between the two inventories is

[a]The NAPAP estimate of 130,400 tons if for emissions from the kraft and sulfite process. The NAPAP estimate for all pulp and paper plants, including combustion emissions, is 608,000 tons of SO^2

TABLE 2-11. COMPARISON OF OTHER INDUSTRIAL PROCESSES VALUES FOR 1985 TRENDS AND NAPAP

Category	TRENDS Published	TRENDS Calculated	NAPAP Published
Kraft Pulp Production (2611, 2621, 2631)			
Emissions (tons)	250,000	167,766	130,400
Air-dry unbleached pulp (10^3 tons)	44,184	44,184	29,399
Carbon Black Production (2895)			
Emissions (tons)	10,000	14,585	28,000
Tons Produced (10^3 tons)	1,285.5	1,285	1,111
Sulfuric Acid Production (2819)			
Emissions (tons)	210,000	215,405	217,000
Gross, new and fortified (10^3 tons)	39,890	39,890	
Sulfur Recovery Production			
At Petroleum Refineries (10^3 tons)	2,940	3,234	
At Natural Gas Facilities (10^3 tons)	2,373	2,610	
Petroleum Refineries (2911)			
F.C.C. Emissions (tons)	326,317	326,317	204,647
T.C.C. Emissions (tons)	522	522	7,273
Flares Emissions (tons)	35,078		15,671
Process Heaters - Oil Emissions (tons)	44,360	76,911	117,512
Process Heaters - Gas Emissions (tons)	231,106	238,547	117,237
Sulfur Recovery Emissions (tons)	202,125	172,696	29,117
Other NAPAP Refinery Emissions (tons)			149,925
Total Emissions (tons)	830,000[a]	814,993	640,000

(continued)

TABLE 2-11. COMPARISON OF OTHER INDUSTRIAL PROCESSES VALUES FOR 1985 TRENDS AND NAPAP (Continued)

Category	TRENDS Published	TRENDS Calculated	NAPAP Published
Oil and Gas Production (1311)			
Combustion Emissions (tons)	441	441	7,660
Sulfur Recovery Emissions (tons)	163,143	139,374	59,498
Other NAPAP Natural Gas Production Emissions (tons)			265,000
Total Emissions (tons)	160,000	139,815	332,158
Iron and Steel Industry			
Coke Emissions (tons)	162,000	162,000	74,629
Sintering Emissions (tons)	21,000	35,058	33,058
Open Hearth Furnace Emissions (tons)	4,650	1,169	1,169
Roll and Finish (tons)	168,000	86,948	25,304
Other NAPAP Iron and Steel Emissions (tons)			67,985
Total Emissions (tons)	360,000	285,000	212,000
Raw steel production (10^3 tons)	88,300	88,300	
Cement Manufacturing (3241)			
Emissions (tons)	620,000	210,500[b]	290,653
Clinker produced (10^3 tons)	77,895	77,895	60,166
Glass Manufacturing (3211, 3221, 3229)			
Emissions (tons)	30,000	28,508	23,000
10^3 Tons produced	16,245.8	16,245.8	10,404
Lime Manufacturing (3274)			
Emissions (tons)	30,000	42,000	32,000
10^3 Tons Produced	15,800	15,800	16,634
Total Emissions (10_6 tons)	2.5	1.9	1.9

[a]Does not add to total due to independent rounding.
[b]Assuming no SO_2 controls.

119,600 tons of SO_2 (92 percent).

2.3.1.1 *TRENDS Activity*

In TRENDS, the production of sulfate and sulfite is obtained from Table 4 "Production and Shipments of Woodpulp, by Type of Pulp: 1986 and 1985" of *Current Industrial Reports: Pulp, Paper and Board 1986*.[22] The production of sulfate (Kraft pulping) was 42,563,831 short tons in 1985. The production for sulfite was 1,620,084 short tons in 1985. The total production of 44,183,900 tons is consistent with the activity value published in the TRENDS activity spreadsheet.

2.3.1.2 *TRENDS Emission Factor*

The TRENDS procedure document lists SO_2 emissions from two categories: Kraft pulping (sulfate) and sulfite pulping. The emission factor for sulfate (kraft) pulping is 7.0 lbs/air-dry ton of unbleached pulp (SCC 3-07-001-04). This emission factor matches the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants* document.[7]

In the case of sulfite, the emission factor is derived from the uncontrolled factor (52 lbs/ton) and the controlled factor (20 lbs/ton), both based on a now obsolete version of AP-42[19], and the assumption that 90 percent of production is at the controlled rate. The SO_2 emission factor for sulfite pulping is calculated as:

$$(52.0 * 0.10 + 20 * 0.90) = 23.2 \text{ lbs/ton.}$$

2.3.1.3 *TRENDS Emissions*

Emissions for kraft (sulfate) pulping are calculated from the Kraft production data.

$$42{,}563{,}831 * 7.0 / 2000 = 148{,}973 \text{ tons of } SO_2$$

Emissions from sulfite pulping (assuming 90 percent control) are calculated from the weighted emission factor and sulfite production.

1,620,084 * 23.2 / 2000 = 18,793 tons of SO_2

Total emissions are simply the sum of Kraft and sulfite processes.

Total emissions = 148,973 + 18,793 = 167,766 tons of SO_2

The sum of these estimates does not match the published TRENDS estimate. Because the activity value did match the TRENDS spreadsheet, the emission factor was researched further. Backcalculating the TRENDS emission factor from the published emission estimate (250,000 tons of SO_2) and the production data results in an overall emission factor of:

250,000 / 44,183,915 * 2000 = 11.3 lbs/ton.

An emission factor of 11.3 was apparently used in both the 1990 and 1991 TRENDS estimate.

2.3.1.4 *NAPAP Activity*

The NAPAP production cannot be determined without a better understanding of the woodpulping process. The production number for the recovery furnace direct contact evaporator in the kraft pulping category is 29,398,475 air-dry tons of unbleached pulp. It is unclear if this production should be added to other production numbers or if this value would represent all of the reported pulp produced through the kraft process.

2.3.1.5 *NAPAP Emissions*

The NAPAP emissions for the Kraft and sulfite SCC codes are as follows.

Kraft:

SCC	Description	Tons SO_2 Emitted
3-07-001-01	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Digestor Relief and Blow tank, general	159
3-07-001-02	Pulp & Paper and Wood Products Sulfate (Kraft) Pulping: Washer/screens general	17
3-07-001-03	Pulp & Paper and Wood Products Sulfate (Kraft) Pulping: Multi-effect evaporator general	23
3-07-001-04	Pulp & Paper and Wood Products Sulfate (Kraft) Pulping: Recovery Furnace Direct contact evaporator	85,407
3-07-001-05	Pulp & Paper and Wood Products Sulfate (Kraft) Pulping: Smelt dissolving tank general	2,357
3-07-001-06	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Lime kiln general	11,220
3-07-001-08	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Fluid bed calciner: general	171
3-07-001-09	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Liquor oxidation tower, general	455
3-07-001-10	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Recovery furnace indirect contact evaporator	22,870
3-07-001-99	Pulp & Paper and Wood Products - Sulfate (Kraft) Pulping: Other not classified	43
Total		122,722

Sulfite:

SCC	Description	Tons SO_2 Emitted
3-07-002-03	Pulp & Paper and Wood Products - Sulfite Pulping: Digester blow pit dump tank: all bases except Calcium	44
3-07-002-11	Pulp & Paper and Wood Products - Sulfite Pulping: Digester blow pit dump tank: Calcium	1,445
3-07-002-14	Pulp & Paper and Wood Products - Sulfite Pulping: Digester blow pit dump tank: NH_3 with process change	1,362
3-07-002-21	Pulp & Paper and Wood Products - Sulfite Pulping: Recovery system MgO	417
3-07-002-22	Pulp & Paper and Wood Products - Sulfite Pulping: Recovery system NH_3	543
3-07-002-23	Pulp & Paper and Wood Products - Sulfite Pulping: Recovery system Na	1,814

SCC	Description	Tons SO_2 Emitted
3-07-002-31	Pulp & Paper and Wood Products - Sulfite Pulping: Acid plant NH_3	193
3-07-002-32	Pulp & Paper and Wood Products Sulfite Pulping: Acid Plant Na	5
3-07-002-33	Pulp & Paper and Wood Products - Sulfite Pulping: Acid plant Ca	249
3-07-002-34	Pulp & Paper and Wood Products Sulfite Pulping: Knotters washers screens etc.	8
3-07-002-99	Pulp & Paper and Wood Products Sulfite Pulping: Other not classified	608
Total		6,688

Additional emissions of 975 tons are listed in NAPAP for semi-chemical (neutral sulfite) woodpulp pulping. Therefore, total pulp production emissions equal 130,385 tons of SO_2.

2.3.1.6 *Conclusion*

For kraft pulping, the NAPAP and TRENDS activity values are 29,398,475 and 42,563,831 tons, respectively. The NAPAP production value does not report production for all of the records where emissions are reported and therefore the production value is low relative to the emission estimate.

The TRENDS method apparently used an emission factor of 11.3 to calculate kraft emissions, when a more appropriate value would have been 7 lbs/ton of air-dry unbleached pulp. It is unclear how the overall emission factor of 11.3 lbs/ton of air-dry unbleached pulp was derived; it was not derived from the methodology listed in the TRENDS procedures manual, at least not for the 1985 study year. The 11.3 emission factor is significantly higher (nearly 50 percent) than one calculated following the TRENDS procedure. The TRENDS emission estimation procedures from the pulp industry should be revisited based on seeming discrepancies in the TRENDS emission factor(s) and the development of new emission factors. Based solely on the discrepancy, TRENDS emissions may be overstated by nearly 70,000 tons. Also, TRENDS does not account for the effect of any controls. These two issues could result in an overestimation of SO_2 emissions from wood pulping processes.

The TRENDS procedure does not include a third type of paper pulping process, semi-chemical. Activity data for semi-chemical pulping are available and emission factors exist in the AP-42.[19] Published statistics indicate that semi-chemical has recently overtaken sulfite (3.9×10^6 versus 1.6×10^6 tons of production). If the semichemical production is increasing with fewer associated SO_2 emissions, this is an industry trend that should be reflected in the emission estimates.

The TRENDS procedure needs to be revised to account for the new emission factors that have been developed in 1990. The vast majority of pulp is produced through the Kraft process, therefore expenditure of significant effort to improve the sulfite factor may not be warranted. The TRENDS number should be produced as at least two separate numbers, Kraft and sulfite, but possibly as three numbers to include semi-chemical. The TRENDS procedure should also be rewritten to document the development of the emission factor and control assumptions.

2.3.2 Chemical Manufacturing

Within the chemical manufacturing group, TRENDS estimates SO_2 emissions for carbon black and sulfuric acid manufacture. TRENDS also estimates elemental sulfur production, however, the emissions are categorized as recovered sulfur within the petroleum refining and natural gas production categories.

2.3.3 Carbon Black Production

The 1985 TRENDS emission value is 10,000 tons SO_2. The 1985 NAPAP value is 28,000 for carbon black production. The discrepancy between the two inventories is 18,000 tons of SO_2 (64 percent).

TRENDS carbon black activity

The total production of carbon black produced as reported in "Facts and Figures for the Chemical Industry" in the *Chemical and Engineering News* is 2.57 billion pounds in 1985.[12] This is equivalent to a 1985 production value of 1,285,000 tons. This value matches the TRENDS activity spreadsheet. Carbon black production is divided into oil and gas processes; TRENDS creates this split using a fixed assumption (*i.e.*, this split is not updated annually).

- Oil Process: 90 percent of total production
- Gas Process: 10 percent of total production

TRENDS carbon black emission factors

The TRENDS methodology relies on the emission factor for the flared furnace published in Table 5.3-3, AP-42 (Fourth Edition)[19] (there are no SO_x emission factors in the AIRS SCC document). The TRENDS procedure starts with uncontrolled emissions.

Description	lbs SO_x/ton
Flared Furnace Exhaust (Oil Process)	50

The TRENDS methodology for the remaining steps is not clear. The procedures manual states that a controlled emission factor (based on CO control efficiency) is calculated as follows:

EF = CO Control Efficiency * 50 lbs/ton.

The emission factor reported in the TRENDS printout is 22.7 lbs/ton, indicating a CO control efficiency of:

CO control efficiency = 22.7 / 50 = 0.454 or 45 percent.

It is not clear if this control efficiency is to be applied to CO emissions or if the control efficiency is the result of a CO boiler and incinerator. The CO boiler and incinerator has a lower SO_x emission factor than the flare (35.2 lb/ton versus 50 lb/ton).

There is no emission factor reported for the gas process. In addition, it does not appear that the activity value is weighted toward oil versus gas.

TRENDS carbon black emissions

Using the TRENDS emission factor results in emissions of:

1,285,000 * 22.7 / 2000 = 14,585 tons of SO_2.

The published TRENDS value is rounded to the nearest 10,000 tons and is therefore reported as 10,000 tons of SO_2.

NAPAP carbon black activity

The 1985 NAPAP inventory reports the following nine separate SCCs.

SCC	Description	Tons produced
3-01-005-01	Chemical manufacturing - Carbon Black Production: Channel Process	29,000
3-01-005-02	Chemical manufacturing - Carbon Black Production: Thermal Process	0
3-01-005-03	Chemical manufacturing - Carbon Black Production: Gas Furnace Process, Main Vent	98,179
3-01-005-04	Chemical manufacturing - Carbon Black Production: Oil Furnace Process, Main Vent	1,013,232
3-01-005-06	Chemical manufacturing - Carbon Black Production: Transport Air Vent	821,308
3-01-005-07	Chemical manufacturing - Carbon Black Production: Pellet Dryer	981,213
3-01-005-08	Chemical manufacturing - Carbon Black Production: Bagging/Loading	38,600
3-01-005-09	Chemical manufacturing - Carbon Black Production: Furnace Process, Fugitives	15,824
3-01-005-99	Chemical manufacturing - Carbon Black Production: Other Not Classified	134,879

NAPAP carbon black emissions

The following emissions are reported for Carbon Black Production in the NAPAP inventory:

SCC	Description	Tons SO_2 Emitted
3-01-005-01	Chemical manufacturing Carbon Black Production: Channel Process	10
3-01-005-02	Chemical manufacturing - Carbon Black Production: Thermal Process	197
3-01-005-03	Chemical manufacturing - Carbon Black Production: Gas Furnace Process, Main Vent	1,075
3-01-005-04	Chemical manufacturing Carbon Black Production: Oil Furnace Process, Main Vent	3.958
3-01-005-06	Chemical manufacturing - Carbon Black Production: Transport Air Vent	2.410
3-01-005-07	Chemical manufacturing Carbon Black Production: Pellet Dryer	15.183
3-01-005-08	Chemical manufacturing - Carbon Black Production: Bagging/Loading	642
3-01-005-09	Chemical manufacturing - Carbon Black Production: Furnace Process, Fugitives	4,013
3-01-005-99	Chemical manufacturing - Carbon Black Production: Other Not Classified	543
TOTAL		28,031

Conclusion

The carbon black production emission estimates are 28,031 tons of SO_2 in NAPAP versus 14,585 tons of SO_2 in TRENDS. The TRENDS method appears to underestimate the emissions from carbon black manufacture.

The total NAPAP production for the oil furnace of 1,013,232 is very similar to the value TRENDS references (90 percent of total production) 1,156,500. The NAPAP value for the gas furnace 98,179 is less similar to the value TRENDS references (10 percent of total production of 128,500 tons).

Two questionable items need to be addressed regarding the NAPAP emission estimates and the TRENDS emission factor. The NAPAP emission estimates by SCC show only a minority of emissions from the oil furnace (3,958 out of 28,031 tons), although logically this would be the source of most emissions. However, the pellet dryer combustion furnace (with emissions of 15.183

tons) is, in essence, a thermal incinerator and emissions associated with the furnace itself are emitted here. It is likely that engineers coding the NAPAP inventory indicated the vents as discrete emission points in addition to the oil furnace emission source.

Second, the TRENDS emission factor appears to be too small. The TRENDS procedure initially has a fairly high emission factor of 50 lbs/ton for the flare from an oil furnace process (this emission factor is supported by AP-42). If a CO boiler and incinerator exist, primarily to control CO emissions, the AP-42 SO_2 emission factor drops to 35.2 lbs/ton. It is unlikely that the emission factor would drop as low as 22.7 lbs/ton (the TRENDS number), even if all sources had a CO boiler and incinerator.

If the TRENDS estimate were computed with the original emission factor of 50 lbs/ton, the TRENDS emissions would be:

1,285,000 * 50 / 2000 = 32,125 tons of SO_2.

This value is very close to the NAPAP estimate of 28,031 tons of SO_2.

If all the sources are assumed to be controlled with a CO boiler and incinerator, the emission factor would be 35.2 lbs/ton and the emissions would be:

1,285,000 * 35.2 / 2000 = 22,616 tons of SO_2.

As noted, the largest source of emissions in NAPAP is for the pellet dryer. There is no corresponding category in TRENDS for the pellet dryer, although it is likely that emissions have been accounted for. As stated earlier, there is no NAPAP category specifically for the flare, however, the flare actually represents otherwise uncontrolled oil furnace emissions.

The TRENDS documentation probably needs to be modified to ensure that all emission points and sources are included. Further investigation of the NAPAP value is warranted to determine why emissions associated with the oil furnace were distributed to other emission points (vents) if possible.

Finally, the assumption that flares represent otherwise uncontrolled emissions could be confirmed by looking at the control equipment for these sources coded in NAPAP.

2.3.4 Sulfuric Acid

The 1985 TRENDS value is 210,000 tons SO_2. The 1985 NAPAP value is 217,000 for sulfuric acid production. The discrepancy between the two inventories is 7,000 tons of SO_2 (3 percent).

TRENDS sulfuric acid activity

The 1985 production of sulfuric acid was obtained from Table 1 "Production and Shipments of Selected Inorganic Chemicals: 1982 to 1986" of *Current Industrial Reports, Inorganic Chemicals*[24] and was 39,889,900 short tons, gross (new and fortified).

The 1984 production is used in the calculation of the emission factor. The 1984 production was obtained from the same source and was 41,801,900 short tons. The TRENDS activity spreadsheet lists the 1984 production as 39,683,000 tons of sulfuric acid.

TRENDS sulfuric acid emission factor

The TRENDS procedure manual provides the following equation for the development of an SO_2 emission factor. The equation assumes that each year 5 percent of the existing production comes into compliance with the New Source Performance Standard (NSPS)[b] and any new production will also be in compliance with the NSPS.

$$EF_i = \frac{(0.95 * EF_{i-1} * P_{i-1}) + (0.05 * EF_{NSPS} * P_{i-1}) + ((P_i - P_{i-1}) * EF_{NSPS})}{P_i}$$

[b] 40 CFR Section 60 Subpart H.

where,

i	= 1985
EF_{NSPS}	= NSPS emission factor (4 lbs SO_2/ton of 100 percent H_2SO_4 production)
P	= Total Production

Because the production for 1985 (P_i) is less than the production for 1984 (P_{i-1}) (based on the information in *Current Industrial Reports*), the last term in the equation should be set to zero. Emissions from new capacity at the NSPS emission level should only apply to production above the previous record-high production level.

In order to apply this equation, one must know the 1984 emission factor. The 1984 emission factor is backed out based on the 1984 production (as reported in the TRENDS activity spreadsheet) and the 1984 published TRENDS emission estimate. Note that the **published** TRENDS 1984 activity is lower than the 1985 production which reintroduces the last term of the equation. The 1984 emission factor is:

210,000 / 39,683,000 * 2000 = 10.6 lb/ton of H_2SO_4 production.

The 1985 emission factor is then calculated using the above equation:

$$EF_{1985} = [(0.95 * EF_{1984} * P_{1984}) + (0.05 * 4 * P_{1984}) + (P_{1985} - P_{1984} * 4] / P_{1985}$$
$$= [(0.95*10.6*39{,}683{,}000)+(0.05*4*39{,}683{,}000)+(206{,}900*4)]/39{,}889{,}900$$
$$= 10.2 \text{ lb/ton of sulfuric acid produced}$$

(The emission factor for 1985 that is backcalculated based on the published TRENDS emission estimate and the 1985 production is 10.5 lb/ton of sulfuric acid produced.)

TRENDS sulfuric acid emissions

The TRENDS emissions were not calculated using the emission factor derived from the equation, rather the emissions were calculated using an emission factor of 10.5 lb/ton of sulfuric acid produced. The emissions were calculated as follows:

39,889,900 * 10.5 / 2000 = 209,421 tons of SO_2.

If the TRENDS procedure is followed and the correct 1984 activity data are used, the emission factor for 1985 would be 10.8 lb/ton of sulfuric acid produced and the 1985 emissions would be slightly higher.

39,889,900 * 10.8 / 2000 = 215,405 tons of SO_2.

NAPAP sulfuric acid activity

The 1985 NAPAP inventory reports production for sulfuric acid production as follows.

SCC	Description	Tons 100% H_2SO_4
3-01-022-01	Chemical Manufacturing - Sulfuric Acid - Chamber process: general	211,236
3-01-023-01	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.9% conversion	14,886,621
3-01-023-04	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.5% conversion	1,592,842
3-01-023-06	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.0% conversion	3,462,965
3-01-023-08	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 98.0% conversion	7,113,929
3-01-023-10	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 97.0% conversion	2,842,025
3-01-023-12	Chemical Manufacturing - Sulfuric Acid Contact process: absorber @ 96.0% conversion	40,588
3-01-023-18	Chemical Manufacturing Sulfuric Acid - Contact process: absorber @ 93.0% conversion	3,552,216

SCC	Description	Tons 100% H_2SO_4
3-01-023-19	Chemical Manufacturing - Sulfuric Acid - Contact process: Concentrator	40,050
3-01-023-20	Chemical Manufacturing Sulfuric Acid - Contact process: Tank car and truck unloading	247,520
3-01-023-21	Chemical Manufacturing - Sulfuric Acid Contact process: Storage tank vent	2,335,790
3-01-023-22	Chemical Manufacturing - Sulfuric Acid - Contact process: Process equipment leaks	278,551
3-01-023-99	Chemical Manufacturing Sulfuric Acid Contact process: Other Not Classified	437,373

NAPAP sulfuric acid emissions

The 1985 reported emissions for sulfuric acid production are as follows.

SCC	Description	Tons SO_2 Emitted
3-01-022-01	Chemical Manufacturing - Sulfuric Acid - Chamber process: general	2,091
3-01-023-01	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.9% conversion	32,947
3-01-023-04	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.5% conversion	4,300
3-01-023-06	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 99.0% conversion	13,551
3-01-023-08	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 98.0% conversion	76,707
3-01-023-10	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 97.0% conversion	25,893
3-01-023-12	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 96.0% conversion	1,445
3-01-023-18	Chemical Manufacturing - Sulfuric Acid - Contact process: absorber @ 93.0% conversion	10,905
3-01-023-19	Chemical Manufacturing Sulfuric Acid - Contact process: Concentrator	0
3-01-023-20	Chemical Manufacturing - Sulfuric Acid Contact process: Tank car and truck unloading	1
3-01-023-21	Chemical Manufacturing - Sulfuric Acid - Contact process: Storage tank vent	94
3-01-023-22	Chemical Manufacturing - Sulfuric Acid - Contact process: Process equipment leaks	46,930

SCC	Description	Tons SO_2 Emitted
3-01-023-99	Chemical Manufacturing - Sulfuric Acid - Contact process: Other Not Classified	2,302
Total		217,166

Conclusions

The NAPAP estimate of 217,166 tons of SO_2 is extremely close to the TRENDS estimate of 215,405 tons of SO_2. Nevertheless, the origin of the initial emission factor in the TRENDS procedure is not documented and therefore the emission factor for the category is somewhat suspect. One concern about this category is the production of H_2SO_4 from recovered sulfur. The NSPS does not apply to sulfuric acid production in conjunction with SO_2 controls. It is unclear if the NAPAP data reflect only the chemical companies producing sulfuric acid or also include byproduct H_2SO_4 production.

There appears to be an error in the emission factor used to develop the published TRENDS estimate. If the TRENDS procedure is followed in the development of the 1985 emission factor (using the 1984 emission factor and the correct 1984 production), the 1985 emission factor is 10.8 lb/ton of sulfuric acid produced as opposed to the value of 10.5 lb/ton of sulfuric acid produced, which was apparently used in the published TRENDS report.

The NSPS emission factor of 4 lb SO_2/ton of 100 percent sulfuric acid produced is consistent with the emission factor for sulfuric acid contact process, 99.9 percent conversion (SCC 3-01-023-01). As shown in the NAPAP data, the activity for that SCC dominates the category. An analysis of the penetration of the NSPS emission limit into this source category could be conducted by contacting the Stationary Source Compliance Division of OAQPS and by analyzing the BACT/LAER Clearinghouse. As stated above, the estimates are extremely close and may not warrant any further investigation.

An analysis of the production data provided in *Current Industrial Reports, Inorganic Chemicals*[24] reveals that production had a low value of 33,233,000 tons of sulfuric acid in 1982 and a high of 44,336,818 in 1990. Because the NSPS was promulgated in the 1970's, production over

33,233,000 (and at least 25 percent of production) should be at the NSPS level. The NAPAP data indicate that approximately 50 percent of 1985 production was at the NSPS level.

2.3.5 Sulfur Recovery Plants

TRENDS reports SO_2 emissions from sulfur recovery plants in two categories, natural gas production and petroleum refining. As a result, it is not possible to directly assess whether the published TRENDS emission estimates were successfully recreated due to errors in both the published TRENDS activity data and emission factors. The TRENDS emission estimates using the erroneous TRENDS spreadsheet information are 202,000 tons for petroleum refineries and 163,000 tons for natural gas production. The corresponding NAPAP emission estimates are 29,000 tons for petroleum refineries and 59,000 tons for natural gas production.

2.3.5.1 *TRENDS Activity*

The quantity of sulfur recovered by natural gas plants and petroleum refineries in 1985 is reported in Table 4 "Recovered Sulfur Produced and Shipped in the United States" of *Minerals Yearbook 1989 "Sulfur."*[4] The production at petroleum refineries was 2,940,000 metric tons (3,234,000 short tons) and the production at natural gas plants was 2,373,000 metric tons (2,610,000 short tons).

The TRENDS activity spreadsheet erroneously left these activity rates in metric units.

2.3.5.2 *TRENDS Emission Factors*

According to the TRENDS procedure manual, the emission factor is derived annually from the emissions and throughput reported to AIRS/FS in SCC 3-01-032-01 through 3-01-032-04. In 1985 the throughput values were reported as follows.

SCC	Description	Tons 100% Sulfur
3-01-032-01	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (92-95% removal)	154,728

SCC	Description	Tons 100% Sulfur
3-01-032-02	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 3 stage w/o control (95-96% removal)	754,087
3-01-032-03	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 4 stage w/o control (96-97% removal)	105,890
3-01-032-04	Chemical Manufacturing Elemental Sulfur Production: Sulfur removal process (99.9% removal)	1,374,263
Total		2,388,968

In 1985 the emissions were reported as follows.

SCC	Description	Tons SO_2 Emitted
3-01-032-01	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (92-95% removal)	32,566
3-01-032-02	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 3 stage w/o control (95-96% removal)	30,301
3-01-032-03	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 4 stage w/o control (96-97% removal)	5,281
3-01-032-04	Chemical Manufacturing - Elemental Sulfur Production: Sulfur removal process (99.9% removal)	59,386
Total		127,534

The emission factor is obtained by dividing the total emissions by the sum of the operating rates. The emission factor for 1985 should be:

127,534 / 2,388,968 * 2000 = 106.8 lbs/ton of sulfur.

The emission factor reported through the TRENDS spreadsheets for both 1990 and 1991 is 137.5 lb/ton of sulfur produced.

2.3.5.3 *TRENDS Emissions*

The TRENDS emission estimates are calculated for both natural gas production and petroleum refining using the emission factor of 137.5 lb/ton of sulfur produced and the production rates in the TRENDS activity spreadsheet. For petroleum refineries the emissions are 202,125 tons:

2,940,000 * 137.5 / 2000 = 202,125 tons SO_2

The emissions for natural gas fields are 163,143 tons:

2,373,000 * 137.5 / 2000 = 163,143 tons SO_2

The total emissions are 365,269 tons:

202,125 + 163,143 = 365,269 tons SO_2

Using the emission factor of 106.8 lbs/ton of sulfur produced derived by following the TRENDS procedure manual and the correct activity data would result in the following emission estimates for petroleum refineries:

3,234,000 * 106.8 / 2000 = 172,696 tons SO_2

The emissions at natural gas fields are 139,374 tons:

2,610,000 * 106.8 / 2000 = 139,374 tons SO_2

The total emissions are 312,070 tons:

172,696 + 139,374 = 312,070 tons SO_2

2.3.5.4 ***NAPAP Activity***

The 1985 reported throughput values were reported above. In addition NAPAP reports 191,676 tons product under *Other not classified.* The production sums to 2,580,644 tons of recovered sulfur versus the 5,844,000 tons reported through the *Minerals Yearbook.*[4] Only half of the records that reported sulfur emissions reported a sulfur production or throughput value.

2.3.5.5 *NAPAP Emissions*

In order to split the emissions between petroleum refineries and natural gas production, the sulfur production emissions were put in a matrix of the SCC versus the SIC. The matrix is presented below.

SO_2 EMISSIONS (tons)

SIC	Description	SCC 30103201	SCC 30103202	SCC 30103203	SCC 30103204	Total
1300	Oil and Gas Extraction		541			541
1311	Crude Petroleum and Natural gas	9,829	9,897	670	21,807	42,203
1321	Natural gas liquids	4,482		2,629	7,887	14,998
2801	Chemicals and Allied Products			908		908
2819	Industrial Inorganic Chemicals, Not elsewhere classified	5,366	4,875	982	19,942	31,165
2869	Industrial Organic Chemicals, Not elsewhere classified	5,674	1,133			6,807
2911	Petroleum Refining	7,175	12,100	92	9,750	29,117
3011	Tires and Inner Tubes	40				40
4922	Natural Gas Transmission		1,756			1,756
	Other Not Classified					1,171
Total		32,566	30,302	5,281	59,386	128,706

Natural gas production includes emissions from four SIC's: 1300, 1311, 1321, and 4922 and were 59,498 tons of SO_2. Petroleum Refining was represented by only one SIC and emissions were 29,117 tons of SO_2. In the NAPAP inventory, tire and chemical production were responsible for the remaining 38,920 tons of SO_2. In addition, NAPAP reports 1,171 tons of SO_2 emissions under *Other not classified*. The total NAPAP emissions sum to 128,706 tons of SO_2.

2.3.5.6 *Conclusion*

TRENDS reports SO_2 emissions from sulfur recovery plants in two categories, natural gas production and petroleum refining. As a result, it is not possible to directly assess whether the published emission estimates were successfully recreated, although using the emission estimates does allow the total natural gas production and total petroleum refinery estimates to match the published values. Errors were discovered in both the activity data and the emission factors that were used to calculate the published 1985 TRENDS estimates. As a result, the published TRENDS emission estimate is too high. The estimates using the erroneous information are 202,000 tons for petroleum refineries and 163,000 tons for natural gas production. The corresponding NAPAP emission estimates are 29,117 tons for petroleum refineries and 59,498 tons for natural gas production.

In the TRENDS estimate, the activity data were erroneously left in metric units rather than converted to english units. The emission factor was not calculated from AIRS data, as the procedure manual indicated, but rather was held constant. Using the revised emission factor (106.8 lbs/ton of sulfur produced versus 137.5 lbs/ton of sulfur produced) and corrected activity data resulted in TRENDS emission estimates of 172,696 tons for petroleum refineries and 139,374 tons for natural gas production (a decrease of 53,198 tons of SO_2).

The estimates in NAPAP and TRENDS are still very different; 312,070 versus 88,615 tons of SO_2. The TRENDS method, when applied correctly, probably overestimates emissions from sulfur recovery plants. NAPAP may underestimate emissions from sulfur recovery plants or the emissions may be reported in other areas of the inventory (i.e., under petroleum refining or natural gas production as opposed to sulfur production).

The emission factors reported in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] are as follows.

SCC	Description	Emission Factor	Units
3-01-032-01	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (92-95% removal)	280	lb/tons 100% sulfur
3-01-032-02	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 3 stage w/o control (95-96% removal)	189	lb/tons 100% sulfur
3-01-032-03	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 4 stage w/o control (96-97% removal)	145	lb/tons 100% sulfur

SCC	Description	Emission Factor	Units
3-01-032-04	Chemical Manufacturing - Elemental Sulfur Production: Sulfur removal process (99.9% removal)	4	lb/tons 100% sulfur

Multiplying the NAPAP sulfur recovery production values by these emission factors results in total emissions of 103,348 tons of SO_2. There is a discrepancy between the production values, emission factors, and reported emissions in the NAPAP inventory. The emissions for 95-96 percent recovery appear to be underestimated and the emissions for 99.9 percent recovery appear to be overestimated. Therefore, there are probably errors in the NAPAP values, either in the reported production or in the reported emissions.

Additional research should be expended on this category to try and determine what types of sulfur recovery plants are in use in petroleum refineries and natural gas production fields. Once there is additional information, a new appropriately weighted emission factor could be developed for the TRENDS procedure.

2.3.6 Petroleum Refineries

In TRENDS the SO_2 emissions from petroleum refineries are reported for six categories: Thermal Catalytic Cracking; Fluid Catalytic Cracking; Flares; Process Heaters   Oil; Process Heater - Gas; and Sulfur Recovery. The 1985 TRENDS value is 830,000 tons SO_2. The 1985 NAPAP value for the same six categories is 490,000 tons of SO_2, although the total petroleum refining estimate is 640,000 tons of SO_2. The difference between the two petroleum refining emission estimates is 190,000 tons of SO_2 (30 percent).

2.3.6.1 *TRENDS Activity*

The TRENDS activity data are presented below for the six categories. The full discussion of the derivation of sulfur recovery emissions was presented earlier but is summarized below. In all of the categories except sulfur recovery, the activity data derived following the TRENDS procedure manual were consistent with the published TRENDS activity spreadsheet.

Catalytic cracking

In TRENDS, the petroleum production activity data were obtained from the "Annual Refining Survey" of the *Oil & Gas Journal.*[25] Prior to 1989, the survey also provided the split between fluid catalytic cracking (FCC) and thermal catalytic cracking (TCC or thermofor). Within the survey, footnotes indicate whether the fresh feed for catalytic cracking is fluid or "other". "Other" represents thermal cracking. The TRENDS method has changed recently due to the discontinuation of the reporting of fluid versus thermal catalytic cracking. The following discussion pertains to the documented method for the development of the 1985 estimates.

The total capacity of catalytic cracking fresh feed is obtained from the Annual Refining Survey in the *Oil and Gas Journal.*[25] The total fresh feed, catalytic cracking, charge capacity as of January 1, 1986 was 5,234,100 barrels per stream day.

To convert from capacity to annual throughput, the ratio of production to capacity is obtained from the *Bureau of Economic Analysis, Refinery Operating Ratio, Crude Petroleum.*[26] For 1985 the value is 78 percent. The conversion factor for stream day to year is 328.5 (365 calendar days per year * 0.9 calendar day per stream day).

Total 1985 catalytic cracking throughput was:

5,234,100 * 328.5 * 0.78 = 1,341,133,000 barrels/year.

In the Annual Refining Survey, the *Oil & Gas Journal*[25] differentiates between "Fluid" and "Other" catalytic cracking. Fluid cracking was 5,166,300 barrels per stream day (1,323,761,000 barrels/year). Other (thermal) was 67,800 barrels per stream day (17,372,394 barrels/year).

FCC = 1,323,761 x 10^3 bbl/year

TCC = 17,372 x 10^3 bbl/year

Flares

The activity for flares is derived from the total refinery crude capacity. This capacity is converted to an annual value and is multiplied by the percent control efficiency for blowdown systems from the TRENDS procedure volatile organic compound (VOC) section.

The TRENDS activity spreadsheet reports a 1985 value as 2,608 x 10^6 bbl.

Process heaters

Process heater emissions are divided into oil and gas. Both categories use activity data from Table 43 "Fuels Consumed at Refineries by PAD District, 1985" of *Petroleum Supply Annual 1985*.[5]

The quantity of oil consumed at petroleum refineries is the sum of distillate, residual, and crude oil. The oil consumed in 1985 was reported as:

758 + 84 + 13,326 = 14,168 x 10^3 barrels = 595,056 x 10^3 gallons.

The quantity of gas consumed at petroleum refineries is the sum of natural gas and still (process) gas. Natural gas is reported in 10^6 ft^3 (million cubic feet). Still (process) gas is reported in 10^3 bbl and must be converted using the conversion factor of 6.3 x 10^6 $ft^3/10^3$ barrel equivalent. The gas consumed in 1985 was reported as:

487,830 + 212,443 * 6.3 = 1,826,220 x 10^6 ft^3.

Sulfur recovery

The quantity of sulfur recovered by petroleum refineries in 1985 is reported in Table 4 "Recovered Sulfur Produced and Shipped in the United States" of *Minerals Yearbook 1989 "Sulfur."*[4] The production from petroleum refineries was 2,940,000 metric tons (3,234,000 short tons). The TRENDS activity spreadsheet erroneously left this activity rate in metric units.

2.3.6.2 *TRENDS Emission Factors*

The emission factors for this category are rather complex. The emission factors cited in the TRENDS procedures manual or in the TRENDS spreadsheets are as follows.

SCC	Description	Emission Factor	Units
3-06-001-05	Petroleum Industry - Process Heaters: Natural Gas-fired	0.6	lbs/10^6 ft^3 burned
3-06-001-06	Petroleum Industry - Process Heaters: Process Gas-fired	950.0S	lbs/10^6 ft^3 burned
3-06-002-01	Petroleum Industry - Fluid Catalytic Cracking Units	493	lbs/10^3 BBL fresh feed
3-06-002-02 [sic]	Petroleum Industry - Thermal Catalytic Cracking Units	60	lbs/10^3 BBL fresh feed
3-06-004-01	Petroleum Industry - Blowdown systems: w/ vapor recovery sys. w/ flaring	26.9	lbs/10^3 BBL refinery feed
1-02-004-01	External Combustion Boilers - Industrial - Residual Oil: Grade 6 oil	158.6S	lbs/10^3 gallon burned

The SCC for thermal catalytic cracking (3-06-002-02) appears to be a typographical error. The correct SCC for thermal catalytic cracking units is 3-06-003-01. The SCC 3-06-003-01 will be used throughout the rest of this discussion.

These emission factors match the document *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants.*[7] The TRENDS procedure manual instructs the user to use the TRENDS emission factor for industrial - residual oil boilers and also to estimate the sulfur content from a standard AIRS report for SCC 3-06-001-03 (Petroleum Industry - Process Heaters: Oil fired). These two instructions are inconsistent because the TRENDS procedure for industrial-residual oil does not use the AIRS sulfur content. The average sulfur content as reported in NAPAP for SCC 3-06-001-03 is 1.09 percent, resulting in an emission factor of:

$158.6 * 1.09 = 172.8$ lb/10^3 gallon burned.

The emission factor for the TRENDS industrial residual oil category is based on a sulfur content from *Heating Oils, 1985*[6] and for 1985 this was calculated as 1.63 percent. This results in an emission factor of:

$158.6 * 1.63 = 258.5$ lb/10^3 gallon burned.

Finally, the TRENDS spreadsheets for both the 1990 and 1991 estimates used an emission factor of 6248 lbs/10^3 bbl burned (148.76 lbs/10^3 gallon burned). This translates to a sulfur content of 0.94 percent.

The emission factor for natural gas and refinery gas is to be weighted based on the throughput listed in Table 43 "Fuels Consumed at Refineries by PAD District, 1985" of *Petroleum Supply Annual 1985*.[5] The emission factor for refinery gas is listed in the TRENDS procedures manual as 356.25 lbs/10^6 ft^3. This translates into an assumed sulfur content of 0.375 percent. The emission factor for combustion of natural gas is 0.6 lbs/10^6 ft^3. The total gas combustion is 1,826,220 x 10^6 ft^3. Natural gas is 26.7 percent of the total gas burned and process gas is 73.3 percent of the total gas burned. Therefore the weighted emission factor is:

$0.267 * 0.6 + 0.733 * 356.25 = 261$ lb/10^6 ft^3 burned.

The weighted average emission factor in the TRENDS spreadsheet for process heaters gas combustion was 253.1 for both 1990 and 1991.

Sulfur Recovery

According to the TRENDS procedure manual, the emission factor is derived annually from the emissions and throughput reported to AIRS/FS in SCC 3-01-032-01 through 3-01-032-04. In 1985 the throughput values were reported as 2,388,968 tons of sulfur. In 1985 the emissions are reported as 127,534 tons of SO_2. The emission factor is obtained by dividing the total emissions by the sum of the operating rates. The emission factor for 1985 should be:

127,534 / 2,388,968 * 2000 = 106.8 lbs/ton of sulfur.

The emission factor reported through the TRENDS spreadsheets for both 1990 and 1991 is 137.5 lb/ton of sulfur produced.

2.3.6.3 *TRENDS Emissions*

Using the TRENDS emission factors and activity data published in the TRENDS activity spreadsheet and adding the emissions from sulfur recovery described in the preceding section, results in the following 1985 emissions.

Description	Tons SO_2 Emitted
Fluid Catalytic Cracking	326,317
Thermal Catalytic Cracking	522
Flares (Blowdown System)	35,078
Process Heaters: Oil	44,360
Process Heaters: Gas	231,106
Sulfur Recovery Units	202,125
Total	839,508

The published TRENDS value is 830,000 tons. The discrepancy may be due to independent rounding or an incorrect assumption in the recreation of the TRENDS emission estimates.

2.3.6.4 *NAPAP Activity*

NAPAP activity data are presented below for comparative purposes. These data were not priority elements for all sources in that inventory.

SCC	Description	Value	Units
1-02-007-01	External Combustion Boilers Industrial: Process Gas, Petroleum Refining Gas	17,345	10^6 ft^3 gas burned
3-06-001-01	Petroleum Industry - Process heaters: Oil fired	62,040	10^3 bbls oil burned
3-06-001-02	Petroleum Industry - Process heaters: Gas fired	116,387,121	10^3 ft^3 gas burned
3-06-001-03	Petroleum Industry - Process heaters: Oil fired	11,747,943	10^3 gallons oil burned
3-06-001-04	Petroleum Industry - Process heaters: Gas fired	38,503,093	10^6 ft^3 gas burned
3-06-001-05	Petroleum Industry - Process heaters: Natural gas fired	311,504	10^6 ft^3 gas burned
3-06-001-06	Petroleum Industry - Process heaters: Process gas fired	155,477	10^6 ft^3 gas burned
3-06-002-01	Petroleum Industry - Fluid catalytic cracking unit	1,584,926	10^3 bbls fresh feed
3-06-003-01	Petroleum Industry - Thermal catalytic cracking unit	171,954	10^3 bbls fresh feed
3-06-004-01	Petroleum Industry - Blowdown systems: w/ vapor recovery sys. w/ flaring	11,603,678	10^3 bbls refinery feed
3-06-004-02	Petroleum Industry - Blowdown systems: w/o controls	519,999	10^3 bbls refinery feed
1-02-004-01	External Combustion Industrial: Residual oil, grade 6 oil	3,679,030	10^3 gallons oil burned

Additional NAPAP production was added for two categories of process heaters burning oil (3-06-001-01 and 03), and two categories of process heaters burning gas (3-06-001-02 and 04).

2.3.6.5 *NAPAP Emissions*

The following emission estimates were reported through NAPAP for the categories of petroleum refining emissions that are estimated in the TRENDS method:

SCC	Description	Tons SO_2 Emitted
1-02-007-01	External Combustion Boilers Industrial: Process Gas, Petroleum Refining Gas	41,647
3-01-032-01	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (92-95% removal) (SIC 2911 only)	7,175
3-01-032-02	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (95-96% removal) (SIC 2911 only)	12,100
3-01-032-03	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (96-97% removal) (SIC 2911 only)	92
3-01-032-04	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (99.9% removal) (SIC 2911 only)	9,750
3-06-001-01	Petroleum Industry - Process heaters: Oil fired	4,762
3-06-001-02	Petroleum Industry - Process heaters: Gas fired	3,368
3-06-001-03	Petroleum Industry - Process heaters: Oil fired	75,174
3-06-001-04	Petroleum Industry - Process heaters: Gas fired	57,923
3-06-001-05	Petroleum Industry - Process heaters: Natural gas fired	549
3-06-001-06	Petroleum Industry - Process heaters: Process gas fired	13,750
3-06-002-01	Petroleum Industry - Fluid catalytic cracking unit	204,647
3-06-003-01	Petroleum Industry - Thermal catalytic cracking unit	7,273
3-06-004-01	Petroleum Industry - Blowdown systems: w/ vapor recovery sys. w/ flaring	15,671
3-06-009-02	Petroleum Industry - Flares: Residual oil	22
3-06-009-03	Petroleum Industry - Flares: Natural gas	2,456
3-06-009-04	Petroleum Industry - Flares: Process gas	17,803
3-06-009-99	Petroleum Industry - Flares: Other not classified	8,707
1-02-004-01	External Combustion - Industrial: Residual oil, grade 6 oil (SIC 2911 only)	37,576
Total		520,445

Additional emissions are listed under Petroleum Refining in NAPAP for the following SCC categories.

SCC	Description	Tons SO_2 Emitted
3-06-001-07	Petroleum Industry - Process heaters: LPG fired	60
3-06-001-99	Petroleum Industry Process heaters: Other not classified	7,558
3-06-002-02	Petroleum Industry Fluid Catalytic Cracking units: Catalyst handling system	327
3-06-004-02	Petroleum Industry Blowdown systems: w/o control	66
3-06-005-03	Petroleum Industry - Fugitive emissions: Process drains and wastewater separators	20
3-06-005-04	Petroleum Industry - Fugitive emissions: Process drains and wastewater separators	1,060
3-06-006-03	Petroleum Industry - Vacuum distillate column condensor	110
3-06-008-01	Petroleum Industry - Fugitive emissions: Pipeline valves and flanges	220
3-06-008-05	Petroleum Industry - Fugitive emissions: Misc, Sampling/ Non-Asphalt Blowing/ Purging/etc.	12,091
3-06-010-01	Petroleum Industry - Sludge converter: general	135
3-06-011-01	Petroleum Industry - Asphalt blowing: general	91
3-06-012-01	Petroleum Industry - Fluid coking units: general	26,920
3-06-014-01	Petroleum Industry - Petroleum coke calcining	12,560
3-06-099-02	Petroleum Industry - Incinerators: Residual oil	8,927
3-06-099-03	Petroleum Industry - Incinerators: Natural gas	16,183
3-06-099-04	Petroleum Industry - Incinerators: Process gas	4,208
3-06-888	Petroleum Industry - Fugitive emissions: Not classified	1,739
3-06-999	Petroleum Industry Miscellaneous: Not classified	17,097
Total		109,372

Finally, the distillate oil, residual oil, and natural gas combustion sections specifically excluded petroleum refining emissions. The emissions excluded from these three combustion categories add an additional 11,496 tons of SO_2 to this section, bringing the total reported NAPAP emissions for the petroleum industry to 641,313 tons of SO_2.

2.3.6.6 *Conclusion*

The petroleum refining emission estimates in TRENDS and NAPAP are quite different. The TRENDS method estimates emissions for six categories for a combined estimate of 830,000 tons of SO_2. NAPAP estimates emissions for many more categories. For the six categories that correspond to the TRENDS estimate, NAPAP estimates 520,445 tons of SO_2. NAPAP has a total estimate of about 640,000 tons for petroleum refining.

Fluid catalytic cracking dominates the TREND estimate with 326,317 tons. The NAPAP estimate is significantly lower, 204,647 tons of SO_2. It is unclear why the NAPAP emission estimate is so much lower; the reported NAPAP activity is actually higher than the TRENDS activity (1,585 versus 1,324 x 10^6 bbl/year fresh feed).

Thermal catalytic cracking activity relies on an annual survey conducted by the *Oil & Gas Journal*.[25] The NAPAP emission estimate and the NAPAP activity are both an order of magnitude higher than the TRENDS values. The emissions are 7,273 tons versus 522 tons and the activity is 12 versus 17 x 10^6 bbl/year fresh feed.

NAPAP reports significantly higher emissions for oil combustion at petroleum refineries. NAPAP has an emission estimate of 117,512 tons versus the TRENDS estimate of 44,360 tons of SO_2. The emission factor for SCC 1-02-004-01 is listed in TRENDS for process heaters - oil. This SCC is for grade 6 residual oil burned in external combustion boilers - industrial. The petroleum refining section also has a general SCC for oil-fired process heaters (3-06-001-03) with the same emission factor and has added an SCC (3-06-001-11) for large grade 6 oil-fired process heaters (>100 MMBTU). (This new SCC has a slightly higher emission factor, 159.3S lbs/10^3 gallons burned versus 158.6S lbs/10^3 gallons burned). The TRENDS method should be rewritten to utilize these SCC codes.

The sulfur content of the oil burned and consequently the emission factor used by TRENDS for oil-fired process heaters appears to be too low. The majority of the oil reported burned is actually crude oil (94 percent) and the distillate oil (5.4 percent) is far more significant than the residual oil (0.6 percent). Therefore, the use of a residual oil emission factor is not very accurate. There is no emission factor for combustion of crude oil in process heaters at a petroleum refinery. Emission factors used in the industrial oil combustion section are 42.3 lbs/10^3 gallon burned for distillate oil and 258.5 lbs/10^3 gallon burned for residual oil. Using the residual oil emission factor, which appears to be the intent of the TRENDS procedure manual, would result in process heater oil emissions of:

$$258.5 * 595{,}056 / 2000 = 76{,}911 \text{ tons of } SO_2.$$

The emission estimates for gas-fired process heaters are also very different in TRENDS and NAPAP. The NAPAP estimate is 117,237 tons and the TRENDS estimate is 231,106 tons of SO_2. For gas-fired process heater emissions, the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] lists the emission factors as 0.6 lbs/10^6 ft^3 for natural-gas fired versus 950.0S lbs/10^6 ft^3 for process-gas fired. The emission factor of 253.1 lbs/10^6 ft^3 used in TRENDS is between the emission factors for the two fuels. In TRENDS, the quantity of process gas burned as a fuel is three times as high as the amount of natural gas burned. It is unclear why the two fuels are added together in the activity section. An emission factor weighted by quantity of fuel burned would be 261.2 lbs/10^6 ft^3, which would result in an emission estimate of 238,547 tons of SO_2. It is unclear if the natural gas emissions bear calculating since they only contribute approximately 146 tons of SO_2 to the total estimate.

Finally, the emission estimates for sulfur recovery at petroleum refineries is also very different. The NAPAP inventory reports emissions of 29,117 tons of SO_2 and the TRENDS estimate is 202,125 tons of SO_2. Errors were discovered in the execution of the TRENDS method (as discussed in Section 2.3.3). The TRENDS emission estimate should be 172,696 tons of SO_2, however, the numbers are still very dissimilar. Research into the types of sulfur recovery units employed at petroleum refineries (and their emissions) is warranted.

The data required to determine thermal catalytic cracking versus the fluid catalytic cracking are no longer available. The thermal catalytic cracking contributes 0.16 percent of the cracking emissions in the TRENDS estimate but contributes 3.4 percent in the NAPAP inventory. Significant effort to identify a replacement source of data for thermal cracking may not be warranted, however, additional research into why the NAPAP activity rates for thermal catalytic cracking are so different from TRENDS may be warranted. Effort to determine why the fluid catalytic cracking emission estimate is so much lower in NAPAP is definitely warranted.

2.3.7 Natural Gas Production

The TRENDS procedure has two components of emissions from the production of natural gas, combustion and sulfur recovery. The combustion of natural gas during production contributes a small amount of emissions (441 tons of SO_2) as was reported in Section 2.1.5. Emissions from sulfur recovery are far more significant (163,000 tons) as was reported in Section 2.3.3. This section presents the results of the combustion and the sulfur recovery emission estimates that TRENDS publishes as Natural Gas Production. There is no section in the TRENDS procedure manual specifically for natural gas production, rather the estimate originates in the two sections for natural gas combustion and sulfur recovery.

The NAPAP estimate is 7,660 tons for combustion of natural gas during production and 59,500 tons of SO_2 from sulfur recovery units at natural gas production facilities. In addition, NAPAP reports 265,000 tons of SO_2 from other emission sources in natural gas production, resulting in a total estimate of 332,000 tons of SO_2. The difference between the two estimates is 172,000 tons of SO_2 (52 percent).

2.3.7.1 *TRENDS Activity*

The natural gas consumption for gas pipelines and plants is the sum of pipelines fuel and lease and plant fuel. These values are obtained from Table 13 "Consumption of Natural Gas" of *Natural Gas Annual, 1985*.[13] The value for 1985 for lease and plant fuel is 966,047 x 10^6 ft^3 and the

1985 value for pipelines fuel is 503,766 x 10^6 ft^3. Therefore the total gas pipelines and plants natural gas combustion rate is:

966,047 + 503,766 = 1,469,813 x 10^6 ft^3.

The quantity of sulfur recovered by natural gas plants is reported in Table 4 "Recovered Sulfur Produced and Shipped in the United States" of *Minerals Yearbook 1989 "Sulfur."*[4] The production from natural gas plants was 2,373,000 metric tons (2,610,000 short tons). The TRENDS activity spreadsheet erroneously left these activity rates in metric units.

2.3.7.2 *TRENDS Emission Factor*

The TRENDS emissions factor is 0.6 lb $SO_2/10^6$ ft^3 burned for natural gas combustion in the production of natural gas. This emission factor is consistent with all of the natural gas combustion emission factors listed in *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants.*[7]

According to the TRENDS procedure manual, the emission factor for sulfur recovery at natural gas plants is derived annually from the emissions and throughput reported to AIRS/FS in SCC 3-01-032-01 through 3-01-032-04. In 1985 the throughput values were reported as 2,388,968 tons of sulfur. In 1985 the emissions were reported as 127,534 tons of SO_2. The emission factor is obtained by dividing the total emissions by the sum of the operating rates. The emission factor for 1985 should be:

127,534 / 2,388,968 * 2000 = 106.8 lbs/ton of sulfur.

The emission factor reported through the TRENDS spreadsheets for both 1990 and 1991 is 137.5 lb/ton of sulfur produced.

2.3.7.3 *TRENDS Emissions*

TRENDS combustion emissions for natural gas pipelines are calculated as:

0.6 * 1,469,813 / 2000 = 441 tons of SO_2.

The TRENDS emission estimates are calculated for sulfur recovery during natural gas production using the emission factor of 137.5 lb/ton of sulfur produced and the production rates in the TRENDS activity spreadsheet. The emissions for natural gas fields are:

2,373,000 * 137.5 / 2000 = 163,143 tons of SO_2.

Using the emission factor of 106.8 lbs/ton of sulfur produced derived by following the TRENDS procedure manual and the correct activity data would result in the following emission estimates for natural gas fields.

2,610,000 * 106.8 / 2000 = 139,374 tons of SO_2

2.3.7.4 *NAPAP Activity*

The following activity data for natural gas production were reported through the NAPAP inventory.

SCC	Description	10^6 ft^3 Burned
3-10-004-04	Oil and Gas Production - Process Heaters: Natural gas	12,187
3-10-004-14	Oil and Gas Production - Steam generators: Natural gas	2,852
Total		15,039

The sulfur recovered at natural gas plants, as reported in the NAPAP inventory, has not been determined. The following activity data are for the other categories of emissions included in the NAPAP inventory.

SCC	Description	10^6 ft^3 Gas Produced
3-10-002-01	Natural Gas Production: Gas sweeting: Amine Process	5,061,719
3-10-002-02	Natural Gas Production: Gas stripping operations	747,129
3-10-002-03	Natural Gas Production: Compressors	199,002
3-10-002-04	Natural Gas Production: Wells	254,156
3-10-002-05	Natural Gas Production: Flares	64,826
3-10-002-06	Natural Gas Production: Gas Lift	25,915
3-10-002-99	Natural Gas Production: Other not classified	2,099,517

2.3.7.5 *NAPAP Emissions*

Emissions are listed for combustion of natural gas during natural gas production, sulfur recovery, and other NAPAP natural gas production emission sources. The emissions at the 8 digit SCC level are as follows.

SCC	Description	Tons SO_2 Emitted
3-01-032-01	Chemical Manufacturing Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (92-95% removal) (SIC 1311, and 1321 only)	14,311
3-01-032-02	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (95-96% removal) (SIC 1300, 1311, and 4922 only)	12,194
3-01-032-03	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (96-97% removal) (SIC 1311, and 1321 only)	3,299
3-01-032-04	Chemical Manufacturing - Elemental Sulfur Production: Mod. Claus: 2 stage w/o control (99.9% removal) (SIC 1311, and 1321 only)	29,694
3-10-002-01	Natural Gas Production: Gas sweeting: Amine Process	190,241
3-10-002-02	Natural Gas Production: Gas stripping operations	1,427
3-10-002-03	Natural Gas Production: Compressors	31
3-10-002-04	Natural Gas Production: Wells	17
3-10-002-05	Natural Gas Production: Flares	63,055
3-10-002-06	Natural Gas Production: Gas Lift	0
3-10-002-99	Natural Gas Production: Other not classified	10,140
3-10-004-04	Oil and Gas Production Process heaters: Natural gas	442

SCC	Description	Tons SO_2 Emitted
3-10-004-14	Oil and Gas Production - Steam generators: Natural gas	18
Total		324,869

An additional 7,200 tons of SO_2 were excluded from the natural gas combustion - boilers estimate because the emissions were reported with an SIC for oil and natural gas production. This brings the total NAPAP natural gas production emission estimate to 332,069 tons of SO_2.

2.3.7.6 *Conclusion*

The NAPAP and TRENDS estimates for this category are very different. The TRENDS estimate is made up of two numbers, emissions from combustion of natural gas during natural gas production and emissions from sulfur recovery units at natural gas plants.

Both NAPAP and TRENDS have small combustion estimates (460 versus 7,660 tons of SO_2). The estimates for sulfur recovery are very different (163,143 versus 59,498 tons of SO_2) and no explanation for the difference is available. As stated earlier, errors were discovered in the TRENDS estimate and the emissions from sulfur recovery should be 139,374 according to the TRENDS procedure manual. It is unclear why these two values are so different. Research into the type of sulfur recovery units that are utilized in natural gas production should be conducted. Finally, NAPAP reports an additional 264,911 tons of SO_2 from standard natural gas production processes. It is unclear why these processes are not accounted for in the TRENDS method.

2.3.8 Iron and Steel

The 1985 TRENDS emission value is 360,000 tons SO_2. The 1985 NAPAP emission value is 212,000 for iron and steel manufacturing (including byproduct and beehive coke manufacturing). The discrepancy between the two inventories is 148,000 tons of SO_2 (70 percent).

2.3.8.1 *TRENDS Activity*

In TRENDS, there are four categories of SO_2 emissions for the iron and steel industry: coke, sintering, open hearth, and roll and finish. Activity for coke is obtained from *Survey of Current Business*[27] and activity for sintering, open hearth, and roll and finish are obtained from the *Minerals Yearbook 1989 "Iron and Steel."*[4] All of the activity values derived following the TRENDS procedure manual matched the TRENDS activity spreadsheet.

Coke

Activity for Coke emissions is the total beehive and oven (byproduct) production figure. The value is obtained from the U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, *Survey of Current Business, "Petroleum, Coal, and Products"*[27] Beehive and Oven Coke (Byproduct) production. For 1985 the value is 28,651,000 tons. Coke production is also available through Table A5 "Coke and Breeze Production at Coke Plants" of *Quarterly Coal Report*[11] and the 1985 value was 28,651,000 tons. This is consistent with the value of 28,700,000 tons listed in the TRENDS activity spreadsheet.

Sintering

Activity for Sintering is total pig iron production and is obtained from Table 3 "Materials Consumed in Blast Furnaces and Pig Iron Produced" of *Minerals Yearbook 1989 "Iron and Steel"*[4] or from the U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, *Survey of Current Business, "Metals and Manufactures"* Pig iron production.[28] The numbers from these two references are close (49,963,000 versus 50,446,000 tons). The *Minerals Yearbook 1989* value was found in the *Iron and Steel* chapter rather than in the *Iron Ore* chapter. The value used in TRENDS was from the *Survey of Current Business*. The TRENDS method requires dividing the total into three equal portions among the three sintering components (windbox, discharge, and sinter-fugitive), resulting in a value of 16,815,000 tons for sintering. This is consistent with the value of 16,800,000 tons listed in the TRENDS activity spreadsheet.

Open hearth

TRENDS uses a complex process for determining the fraction of steel production in open hearth furnaces (as opposed to an oxygen furnace or an electric arc furnace). Open hearth is obtained by multiplying the fraction of scrap and pig iron consumed in steel production (by type of steelmaking furnace) by the total U.S. raw steel production value.

The data to determine the fraction that is open hearth is obtained from Table 6 "U.S. Consumption of Scrap and Pig Iron in Steel Production, by Type of Steelmaking Furnace" of *Mineral Yearbook 1989 "Iron and Steel."*[4] The values for basic open hearth scrap and iron were summed and were 7,148,000 short tons. The values for basic oxygen scrap and iron were summed and were 59,854,000 short tons. The values for basic electric arc scrap and iron were summed and were 32,755,000 short tons. The total for the three furnace types, basic oxygen, basic open hearth, and basic electric arc, was 99,757,000 short tons. Therefore, the fraction that is basic open hearth is 7.2 percent.

The TRENDS procedure is to obtain total raw steel production from the U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis, *Survey of Current Business, "Metals and Manufactures"*[29] raw steel production. Total raw steel production is also available from Table 1 "Salient Iron and Steel Statistics" of *Minerals Yearbook 1989 "Iron and Steel"* and the value is 88,259,000 short tons in both references.[4]

The open hearth activity is then calculated in TRENDS as:

0.07 * 88,259,000 = 6,178,130 tons.

This is consistent with the TRENDS spreadsheet activity value of 6,200,000 tons.

The fraction of production that is basic open hearth is also available in Table 5 "U.S. Steel Production, By type of Furnace Process" of *Minerals Yearbook 1989 "Iron and Steel."*[4] The value for basic open hearth in 1985 was 7.3 percent. Table 5 also reports that basic open hearth production in 1985 was 6,428,000 short tons. Open hearth production is decreasing and only represents 4.5 percent of 1989 production.

Roll and finish

The activity value for roll and finish operations is total raw steel production. That value was 88,259,000 short tons for 1985 and is consistent with the TRENDS spreadsheet.

2.3.8.2 *TRENDS Emission Factors*

The emission factors are also divided into the four categories.

Coke

The emission factors for coking cited in the TRENDS method are as follows.

SCC	Description	Emission Factor	Units
3-03-003-02	Primary metal production - By-Product Coke Manufacturing: Oven charging	0.02	lbs/ton of coal charged
3-03-003-03	Primary metal production - By-Product Coke Manufacturing: Oven pushing	3.3	lbs/ton of coal charged
3-03-003-04	Primary metal production - By-Product Coke Manufacturing: Quenching	0.4	lbs/ton of coal charged
3-03-003-06	Primary metal production - By-Product Coke Manufacturing: Oven underfiring	4.0	lbs/ton of coal charged
3-03-003-08	Primary metal production - By-Product Coke Manufacturing: Oven/door leaks	0.1	lbs/ton of coal charged
3-03-003-14	Primary metal production - By-Product Coke Manufacturing: Topside leaks	0.1	lbs/ton of coal charged
Total		7.92	lbs/ton of coal charged

These emission factors match the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document. There is a 0.0 emission factor for beehive production-general. An overall emission factor is obtained by adding these factors and dividing by 0.7 to account for 0.7 tons of coke produced per ton coal consumed. This percentage coal to coke is substantiated in Table 2 "Statistical Summary of the Coke Industry in the United States" of *Coke and Coal Chemicals in 1980.*[21] The emission factor for coking is:

7.92 / 0.7 = 11.3 lbs/ton coke produced.

Sintering

The emission factor for sintering was obtained by dividing the 1980 NEDS emissions by the 1980 production. The emission factor is 2.5 lbs/ton produced.

Open hearth

The emission factor for open hearth was obtained by dividing the 1980 NEDS emissions by the 1980 production. The emission factor is 1.5 lbs/ton produced.

Roll and finish

The emission factor for roll and finish is backcalculated from process equipment combustion emissions burning coke oven gas and residual oil. The coke oven gas discussion was originally presented in Section 2.1.1.2. The residual oil discussion was originally presented in Section 2.2.1. The derivation of the coke oven gas component and the residual oil component are repeated below.

Coke oven gas

The TRENDS procedure is to obtain coke oven gas production from *Quarterly Coal Report,*[11] however, coke oven gas production is not provided in that report. Table 23 "Coal Consumption by End-Use Sector" of *Quarterly Coal Report* provides coal consumption by coke plants in 1985 of 41,056,000 short tons. Figure 15 "Production of Coke and Coal Chemicals" of *Coal Data: A Reference*[18] indicates that 11,000 ft^3 of coke oven gas are produced per ton of metallurgical (coking) coal. This results in 1985 coke oven gas production of:

$41{,}056{,}000 * 11{,}000 / 1{,}000{,}000 = 451{,}616 \times 10^6\ ft^3$.

The TRENDS method assumes that 40 percent of the coke oven gas is consumed in the iron and steel industry. Therefore the coke oven gas consumption is:

$451,616 * 0.40 = 180,646 \times 10^6 ft^3$.

The SO_2 emission factor for coke oven gas is 1,091 lbs/10^6 ft^3 as listed in AIRS.[7] Therefore, coke oven gas emissions are:

180,646 * 1,091 / 2000 = 98,542 tons of SO_2.

<u>Residual oil</u>

The quantity of residual oil consumed by steels mills was calculated by taking the quantity in tons of raw steel produced in 1985 and multiplying by a conversion factor for the value of residual oil consumed per ton of raw steel produced. The conversion factor used is 7.38 gal/ton raw steel. The quantity of raw steel produced is obtained from Table 1 "Salient Iron and Steel Statistics" of *Minerals Yearbook 1986 "Iron and Steel"*. The value for 1985 is 88,259,000 short tons. The quantity of residual oil consumed by steel mills is calculated as:

88,259,000 * 7.38 gal/ton raw steel = 651,350,000 gallons.

The emission factor for residual oil combustion is cited in the TRENDS procedure manual as 1,595 lbs/10^3 gal. The emission factor 1,595 is probably a typographical error and should read 159S lb/10^3 gallon burned. The TRENDS procedure manual also states that the emission factor used in the residual oil combustion section should be used. The emission factor cited in Section 2.1.1.2 of this report is 158.6S lb/10^3 gallon burned.

The 158.6S lb/10^3 gallon burned emission factor matches the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document. The average sulfur content of grade 6 fuel oil is obtained from *Heating Oils, 1985*.[6] Again, this reference provides averages for each of five regions. The average sulfur contents range from 1.20 to 1.75

percent in a total of 44 samples. The average national figure based on the number of samples is 1.63 percent. The emission factor for residual oil is:

$158.6 * 1.63 = 258.5$ lb/10^3 gallons burned.

Residual oil emissions at steel mills are then calculated as:

$651{,}350 * 258.5 / 2000 = 84{,}187$ tons of SO_2.

Roll and finish emission factor

The emissions from residual oil combustion are added to coke oven gas emissions and the quantity of emissions from open hearth furnaces are subtracted from the total to yield:

$98{,}542 + 84{,}187 - 4{,}650 = 178{,}079$ tons of SO_2.

The emission factor for roll and finish operations is then calculated as:

EF = $178{,}079 / 88{,}259{,}000 * 2{,}000 = 4.04$ lbs/ton of raw steel.

The overall roll and finish emission factor used in the TRENDS spreadsheets is 3.8 lbs/ton raw steel produced for both 1990 and 1991.

2.3.8.3 *TRENDS Emissions*

TRENDS emissions are calculated using the activity data and emission factors from the TRENDS spreadsheet for the four categories as follows.

Coking

$28{,}700{,}000 * 11.3 / 2000 = 162{,}000$ tons SO_2

Open hearth

6,200,000 * 1.5 / 2000 = 4,650 tons of SO_2

Sintering

16,800,000 * 2.5 / 2000 = 21,000 tons of SO_2

Roll and finish

88,259,000 * 3.8 / 2000 = 168,000 tons of SO_2

Total TRENDS

162,000 + 4,650 + 21,000 + 168,000 = 355,650 tons of SO_2

2.3.8.4 *NAPAP Activity*

The NAPAP production for the four processes is broken out below. The activity data were not high priority elements for all sources in that inventory and are presented for comparison only.

Coking

SCC	Description	Tons of Coal Charged
3-03-003-02	Primary Metal Production - By-Product Coke Manufacturing: Oven charging	35,832,171
3-03-003-03	Primary Metal Production - By-Product Coke Manufacturing: Oven pushing	27,288,497
3-03-003-04	Primary Metal Production - By-Product Coke Manufacturing: Quenching	25,181,912
3-03-003-06	Primary Metal Production - By-Product Coke Manufacturing: Oven underfiring	20,155,913
3-03-003-08	Primary Metal Production By-Product Coke Manufacturing: Oven/door leaks	21,489,908
3-03-003-14	Primary Metal Production - By-Product Coke Manufacturing: Topside leaks	7,764,158
3-03-004-01	Primary Metal Production Coke Manufacturing: Beehive Process, general	405,008

Open hearth

SCC	Description	Tons Produced
3-03-009-01	Primary Metal Production - Steel Production: Open hearth furnace, stack	5,746,973
3-03-009-18	Primary Metal Production - Steel Production: Charging, open hearth	62,002
3-03-009-19	Primary Metal Production - Steel Production: Tapping, open hearth	122,002

Sintering

SCC	Description	Tons Iron Produced
3-03-008-01	Primary Metal Production - Iron Production - Blast Furnaces: Ore charging	16,178,407
3-03-008-11	Primary Metal Production - Iron Production - Sintering: Raw Mat. st'kpiles, coke breeze, limestone, ore fines	38,736,563
3-03-008-13	Primary Metal Production - Iron Production - Sintering: Windbox	19,693,102
3-03-008-17	Primary Metal Production - Iron Production - Sintering: Cooler	7,139,166

Roll and finish

SCC	Description	Tons Produced
3-03-009-31	Primary Metal Production - Steel Production: Hot rolling	5,510,147
3-03-009-33	Primary Metal Production - Steel Production: Reheat furnaces	15,101,751
3-03-009-34	Primary Metal Production - Steel Production: Heat treating furnaces: Annealing	4,972,078
3-03-009-35	Primary Metal Production - Steel Production: Cold rolling	990,995

2.3.8.5 *NAPAP Emissions*

The NAPAP emissions for the four processes are:

Coking

SCC	Description	Tons SO_2 Emitted
3-03-003-02	Primary Metal Production - By-Product Coke Manufacturing: Oven charging	7,305
3-03-003-03	Primary Metal Production By-Product Coke Manufacturing: Oven pushing	13,494
3-03-003-04	Primary Metal Production By-Product Coke Manufacturing: Quenching	3,307
3-03-003-06	Primary Metal Production By-Product Coke Manufacturing: Oven underfiring	40,816
3-03-003-08	Primary Metal Production By-Product Coke Manufacturing: Oven/door leaks	329
3-03-003-14	Primary Metal Production By-Product Coke Manufacturing: Topside leaks	116
Total		65,367

Additional coke manufacturing sources include: coke crushing/screening and handling (41 tons); coal preheater (3,243 tons); gas by-product plant (2,142 tons); coal storage pile (175 tons); other/not classified (2,062 tons); and beehive process general (1;599 tons) for a total additional emissions of 9,262 tons of SO_2. This brings the total coke manufacture emissions to 74,629 tons SO_2.

Open hearth

SCC	Description	Tons SO_2 Emitted
3-03-009-01	Primary Metal Production - Steel Production: Open hearth furnace, stack	1,159
3-03-009-18	Primary Metal Production - Steel Production: Charging, open hearth	5
3-03-009-19	Primary Metal Production - Steel Production: Tapping, open hearth	5
Total		1,169

Sintering

SCC	Description	Tons SO_2 Emitted
3-03-008-11	Primary Metal Production - Iron Production - Sintering: Raw Mat. st'kpiles, coke breeze, limestone, ore fines	470

SCC	Description	Tons SO_2 Emitted
3-03-008-13	Primary Metal Production - Iron Production Sintering: Windbox	33,756
3-03-008-17	Primary Metal Production - Iron Production - Sintering: Cooler	280
Total		34,506

Roll and finish

SCC	Description	Tons SO_2 Emitted
3-03-009-31	Primary Metal Production Steel Production: Hot rolling	2,162
3-03-009-33	Primary Metal Production - Steel Production: Reheat furnaces	6,484
3-03-009-34	Primary Metal Production - Steel Production: Heat treating furnaces: Annealing	390
3-03-009-35	Primary Metal Production - Steel Production: Cold rolling	201
3-04-003-XX	Primary Metal Production - Gray Iron Foundries	2,527
3-04-007-XX	Primary Metal Production - Steel Foundries	13,540
Total		25,304

Additional iron production sources include: ore charging (552 tons); blast heating stoves (2,785 tons); cast house (5,374 tons); other not classified (630 tons,) for total additional emissions of 9,341 tons of SO_2.

Additional steel production sources include: electric arc furnace (alloy steel) (1,749 tons); electric arc furnace (carbon steel) (281 tons); soaking pits (9,353 tons); basic oxygen furnace (BOF) - open hood stack (23 tons); charging and tapping BOF (47 tons); teeming (unleaded steel) and continuous casting (533 tons); and other not classified (4,316 tons) for total additional emissions of 16,302 tons of SO_2.

Finally, several of the combustion categories specifically exclude iron and steel facilities during the development of their emission estimates. The residual oil section excluded 14,318 tons of SO_2. The natural gas - boilers section excluded 10,044 tons of SO_2. The coke and coke oven gas portions of the miscellaneous fuels section specifically excluded iron and steel facilities. The coke and coke oven gas emissions are 747 and 11,252 tons of SO_2 respectively. In addition, 5,981 tons from blast furnace gas combustion are added to the total iron and steel estimate.

This brings the total NAPAP emission estimate for iron and steel production to 204,000 tons of SO_2.

2.3.8.6 *Conclusion*

All four of the iron and steel categories have significantly different emission estimates in TRENDS and NAPAP. The four categories are discussed separately.

For coking emissions, TRENDS lists the six SCC categories that are used in their estimate. Using these six SCC categories provides emission estimates of 65,367 tons (NAPAP) versus 162,000 tons (TRENDS). Even if all of the NAPAP coke emissions are counted, the total NAPAP estimate for coke is only 74,629 tons of SO_2. One possible cause for over estimation in the TRENDS procedure is the inclusion of beehive process coke manufacturing in the activity number. It is not clear whether the beehive process is still used and SO_2 emissions may be much lower. (There is also a 0.0 as an emission factor in the SCC book.) Another possible disconnect is the application of SO_2 control technologies in the NAPAP coke production. Finally, the NAPAP inventory may have emissions from coke production reported in other iron and steel processing steps.

The TRENDS emission factor for sintering (2.5 lbs/ton steel produced) was derived from 1980 NEDS statistics and is therefore quite dated. If the 1985 emissions for sintering (SCC 3-03-008-11 through 20) were divided by one-third of the 1985 production of pig iron (from U.S. Bureau of Mines) the emission factor would be significantly higher. Using the production value for pig iron would yield the following emission factor:

(34,506 tons SO_2 * 2,000)/(16,800,000 tons sintered pig iron) = 4.11 lbs SO_2/ton pig iron

The NAPAP numbers appear to underestimate the open hearth emissions and the TRENDS method may overestimate the open hearth emissions. Open hearth is a process that is declining.

Open hearth emissions are 1,169 tons in NAPAP and 4,650 tons in TRENDS. Using the 1985 NAPAP open hearth emission estimate would change the TRENDS emission factor from 1.5 to 0.38 lbs/ton produced. The difference could also be due to the application of SO_2 control devices in NAPAP.

The 1985 emission estimates underwent more review than the 1980 estimates and therefore the 1985 values are more suitable for use to calculate sintering and open hearth emissions in the TRENDS method. Revising the emission factor based on the 1985 emission estimate would make the TRENDS and NAPAP emission estimates equivalent for these two categories of emissions.

The TRENDS roll and finish estimate of 168,000 tons of SO_2 is substantially higher than the NAPAP estimate of 25,304 tons of SO_2. The TRENDS category may be misnamed as it is really a sum of emissions from combustion of coke oven gas and residual oil. A long and complex procedure is put forth to calculate the roll and finish emission factor. This procedure, if followed, did not change the emission factor used from 1985 to 1990 and 1991. Therefore, it is assumed that the factor has not been recently updated.

The TRENDS procedure assumes that 40 percent of the coke oven gas is burned in iron and steel facilities. As discussed in the miscellaneous fuels section, this estimate may be too low. Table 12 "Production and Disposal of Coke Oven Gas in the United States by Producing State: 1980" of *Coke and Coal Chemicals in 1980* reports that in 1980 coke gas use was 39 percent used by producers in heating ovens, 58 percent was for other use by producers, 1.4 percent commercial sales, and 1.5 percent was wasted.[20] The NAPAP activity data are consistent with these statistics indicating that 99 percent of coke oven gas burned was at iron and steel facilities. In addition, TRENDS uses a coke oven gas average sulfur value of 1.605 percent. The NAPAP inventory lists an average sulfur content for coke oven gas of 0.5 percent. Using the lower sulfur content would result in an emission factor of 340 $lb/10^6\ ft^3$ burned. Assuming 98.6 percent of the coke oven gas is consumed by the iron and steel industry and that the sulfur content of coke oven gas is much lower, would result in 75,700 tons of SO_2 from the coke oven gas portion of the roll and finish estimate. Following the procedure, a roll and finish emission factor of 4.04 lbs/ton was developed versus 3.8 lbs/ton of raw steel in the TRENDS spreadsheet. Both of these emission factors are too high.

The reason the TRENDS roll and finish emission factor was calculated so high is based on the ratio of residual oil used to produce steel. The TRENDS procedures manual uses a factor of 0.00738 x 10^6 gal/10^3 ton of raw steel produced (7.38 gal/ton of steel produced). This factor is too high. Based on the data in Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] the total residual oil used in blast furnaces and steel mills was 5,458,000 barrels in 1985. This corresponds to a new factor of:

5,458,000 * 42 / 88,259,000 = 2.597 gal/ton of steel.

Using the new ratio or residual oil burned/ton of raw steel produced results in emissions of 11.248 tons of SO_2 from the residual oil portion of the roll and finish estimate.

It is unclear why the *Survey of Current Business* is introduced as a reference in the TRENDS procedure. The coke production is available through the *Quarterly Coal Report*, the pig iron and raw steel production data are available through the *Minerals Yearbook "Iron and Steel."*

Finally, the TRENDS procedure does not account for any SO_2 controls. This is probably the most significant difference between the TRENDS and NAPAP estimates.

2.3.9 Cement Manufacturing

The 1985 TRENDS emission value is 620,000 tons SO_2. The 1985 NAPAP value is 290,700 tons for cement manufacturing. The discrepancy between the two inventories is 329,300 tons of SO_2 (113 percent). The discrepancy is due to the difference in the way the fuel emissions are reported.

2.3.9.1 *TRENDS Activity*

In TRENDS, the cement production is obtained from Table 1 "Salient Cement Statistics" of *Minerals Yearbook 1989 "Cement."*[4] The value for 1985 was 77,895,000 short tons.

The activity section of the TRENDS procedure manual does not direct the user to obtain fuel consumption values, however, the emission factor section implies that the user will need fuel consumed in cement manufacture. Therefore, fuel consumed in cement manufacture is obtained from Table 8 "Clinker produced and fuel consumed by the Portland cement industry in the United States by process" of *Minerals Yearbook, 1986 "Cement."*[4] The 1985 values are as follows.

Description	Value
Coal consumed (10^3 tons)	11,606
Oil consumed (10^3 barrels)	755

The oil combustion section of the TRENDS procedure document states that two thirds of the oil consumed by the cement industry is residual oil and the remaining one third is distillate oil (Sections 2.1.1.1 and 2.1.1.2).

2.3.9.2 *TRENDS Emission Factors*

The emission factors cited in the TRENDS method account for the sulfur in the mineral source, the sulfur in coal, the sulfur in residual oil, and the sulfur in distillate oil. TRENDS cites emission factors that are inconsistent with the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants.*[7] The emission factors cited in the TRENDS procedure are as follows.

Description	Emission Factor	Units
Mineral source	10.2	lbs/ton cement produced
Coal	30.45	lbs/ton coal burned
Residual Oil	124.5	lbs/10^3 gal burned
Distillate Oil	112.35	lbs/10^3 gal burned

The emission factor for cement manufacturing kilns in both the wet and dry process matches the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants.*[7] The procedures manual states that the emission factors for coal and residual oil utilize the sulfur value derived in the industrial boilers section. The average sulfur content for bituminous coal was calculated as 1.4 percent (Section 2.1.4). The average sulfur content cited in the Residual Oil (Section 2.1.1.2) is 1.63 percent. The emission factor for distillate oil utilizes an emission factor of 0.3 percent sulfur.

The TRENDS method states that the uncontrolled emission factor is determined by adding the emissions and dividing by the total cement production rate. The TRENDS method does not cite where the fuel consumption values are obtained, however, as stated above, they are available from Table 8 "Clinker produced and fuel consumed by the Portland cement industry in the United States by process" of *Minerals Yearbook, 1986 "Cement."*[4] The uncontrolled emission factor would then be calculated as follows (assuming two-thirds of the oil consumed is residual oil and the remaining one third is distillate oil).

$$\frac{[10.2 * 77{,}895 + 30.45 * 11{,}606 + (125.5 * 0.666 + 112.35 * 0.333) * 31{,}710]}{77{,}895}$$

= 64.04 lbs SO_2/ton of cement produced

The TRENDS manual then directs the user to estimate the control efficiency using linear interpolation and the particulate control efficiency. The TRENDS procedure manual states that the baseline value of 13.75 percent SO_2 control corresponds to a 99 percent particulate control and 12 percent SO_2 control corresponds to 92 percent particulate control. For this analysis the full 13.75 percent SO_2 control will be assumed. This would result in an overall TRENDS emission factor of:

64.04 * (1 - 0.1375) = 55.23 tons of SO_2/ton of cement produced.

The overall emission factor for cement manufacturing listed in the TRENDS spreadsheets is 15.95 lbs/ton of cement produced.

2.3.9.3 *TRENDS Emissions*

Using the emission factor in the TRENDS spreadsheet results in an emission estimate of:

77,895,000 * 15.95 / 2000 = 621,000 tons of SO_2.

2.3.9.4 *NAPAP Activity*

The NAPAP cement production is reported as 44,124,892 tons of cement produced dry process and 16,041,286 tons of cement produced wet process.

2.3.9.5 *NAPAP Emissions*

The NAPAP reported emissions for cement manufacturing are:

SCC	Description	Tons SO_2 Emitted
3-05-006-06	Mineral Products Cement Manufacturing - Dry Process: Kilns	109,150
3-05-007-06	Mineral Products Cement Manufacturing Wet Process: Kilns	76,614
3-90-002-01	In-process Fuel Use - Bituminous Coal: Cement Kiln/Dryer	77,859
3-90-004-02	In-process Fuel Use - Residual Oil: Cement Kiln/Dryer	3,574
3-90-005-02	In-process Fuel Use - Distillate Oil: Cement Kiln/Dryer	2,404
Total		269,601

Additional emissions of 6,040 tons are listed in NAPAP for grinding and drying and primary crushing and other not classified, and an additional 15,012 tons of SO_2 were excluded from the combustion categories of residual oil, distillate oil, bituminous coal, and natural gas, bringing the total NAPAP emission estimate to 290,653 tons of SO_2.

2.3.9.6 *Conclusion*

Since the TRENDS method was last revised and the NAPAP inventory was completed, the Portland cement section of AP-42 has been updated. AP-42 currently lists the uncontrolled SO_2 emission factor for the dry process as 7.0 lbs/ton of clinker produced and for the wet process as 6.0 lbs/ton of clinker produced when coal is the fuel. Coal dominates as the fuel of choice providing 93 percent of kiln fuel consumption. The dry production is overtaking wet production (probably due to the lower energy requirements of dry). Statistics for manufacture of both (using all types of fuel) are available in *Minerals Yearbook "Cement."*[4] Table 8 "Clinker produced and fuel consumed by the Portland cement industry in the United States by process" of *Minerals Yearbook, 1986 "Cement"* provides 1985 statistics is as follows.

Description	Value
Wet process (10^3 tons of clinker produced)	26,066
Dry process (10^3 tons of clinker produced)	37,797
Coal consumed (10^3 tons)	11,606
Oil consumed (barrels)	755,000

Assuming that the AP-42 emission factors (which are for coal burned) apply, emissions can be calculated with these statistics as:

(26,066,000 * 6.0 + 37,797,000 * 7.0) / 2,000 = 210,488 tons of SO_2.

These are uncontrolled emissions. AP-42 states that the use of a baghouse (for particulate control) would result in approximately 75 percent reduction in SO_2 due to the basic nature of the particulate (calcium).

Assuming 75 percent control would result in emissions of:

210,488 * (1 - 0.75) = 52,621 tons of SO_2.

The TRENDS estimate apparently double counts the fuel sulfur emissions. The emission factor that is applied in the TRENDS method is out of date and already accounts for the fuel sulfur. Double counting the fuel sulfur emissions is a significant error in the TRENDS method.

2.3.10 Glass Manufacturing

The 1985 TRENDS emission value is 30,000 tons SO_2. The 1985 NAPAP value is 23,000 for glass manufacturing. The discrepancy between the two inventories is 7,000 tons of SO_2 (30 percent).

2.3.10.1 *TRENDS Activity*

In TRENDS, the glass production is obtained from the *Current Industrial Reports*. The SO_2 emissions are from three categories: container glass - melting furnace; flat glass melting furnace; and pressed and blown glass - melting furnace.

For TRENDS the activity is the sum of total production of flat glass, net packed weight of glass containers, and miscellaneous glass products (pressed and blown glass). Flat glass is obtained from Table 1A "Summary of Flat Glass Production, Shipments, and Inventories: 1986 and 1985" of *Current Industrial Reports: Flat Glass Summary for 1986*.[15] The value for 1985 was 3,670,719 tons. The value for container glass is obtained from Table 5 "Shipments, Production, and Stocks of Glass Containers: 1985" of *Current Industrial Reports: Glass Containers Summary for 1986*.[15] The value for 1985 was 22,196,448,000 pounds or 11,098,224 tons. The value for miscellaneous glass products is an additional 10 percent of the combined flat and container glass production. Total glass production is then calculated as:

(3,670,719 + 11,098,224) * 1.1 = 16,245,837 tons of glass.

This value matches the TRENDS activity spreadsheet.

2.3.10.2 *TRENDS Emission Factors*

The emission factors cited in the TRENDS method are as follows.

SCC	Description	Emission Factor	Units
3-05-014-02	Mineral Products Glass Manufacture: Container glass Melting furnace	3.4	lbs/ton of glass produced
3-05-014-03	Mineral Products Glass Manufacture: Flat glass - Melting furnace	3.0	lbs/ton of glass produced
3-05-014-04	Mineral Products Glass Manufacture: Pressed and blown glass Melting furnace	5.6	lbs/ton of glass produced

These emission factors match the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document. An overall emission factor of 3.56 lbs/ton of glass produced is applied to all glass production in the TRENDS method. The 3.56 emission factor is obtained by assuming that the distribution of glass manufacturing is 75 percent container glass, 15 percent flat glass and 10 percent blown glass.

3.4(.75) + 3.0(.15) + 5.6(.1) = 3.56 lbs SO_2/ton of glass produced

2.3.10.3 *TRENDS Emissions*

Using the TRENDS emission factor results in 1985 emissions of:

16,245,837 * 3.56 / 2000 = 28,918 tons of SO_2.

2.3.10.4 *NAPAP Activity*

The reported NAPAP production is as follows.

SCC	Description	Tons of Glass Produced
3-05-014-02	Mineral Products - Glass Manufacture: Container glass - Melting furnace	7,219,485
3-05-014-03	Mineral Products Glass Manufacture: Flat Glass - Melting furnace	2,397,263

SCC	Description	Tons of Glass Produced
3-05-014-04	Mineral Products - Glass Manufacture: Pressed/Blown glass Melting furnace	787,572
Total		10,404,320

These reported production figures translate into a distribution of 69 percent container glass, 23 percent flat glass, and 8 percent pressed and blown glass. The NAPAP production figures are not complete enough to be used as a basis for distribution of emissions.

2.3.10.5 ***NAPAP Emissions***

The reported 1985 NAPAP emission are not calculated solely using the SCC emission factors. The NAPAP emissions for the three SCC codes are as follows.

SCC	Description	Tons SO_2 Emitted
3-05-014-02	Mineral Products - Glass Manufacture: Container glass - Melting furnace	11,776
3-05-014-03	Mineral Products - Glass Manufacture: Flat Glass - Melting furnace	3,616
3-05-014-04	Mineral Products - Glass Manufacture: Pressed/Blown glass - Melting furnace	3,110
Total		18,502

Additional emissions of 2,215 tons are listed in NAPAP for the SCC category soda lime and 722 tons of SO_2 are included for raw material handling and other not classified. This brings the total NAPAP emission estimate for glass manufacture to 21,439 tons of SO_2. The TRENDS procedure specifically excludes natural gas combustion in the glass industry from the industrial natural gas combustion section. As a result the 1,582 tons of SO_2 that are reported in NAPAP with industrial combustion SCCs and glass manufacture SIC's should also be reported in this section. This brings the NAPAP value to 23,021 tons of SO_2.

2.3.10.6 *Conclusion*

The absolute difference between the TRENDS and NAPAP estimates is fairly small and there is no evidence that either is in error. However, the TRENDS method may benefit from two comments.

The purpose of averaging the production numbers and the emission factors in the TRENDS methodology is unclear. If pressed and blown glass represent 10 percent of the industry (both production and emission factor derivations assume this) the production and corresponding emission factors could be applied directly.

(3,670,719 * 3.0 + 11,098,224 * 3.4 + 1,476,894 * 5.6) / 2000 = 28,508 tons

Based on the NAPAP production numbers, the 10 percent pressed and blown glass assumption may be a small overestimate. Because this type of production has the highest SO_2 emission factor, it would also cause the TRENDS estimate to be an overestimation.

2.3.11 Lime Manufacturing

The 1985 TRENDS value is 30,000 tons SO_2. The 1985 NAPAP value is 32,000 tons for lime. The discrepancy between the two inventories is 2,000 tons of SO_2 (6 percent).

2.3.11.1 *TRENDS Activity*

In TRENDS, the lime manufacturing estimate is obtained from "Facts and Figures for the Chemical Industry" published in *Chemical & Engineering News*.[12] In 1985 the U.S primary production was reported as 15,800,000 tons. Annual lime production is also published in Table 1 "Salient Lime Statistics" of *Minerals Yearbook, 1989 "Lime"*.[4] The 1985 value was reported as 15,690,000 tons of lime sold or used by producers.

2.3.11.2 *TRENDS Emission Factor*

The SO_2 emissions are calculated using an emission factor of 3.4 lbs/ton of lime produced. This emission factor was developed from the actual SO_2 emissions reported in NEDS divided by the NEDS lime production rate as reported in February 1980.

2.3.11.3 *TRENDS Emissions*

Emissions are then calculated as:

3.4 * 15,800,000 / 2,000 = 26,860 tons SO_2.

2.3.11.4 *NAPAP Activity*

The reported lime manufacturing production in NAPAP for the three main SCCs is as follows.

SCC	Description	Tons Lime Produced
3-05-016-03	Mineral Products - Lime Manufacture: Calcining, Vertical Kiln	1,020,000
3-05-016-04	Mineral Products - Lime Manufacture: Calcining, Rotary Kiln	15,479,000
3-05-016-17	Mineral Products - Lime Manufacture: Multiple Hearth Calciner	135,000
Total		16,634,000

2.3.11.5 *NAPAP Emissions*

The reported NAPAP SO_2 emissions for lime manufacture are as follows.

SCC	Description	Tons SO_2 Emitted
3-05-016-03	Mineral Products - Lime Manufacture: Calcining, Vertical Kiln	3,085
3-05-016-04	Mineral Products Lime Manufacture: Calcining, Rotary Kiln	18,647
3-05-016-17	Mineral Products Lime Manufacture: Multiple Hearth Calciner	572
3-90-002-03	In-process Fuel Use: Bituminous Coal, Lime kiln	6,384
3-90-004-03	In-process Fuel Use: In-process fuel: Residual oil, Lime kiln	738
3-90-005-03	In-process Fuel Use: Distillate Oil, Lime kiln	12
Total		29,438

In addition, NAPAP reports emissions of 2,263 tons of SO_2 from the Other Not Classified SCC for lime production, which brings the NAPAP total to 31,701 tons of SO_2.

2.3.11.6 *Conclusion*

The emission estimates in TRENDS and NAPAP are practically identical. Nevertheless, the TRENDS emission factor of 3.4 lbs SO_2/ton of lime produced may be too low. There are the following three emission factors in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document with units of lbs SO_2 emissions/ton of lime produced.

SCC	Description	Emission Factor	Units
3-05-016-03	Mineral Products - Lime Manufacture: Calcining, Vertical kiln	8.2	lbs SO_2/ton of lime produced
3-05-016-04	Mineral Products - Lime Manufacture: Calcining, Rotary kiln	5.1	lbs SO_2/ton of lime produced
3-05-016-17	Mineral Products - Lime Manufacture: Multiple Hearth Calciner	8.2	lbs SO_2/ton of lime produced

The distribution of the three types of lime calcining operations and how they dominate the industry should be investigated if an average emission factor is going to be used. In addition, investigation into the use of control devices for the lime manufacturing industry should be investigated. As discussed in cement, any particulate control device for this industry will have very good SO_2 control due to the properties of the lime particulate being captured.

In the NAPAP inventory, calcining with a rotary kiln is the dominant method. A weighted emission factor based on the production figures used in the 1985 NAPAP inventory would lead to the following results. Total NAPAP production is:

1,020,000 + 15,479,000 + 135,000 = 16,634,000 tons.

By percent, the production is distributed across the three categories.

SCC	Description	Percent production
3-05-016-03	Mineral Products - Lime Manufacture: Calcining, Vertical kiln	6
3-05-016-04	Mineral Products - Lime Manufacture: Calcining, Rotary kiln	93
3-05-016-17	Mineral Products - Lime Manufacture: Multiple Hearth Calciner	1

Using these production percents to weight an emission factor results in a factor in excess of the 3.4 TRENDS figure:

8.2(.07) + 5.1(.93) = 5.3 lbs/ton of lime produced.

Using this emission factor results in a revised *uncontrolled* TRENDS emission rate:

15,800,000 * 5.3 / 2000 = 42,000 tons of SO_2.

2.3.12 Additional Industrial Process Emission Categories in the NAPAP Inventory

The NAPAP inventory includes additional emission categories beyond the categories covered by the TRENDS SO_2 emission estimation method. As stated earlier, the TRENDS method was developed to reflect changes in emissions from large (>10,000 tons of SO_2/year) source categories.

Within the chemical manufacturing group of emissions, TRENDS only reports emissions for carbon black, sulfuric acid and elemental sulfur production. Additional sources within the chemical manufacturing source categories are listed in Table 2-12.

TABLE 2-12. EMISSIONS FROM CHEMICAL MANUFACTURING SOURCES INCLUDED IN NAPAP BUT NOT IN TRENDS

Chemical Manufacturing Source Category (SIC)	SCC	1985 NAPAP (tons)[a]
Ammonia Production (2873)	3-01-003	1.094
Charcoal Manufacture (2861)	3-01-006	4.643
Hydrochloric Acid (2819)	3-01-011	1,540
Plastics Production Specific Products (2821)	3-01-018	1.881
Synthetic Rubber (Manufacturing Only) (2822)	3-01-026	4,663
Ammonium Phosphates (2874)	3-01-030	1.554
Sulfur Recovery Plants[b] (2819)	3-01-032	38,920
Inorganic Pigments (2816)	3-01-035	5,682
Propylene, Butylene, Ethylene, and Olefin Production (2869)	3-01-197	4,184
Nitriles, Acrylonitrile, Adiponitrile Production (2869)	3-01-254	3,281
General Processes - Fugitive Leaks (2865, 2869)	3-01-800	1,945
Waste Gas Flares	3-01-900-99	39,620
No SCC Descriptor	3-01-999	48,091
Other		4.499
Total		161.597

[a]*The 1985 NAPAP Emissions Inventory (version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a, November 1989.
[b]Excluding emissions from sulfur recovery at petroleum refineries and oil and natural gas production plants.

In the mineral products group, TRENDS includes emissions from cement, lime and glass manufacturing in the SO_2 emission estimation method. Mineral product source categories included in the NAPAP SO_2 inventory but not addressed in the TRENDS estimate are listed in Table 2-13.

TABLE 2-13. EMISSIONS FROM MINERAL PRODUCTS SOURCES INCLUDED IN NAPAP BUT NOT IN TRENDS

Mineral Products Source Category (SIC)	SCC	1985 NAPAP (tons)[a]
Asphaltic Concrete (2951)	3-05-002	1,959
Brick Manufacture (3251)	3-05-003	2,193
Ceramic Clay Manufacture (3261)	3-05-008	2,362
Clay & Fly Ash Sintering (3295)	3-05-009	1,389
Coal Cleaning & Surface Mining Operations (1111)	3-05-010	12,481
Fiberglass Manufacture - Wool & Textile Type Fiber (3229, 3296)	3-05-012	2,487
Gypsum Manufacture (3275)	3-05-015	9,394
Phosphate Rock (1475)	3-05-019	4,651
Stone Quarrying/Processing (1411, 1422, 1423, 1429, 1499)	3-05-020	6,190
No SCC Descriptor	3-05-999	5,676
Other		1,918
Total		50,700

[a]*The 1985 NAPAP Emissions Inventory (version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a, November 1989.

Finally, the NAPAP inventory includes additional sources of SO_2 emissions from other industrial processes as listed in Table 2-14.

TABLE 2-14. EMISSIONS FROM OTHER INDUSTRIAL PROCESS SOURCES INCLUDED IN NAPAP BUT NOT IN TRENDS

Source Category (SIC)	SCC	1985 NAPAP (tons)[b]
Sugar Beet Processing (2063)	3-02-016	1,918
Other Food and Agriculture (0100, 0200, 0700, 2000, 2100, 4200, 4400, and 5100)	3-02-XXX	1,449
Other Pulp & Paper and Wood Products (2400, 2500, 2600, and 2700)[b]	3-07-XXX	241
Rubber and Miscellaneous Plastics Products (3000, and 7500)	3-08-XXX	773
Fabricated Metal products (3400, 5000)	3-09-XXX	258
Electrical Equipments (7600)	3-13-XXX	463
Machinery, Miscellaneous Leather, and Leather Products	3-12-XXX 3-20-XXX	2
Organic Solvent/Petroleum Product Evaporation	4-XX-XXX	2,374
Total		7,478

[a]*The 1985 NAPAP Emissions Inventory (version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a, November 1989.
[b]Does not include sulfate (kraft) pulping, sulfite pulping, or neutral sulfite semichemical pulping.

SECTION 3
CONCLUSIONS

This in-depth analysis of the 1985 TRENDS and NAPAP emission estimates for industrial SO_2 sources has led to the following conclusions.

First, the TRENDS method is outdated relative to data that are currently available and the 1985 TRENDS estimates, as currently published, contain numerous mathematical errors. In addition, the TRENDS method relies on average fuel consumption values for some industrial processes. These values should be periodically revised and updated.

Second, the TRENDS method does not account for any control measures in the majority of the industrial SO_2 emission estimates.

Third, the NAPAP activity data are not complete enough to provide a reliable estimate of industrial production. Therefore, the NAPAP activity data do not support the generation of global emission factors for future use in the TRENDS method.

Fourth, for the majority of source categories, the NAPAP emission estimates appear more reasonable than the TRENDS estimates.

Due to findings in this report as well as other factors, the TRENDS methodology has been revised as of 1993; thus, references to TRENDS in this report will no longer be valid for years 1985 and beyond, effective with the 1993 edition of the TRENDS report. The new TRENDS methodology uses the 1985 NAPAP Emission Inventory as a base. Further changes will be seen in the TRENDS reports published in 1994 and thereafter. Thus, the reader is cautioned that comments on the EPA TRENDS report in this document are valid for editions prior to 1993, but are not valid for the editions for 1993 and thereafter.

The following discussion has been excerpted from the previous section.

3.1 COMBUSTION SOURCES

The combustion estimates in TRENDS and NAPAP are very similar. This is due in part to the method utilized by NAPAP to estimate area source emissions. In the NAPAP inventory, the industrial point source fuel usage is subtracted from national fuel use estimates provided by the Department of Energy, and emissions from the unaccounted for fuel are allocated to the area source inventory. This method of determining area source emissions or alternatively of accounting for emissions from unaccounted for fuel use has several drawbacks. First, many sources do not report fuel use. Second, the State of Texas does not report any individual fuel use, instead, all industrial fuel use is reported at the county level to ensure confidentiality. As a result, the initial fuel use estimate, reported through NAPAP, is believed to be an underestimate. Consequently, the NAPAP inventory may allocate too much fuel and therefore too many fuel-related emissions to the area source inventory.

In both the NAPAP and the TRENDS method, the majority of the emissions are from the combustion of bituminous coal. The average sulfur content that is used in the computation of the emission factor is extremely important. The TRENDS method has a complicated procedure to determine an average fuel sulfur content based on statistics for the coal-producing regions. The complex method has not been performed recently. Additional research into average sulfur contents for all of the fuels (bituminous coal, anthracite, lignite, residual oil, distillate oil, crude oil and process gas) is warranted.

3.2 COMBUSTION OF OIL

The TRENDS estimate is 72,480 tons for distillate oil excluding cement plants and petroleum refineries. The NAPAP estimate for the same category is 107,358 tons of SO_2. The NAPAP estimate includes 55,000 tons of SO_2 from area sources. The NAPAP and TRENDS estimates are much closer if the NAPAP estimate does not include area source emissions.

The TRENDS estimate is 459,510 tons for residual oil excluding cement plants, petroleum refineries and steel mills. The NAPAP estimate for the same category of emissions is 605,200 tons of SO_2. The NAPAP estimate includes 242,000 tons of SO_2 from area sources. Again, the two estimates would be much closer if the area source component of the NAPAP total were not included.

There are large discrepancies in the oil activity data (quantity of reported combusted) used in the TRENDS method versus the NAPAP inventory for both categories. TRENDS reports 3.426 million gallons and NAPAP reports approximately 2,000 million gallons of distillate oil consumed. Both values appear to be in error. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* reports 31,684,000 bbls consumed (1,330.7 million gallons). This survey reports an activity that is approximately one-third the value reported in TRENDS.[8]

TRENDS reports 3,555 million gallons and NAPAP reports approximately 6,000 million gallons of residual oil consumed. Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] reports 80,252,000 bbls consumed (3,370.6 million gallons).

The activity data used in TRENDS were derived from *Fuel Oil and Kerosene Sales*.[3] If these data were also used to compute area source activity in NAPAP, this could have resulted in an overestimation of both residual oil and distillate consumed and resulting emissions reported in NAPAP through the area source category. It is likely that the NAPAP point source inventory underreported both distillate and residual oil consumption and that the NAPAP area source inventory overestimated emissions for these two categories. The discrepancy between the distillate oil consumption reported though *Fuel Oil and Kerosene Sales* and *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* should be investigated.

The development of average sulfur contents for distillate and residual oil is not well documented in the TRENDS procedure. The sulfur content assumptions have a large impact on the overall emission factor. Additional effort should be expended to determine reasonable average sulfur contents and to determine if industrial oil consumers are electing to use lower sulfur content oil, and if so, what the overall effects are on emissions from this category.

The NAPAP inventory also includes, as residual oil burned, approximately 932,000 x 10^6 gallons of crude oil which is burned during crude oil production. This oil use is not counted by TRENDS and was placed in the residual oil category because no other category existed in NAPAP

3.3 COAL COMBUSTION

As stated above, industrial coal combustion, specifically bituminous coal combustion is by far the largest single category of industrial SO_2 emissions. In the TRENDS method, emissions from bituminous, subbituminous and lignite are combined in one estimate and coal burned in cement and lime kilns is subtracted. TRENDS assumes that all of the remaining industrial coal combustion occurs in boilers. An average emission factor is developed based on an average sulfur content.

The initial bituminous, subbituminous, and lignite activity value, including coal combusted in lime manufacturing and cement plants, is 75.3 million tons in TRENDS versus 74.5 million tons in NAPAP. Both of these values are fairly consistent with Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* which reports 59.195 million tons of coal burned in the industrial sector. The anthracite activity value that is published in the TRENDS activity spreadsheet could not be replicated. Following the published TRENDS procedure manual resulted in an activity value of 800,000 tons of anthracite versus 658,800 tons of anthracite that is currently in the TRENDS activity spreadsheet.

The published TRENDS emission estimate for coal combustion is a sum of the anthracite value and the bituminous, subbituminous, and lignite value. The published TRENDS value of 1,840,000 tons of SO_2 for coal combustion could not be replicated by following the published TRENDS procedure. The bituminous, subbituminous, and lignite emission estimate in TRENDS, excluding lime and cement emissions, is 1,670,000 tons of SO_2 versus 1,710,000 tons of SO_2 reported in NAPAP The anthracite emission estimate is 11,000 tons of SO_2 in both TRENDS and

NAPAP. Again, the NAPAP inventory relies on a total fuel balance to determine the area source emissions (356,000 tons of SO_2) for this category. For this category the addition of the area source emissions brings the NAPAP and TRENDS estimate closer together. The sulfur contents and resulting emission factors that were actually used in the 1985 estimate are not documented and assumptions made about an average sulfur content for the bituminous, subbituminous, and lignite category may be the reason for the difference.

The four types of coal that constitute the coal combustion category each have slightly different emission factors. The general emission factors for external combustion in industrial boilers are as follows.

Anthracite	1-02-001-01,07	39.0S
Bituminous	1-02-002-01,19	39.0S
Subbituminous	1-02-002-21,29	35.0S
Lignite	1-02-003	30.0S

Although there are a couple of smaller emission factors for some types of bituminous coal combustion (for example fluidized bed), these constitute a very small amount of the coal combustion activity.

Sulfur contents reported in the NAPAP inventory for these four general types of coal range as follows.

1-02-001-01,07	0.7 to 1.2 percent
1-02-002-01,19	1.0 to 1.9 percent
1-02-002-21,29	0.4 to 1.5 percent
1-02-003	0.5 to 0.9 percent

Average sulfur contents, based on emissions and reported coal consumption, are as follows.

1-02-001-01,07	0.7 percent
1-02-002-01,19	1.4 percent
1-02-002-21,29	0.7 percent
1-02-003	0.7 percent

Use of these sulfur contents results in the following average emission factors.

Anthracite	1-02-001-01,07	27.3 lb/ton burned
Bituminous	1-02-002-01,19	54.6 lb/ton burned
Subbituminous	1-02-002-21,29	24.5 lb/ton burned
Lignite	1-02-003	21.0 lb/ton burned

The TRENDS emission factor of 27.3 for anthracite combustion appears reasonable. The TRENDS emission factor of 54.3 for bituminous, subbituminous, and lignite is probably an overestimation.

The TRENDS procedure manual refers to the use of control assumptions as documented in the EIA-767 data. If control assumptions have been applied (EIA-767 data pertain to utilities and should not be used to estimate controls on the industrial sector) they are not documented. There are probably some industrial emission controls that are applied to the NAPAP estimates and are not reflected in the TRENDS method.

3.4 NATURAL GAS COMBUSTION

The TRENDS method excludes natural gas combustion from cement manufacturing, petroleum refineries, the iron and steel industry, glass manufacture, and oil and natural gas production. Once these emissions are excluded, the resulting TRENDS emission estimate is 1,400 tons of SO_2. Because TRENDS rounds their estimates to 10,000 tons/year, the emission estimate for natural gas combustion in boilers is 0.0 tons. The NAPAP emission estimate is 32,800 tons of SO_2 excluding natural gas combustion from cement manufacturing, petroleum refineries, the iron and steel industry, glass manufacture, and oil and natural gas production.

The activity rates for natural gas combustion in boilers reported in the NAPAP inventory are not consistent with the emission estimates. In addition, the total (unadjusted) natural gas reportedly consumed is over 715,188 billion ft^3 in NAPAP versus 5,901 billion ft^3 in TRENDS. This may be due in part to the reporting of natural gas consumption as a feedstock versus as a fuel in the NAPAP inventory. The TRENDS value is fairly consistent with the 4,512 billion ft^3 reported through the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985.*[8]

The high consumption of natural gas in the NAPAP inventory may correlate with an overestimation of natural gas emissions. In the NAPAP inventory, the user had the option of entering an activity rate and allowing the system to calculate emissions based on an emission factor. If the user incorrectly coded the activity for natural gas combustion (usually through a misunderstanding of the appropriate units) and allowed the system to estimate the emissions, the emissions would be overestimated.

Conversion factors are used to correlate natural gas combustion with both the iron and steel industry and the glass manufacturing industry. These factors are suppose to be periodically updated based on information available through the Department of Energy. The value for the steel industry that is currently used is 4.25 million ft^3 of natural gas/10^3 tons of raw steel. The value for the iron and steel industry can be updated with information provided in Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group, and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985.*[8] Natural gas consumed by blast furnaces and steel mills was 400 billion cubic feet (TRENDS calculated 375 billion cubic feet for raw steel). Based on a 1985 raw steel production of 88,259,000, a revised factor for iron and steel would be:

$$400{,}000 / 88{,}259 = 4.53\ 10^6\ ft^3/10^3\ \text{ton raw steel.}$$

The value for glass cannot be recalculated at this time because the reference cited combines stone, clay, and glass products.

3.5 MISCELLANEOUS FUELS

The TRENDS method includes four categories of fuel in the industrial SO_2 miscellaneous fuels category. The emissions from the four categories are published together as one value of 80,000 tons of SO_2. Several apparent errors were discovered in the TRENDS method. Correcting the errors would result in a revised TRENDS estimate of 30,000 tons of SO_2 for miscellaneous fuels. The four fuels are coke, coke oven gas, kerosene, and liquified petroleum gas (LPG) and are discussed separately below.

3.5.1 Coke

The coke emissions are 11,300 tons of SO_2 in NAPAP and 36,000 tons of SO_2 in TRENDS.

There are several problems in the TRENDS activity data. The activity value in the TRENDS spreadsheet could not be reproduced by following the procedure. TRENDS lists 1,343,000 tons in the activity spreadsheet: following the TRENDS procedure resulted in a value of 1,621,000 tons. The *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*[8] lists 1,952,000 tons of coke and breeze for industries other than blast furnaces and steel mills. Therefore, the activity value for coke combustion is probably too low in the TRENDS procedure. Also, it is unclear why the TRENDS procedure includes petroleum coke delivered to electric utilities in the industrial coke activity value.

The coke combustion emission factor used in the TRENDS method probably overestimates the emissions from this category. TRENDS uses an emission factor of 30.0 lb/ton burned. The *AIRS Facility Subsystem SCC and Emission Factor Listing for Criteria Pollutants*[7] has an emission factor of 39.0S lb/ton burned. The NAPAP inventory lists an average coke sulfur content of 0.7 percent which results in an overall emission factor of 27.3 lb/ton burned.

A revised emission estimate using the smaller emission factor and the coke consumption value derived following the published TRENDS procedure would result in a TRENDS coke combustion emission estimate of 22,000 tons of SO_2.

3.5.2 Coke Oven Gas

The coke oven gas emissions are 2,700 tons of SO_2 in NAPAP and 43,300 tons of SO_2 in TRENDS. It appears as though TRENDS overestimates SO_2 emissions for combustion of coke oven gas outside the iron and steel industry.

TRENDS assumes 18.8 percent of the coke oven gas produced is burned in boilers outside the iron and steel industry. The 18.8 percent is not documented. In addition, the TRENDS iron and steel section assumes that 40 percent of coke oven gas is used in the iron and steel process equipment (see Roll and Finish subsection of iron and steel). The TRENDS procedure apparently does not account for the remaining 40 percent of coke oven gas produced. Table 12 "Production and Disposal of Coke Oven Gas in the United States by Producing State: 1980" of *Coke and Coal Chemicals in 1980*[20] reports that in 1980 coke gas use was 39 percent used by producers in heating ovens, 58 percent was for other use by producers, 1.4 percent commercial sales, and 1.5 percent was wasted.

TRENDS lists a coke oven gas average sulfur value of 1.605 percent. The NAPAP inventory lists an average sulfur content for coke oven gas of 0.5 percent. Using a factor of 1.4 percent of coke oven gas burned in industrial boilers outside the iron and steel industry and using the NAPAP average sulfur content results in emissions of:

$$451{,}616 * 0.014 * 680 * 0.5 / 2000 = 1{,}075 \text{ tons of } SO_2.$$

Two issues in the TRENDS method need to be addressed. First, the amount of coke oven gas consumed outside of the iron and steel industry must be examined. Second, a reasonable sulfur content for coke oven gas should be determined.

3.5.3 Kerosene

The kerosene emissions are 421 tons of SO_2 in NAPAP and 2,491 tons of SO_2 in TRENDS. The TRENDS method overestimates kerosene emissions. The emission factor used in the TRENDS procedure to estimate kerosene emissions is actually an emission factor for distillate oil. The emission factor cited is 10.77 lb/10^3 gallon burned. Using a kerosene emission factor of 6.2 lb/10^3 gallon burned results in emissions of:

462,630 * 6.2 / 2000 = 1,434 tons of SO_2.

3.5.4 LPG

The LPG emissions are 52 tons in NAPAP and 109 tons in TRENDS. Both values are insignificant. Following the TRENDS procedure manual did not result in the same activity value for LPG combustion as is published in the TRENDS activity spreadsheet. The LPG activity value used in the 1985 TRENDS estimate is higher (1;979 million gallons versus 1,116 million gallons) than the value reported through the *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*.[8] Using the value reported through the survey results in emissions of:

1,116,000 * 86.5 * 0.0013 / 2000 = 63 tons of SO_2.

The TRENDS procedure for determining LPG combustion activity is difficult to understand. A preferred approach may be to hold the value constant and update it every three years with a new *Manufacturing Energy Consumption Survey.*

3.6 WOOD

The TRENDS emission estimate for wood combustion is 10,000 tons of SO_2. The NAPAP estimate is 41,700 tons of SO_2. The area source component of the NAPAP estimate is rather substantial (17,000 tons of SO_2). Nearly half of the NAPAP point source emissions are from a general in-process wood combustion category. The emission factor for this category (3-90-008-89) is 38.0S lbs/ton burned. NAPAP also reports an average sulfur content of 1.5 percent for the SCC. The resulting emission factor (57 lb/ton of wood burned) is substantially higher than the emission factor used in TRENDS and the rest of the NAPAP categories (0.15 lb/ton burned). As a result, this SCC category is responsible for a disproportionate share of the NAPAP wood combustion point source emissions. Due to the high emissions for this one point source category and the high area source estimate, the NAPAP inventory probably overestimates the wood combustion emissions.

Following the TRENDS procedure did not recreate the activity value that was used in the calculation of the 1985 emission estimate for wood combustion. However, once the emission estimate is rounded to the nearest 10,000 tons, the difference is insubstantial.

3.7 NON-FERROUS SMELTING SOURCES

Non-ferrous smelting emissions are an important component of industrial SO_2 emissions because sulfur is present in the ores. Consequently, sulfur recovery is a important component of the emission estimate. The TRENDS method determines sulfur recovery through statistics reported through the *Minerals Yearbook*. The values cited in the reference (501,5000 tons of SO_2 recovered as H_2SO_4) were apparently not used in the development of the published 1985 TRENDS emission estimate (327,900 tons of SO_2 recovered as H_2SO_4).

The TRENDS method includes emission estimates for primary copper, primary lead, primary zinc, primary aluminum, and secondary lead. The primary copper estimates are obtained on a point by point basis from the remaining domestic primary copper smelters. As a result, the TRENDS and NAPAP estimate are consistent for primary copper smelters.

The primary lead and primary zinc estimates are combined and reported as one value. Following the TRENDS procedure did not recreate the published primary lead and primary zinc emission estimate. The TRENDS method appears to overestimate the emissions from primary lead, primary zinc, primary aluminum and secondary lead.

3.7.1 Primary Zinc

The TRENDS published estimate for primary zinc production is combined with the primary lead estimate and the published total of 240,000 tons of SO_2 from both industries could not be recreated. This discussion is based on the estimate for primary zinc that was developed following the TRENDS procedure. The NAPAP and TRENDS estimates for emissions from primary zinc production are very different. NAPAP reported emissions of 7,642 tons of SO_2 and the TRENDS method resulted in an emission estimate of 93,864 tons of SO_2. As stated above, the value used for sulfur recovered as H_2SO_4 apparently was in error and this error could account for the inability to recreate the published TRENDS value.

The TRENDS method only accounts for emissions from multiple hearth roasters. In addition, TRENDS assumes all roasting is done in a multiple hearth roaster. Two additional SCCs for roasting exist, flash roaster (3-03-030-07) and fluid bed roaster (3-03-030-08). Both have a smaller emission factor (404.4 and 223.5 lbs/ton of concentrated ore processed respectively) than the multiple hearth roaster (1100 lbs/ton of concentrated ore processed).

The NAPAP inventory did not report the majority of emissions through the multiple hearth roaster. The NAPAP inventory may have overestimated SO_2 emissions from some of the other processes in zinc production (specifically the sinter strand and the vertical retort/electrothermal furnace SCC 3-03-030-03,05). The discrepancy in NAPAP where the majority of emissions were not reported through the roasting process needs to be investigated.

3.7.2 Primary Lead

As mentioned above, the published TRENDS value of 240,000 tons of SO_2 for primary lead and zinc could not be recreated. The TRENDS estimate developed following the TRENDS procedure was 34,500 tons of SO_2, which differs markedly from the NAPAP estimate of 98,775 tons of SO_2.

The TRENDS method for determining primary lead SO_2 emissions is very complex and appears to be outdated relative to the data that are currently provided in the *Minerals Yearbook, 1989*.[4] The TRENDS method has four steps to determine lead processing. After following the four steps, the result was a lead processing value of 975,378 short tons, which did not match the value of 759,300 tons in the TRENDS activity spreadsheet. After analyzing the four steps that currently comprise the TRENDS emission estimation procedure for primary lead, it appears that the final number is a simple sum of the emissions reported through NEDS (now AFS) and the sulfur recovered as sulfuric acid. The recovered sulfur is then subtracted from the emission estimate. Therefore there should be complete agreement between NAPAP and TRENDS for this category. If the product of the TRENDS method is intended to be different from the simple sum, there are errors in the TRENDS procedure manual that need to be addressed.

The NAPAP activity for this category is fairly close to the activity published in the *Minerals Yearbook*.[4] The *Minerals Yearbook* cites a 1985 production of 543,403 short tons. TRENDS assumes that there is a 2:1 ratio of concentrated ore processed to lead produced. NAPAP reports 1,006,182 tons of concentrated ore processed in the blast furnace, which would correspond to a lead production rate of 503,000 tons of lead.

3.7.3 Primary Aluminum

The TRENDS estimate is 70,000 tons of SO_2 from primary aluminum smelters, the NAPAP estimate is 58,400 tons of SO_2. The TRENDS estimate relies on an average emission factor derived from the 1980 NEDS data for the State of Washington. The validity of the TRENDS emission factor for primary aluminum could not be confirmed and appears suspect for two reasons. First, it relies on one set of old emissions (not test) data. Second, there is no documentation of an adjustment due to controls.

There are three very different emission factors in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants* document for primary aluminum smelting, prebake (57.3 lbs/ton), HSS (10.0 lbs/ton), and VSS (17.0 lbs/ton).[7] An investigation into the distribution of the three types of electro-reduction processes, their controls and how they dominate the primary aluminum industry should be undertaken to develop an appropriately weighted emission factor. The 1985 NAPAP production estimates provide the following distribution between the three process types: prebake (77.2 percent of production), HSS (7.9 percent of production), and VSS (14.8 percent of production). Using this weighing would result in an emission factor of 47.5 lbs/ton (versus the current TRENDS emission factor of 36.85 lbs/ton). If the 1985 NAPAP primary aluminum emission estimate is used to develop a revised emission factor, an overall factor of 19.8 lbs/ton Al produced results. The absolute factor is lower presumably because NAPAP accounts for the effect of SO_2 controls.

In the NAPAP inventory, only 38,063 tons of SO_2 are attributable to the three processes covered by the TRENDS method. Of the processes that are not included in TRENDS, aluminum hydroxide calcining is the most important. TRENDS includes the aluminum hydroxide calcining process in the estimation of TSP and PM-10 emissions but not in the SO_2 estimate.

3.7.4 Secondary Lead

The TRENDS estimate for secondary lead smelters is 30,000 tons of SO_2 compared to 20,700 tons of SO_2 reported in the NAPAP inventory. The TRENDS estimate has a slight error in that the activity value for the blast furnace was not converted to english units. This will not make a significant difference in the published TRENDS estimate, because the values that are published are rounded to the nearest 10,000 tons. The TRENDS estimate does not account for SO_2 controls such as baghouses and wet scrubbers.

There is a new SCC, with an SO_2 emission factor of 144.0S lbs $SO_2/10^3$ gallons burned, for this category. The SCC is 3-04-004-07 for pot furnace heater burning distillate oil. This SCC is not in the TRENDS method and not in the NAPAP inventory.

3.7.5 Other Non-ferrous Emissions Reported in NAPAP

Additional emissions of 41,511 tons of SO_2 are reported for other non-ferrous emission categories in the NAPAP inventory. The largest source categories include ferroalloy manufacture, furnace electrode manufacture, secondary aluminum and secondary zinc. Of these categories only the ferroalloy source category has emissions of more than 10,000 tons of SO_2 in 1985.

3.8 OTHER INDUSTRIAL PROCESS EMISSION SOURCES

Significant differences exist in the 1985 TRENDS and NAPAP SO_2 emission estimates for other industrial process emissions. In general, the TRENDS estimates depend on national production figures developed by the Department of Energy and the Department of Commerce and an emission factor. The emission factor often represents the largest sources of emissions within the category. To compare the NAPAP and TRENDS estimate, the entire NAPAP estimate for the category is used. This would include in-process fuel, fugitive emissions, and processes that are not specifically cited in the TRENDS method.

The TRENDS method, with very few exceptions, does not include effects of air pollution control devices unless the effects are inherent in the process (*e.g.*, sulfur recovery) or in the emission factor. The TRENDS estimates for most categories are significantly higher than the corresponding NAPAP estimates. A major exception to this statement is the category Oil and Natural Gas Production.

The NAPAP inventory includes many additional source categories that are not included in the TRENDS industrial SO_2 emission estimation method. The TRENDS method includes only three categories in the chemical manufacturing group; sulfur, sulfuric acid, and carbon black. The NAPAP inventory includes ten additional chemical manufacturing source categories with combined additional emissions of 127,000 tons of SO_2. The TRENDS method includes three categories in the mineral products manufacturing group; cement, glass, and lime. The NAPAP inventory includes nine additional mineral products manufacturing source categories with combined additional emissions of 50,800 tons of SO_2.

3.8.1 Kraft Pulp Production

The published TRENDS value for pulp and paper production is 250,000 tons of SO_2 and is probably an overestimate. The NAPAP value is 130,400 tons of SO_2.

The TRENDS method apparently used an emission factor of 11.3 lbs/ton of air-dry unbleached pulp to calculate kraft emissions, when a more appropriate value would have been approximately 7 lbs/ton of air-dry unbleached pulp. It is unclear how the 11.3 emission factor was derived since it is significantly higher (nearly 50 percent) than one calculated following the TRENDS procedure. Based solely on the discrepancy, TRENDS emissions may be overstated by nearly 70,000 tons. Also, TRENDS does not account for the effect of any controls. These two issues could result in an overestimation of SO_2 emissions from wood pulping processes.

The TRENDS procedure does not include a third type of paper pulping process, semi-chemical. Activity data for semi-chemical pulping are available and emission factors exist in AP-42.[19] Published statistics indicate that semi-chemical production has recently overtaken sulfite (3.9×10^6 vs. 1.6×10^6 tons) production. If the semi-chemical production is increasing with fewer associated SO_2 emissions, this industry trend should be reflected in the emission estimates.

3.8.2 Carbon Black Manufacture

The carbon black production emission estimates are 28,031 tons of SO_2 in NAPAP versus 14,585 tons of SO_2 in TRENDS. The TRENDS method appears to underestimate the emissions from carbon black manufacture.

The total NAPAP production for the oil furnace of 1,013,232 is very similar to the value TRENDS references (90 percent of total production) 1,156,500. The NAPAP value for the gas furnace 98,179 is less similar to the value TRENDS references (10 percent of total production) 128,500 tons.

Two questionable items need to be addressed regarding the NAPAP emission estimates and the TRENDS emission factor. The NAPAP emission estimates by SCC show only a minority of emissions from the oil furnace (3,958 out of 28,031 tons), although logically this would be the source of most emissions. However, the pellet dryer combustion furnace (with emissions of 15,183 tons) is, in essence, a thermal incinerator and emissions associated with the furnace itself are emitted here. It is likely that engineers coding the NAPAP inventory indicated the vents as discrete emission points in addition to the oil furnace emission source.

Second, the TRENDS emission factor appears to be too small. The TRENDS procedure initially uses a fairly high emission factor of 50 lbs/ton for the flare from an oil furnace process (this emission factor is supported by AP-42). If a CO boiler and incinerator exist, primarily to control CO emissions, the AP-42 SO_2 emission factor drops to 35.2 lbs/ton. The TRENDS number is 22.7 lbs/ton, and is unlikely that the emission factor would drop that low, even if all sources had a CO boiler and incinerator.

As noted, the largest source of emissions in NAPAP is for the pellet dryer. There is no corresponding category in TRENDS for the pellet dryer, although it is likely that emissions have been accounted for. As stated earlier, there is no NAPAP category specifically for the flare, however, the flare actually represents otherwise uncontrolled oil furnace emissions.

The TRENDS documentation probably needs to be modified to ensure that all emission points and sources are included. Further investigation of the NAPAP value is warranted to determine why emissions associated with the oil furnace were distributed to other emission points (vents) if possible. Finally, the assumption that flares represent otherwise uncontrolled emissions could be confirmed by looking at the control equipment for these sources coded in NAPAP.

3.8.3 Sulfuric Acid

The NAPAP estimate of 217,166 tons of SO_2 is extremely close to the TRENDS estimate of 215,405 tons of SO_2. One concern about this category is the production of H_2SO_4 from recovered sulfur. The NSPS does not apply to sulfuric acid production in conjunction with SO_2 controls. It is unclear if the NAPAP data reflect only the chemical companies producing sulfuric acid or if NAPAP estimates also reflect byproduct H_2SO_4 production.

There are several minor errors in the development of the published TRENDS estimate. The errors included use of an incorrect production value for 1984 from which the 1985 emission factor is derived. Because the TRENDS estimates are rounded to 10,000 tons of SO_2, the error did not make a significant difference in the published estimate.

This is the only category of industrial SO_2 emissions where the TRENDS method addressed the implementation of NSPS. The NSPS emission factor of 4 lb SO_2/ton of 100 percent sulfuric acid produced is consistent with the emission factor for sulfuric acid contact process, 99.9 percent conversion. In the NAPAP inventory, the activity for 99.9 percent conversion dominates the category. An analysis of the production data provided in *Current Industrial Reports, Inorganic Chemicals*[22] reveals that production had a low value of 33,233,000 tons of sulfuric acid in 1982 and a high of 44,336,818 in 1990. Because the NSPS was promulgated in the 1970's, production over 33,233,000 (and at least 25 percent of production) should be at the NSPS level. The NAPAP data indicate that approximately 50 percent of 1985 production was at the NSPS level.

3.8.4 Sulfur Recovery Plants

The TRENDS procedure manual has a separate section for estimating SO_2 emissions from sulfur recovery plants. The resulting emission estimates are published in two other categories, natural gas production and petroleum refining. As a result, it is not possible to directly assess whether the published emission estimates were successfully recreated although using the emission estimates does allow the total natural gas production and total petroleum refinery estimates to match the published values.

Errors were discovered in both the activity data and the emission factors that were used to calculate the published 1985 estimates. As a result, the published TRENDS emission estimate is too high. The estimates using the erroneous information are 202,000 tons for petroleum refineries and 163,000 tons for natural gas production. The corresponding NAPAP emission estimates are 29,117 tons for petroleum refineries and 59,498 tons for natural gas production.

The activity data were erroneously left in metric units rather than converted to English units. The emission factor was not calculated from AIRS data, as the procedure manual indicated, but rather was held constant. Using the revised emission factor (106.8 lbs/ton of sulfur produced versus

137.5 lbs/ton of sulfur produced) and corrected activity data resulted in TRENDS emission estimates of 172,696 tons for petroleum refineries and 139,374 tons for natural gas production (a decrease of 53,198 tons of SO_2).

The emission factors reported in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] range from 280 to 4 lbs/ton 100 percent sulfur recovered depending on the sulfur removal efficiency. Multiplying the NAPAP sulfur recovery production values by these emission factors results in a higher NAPAP total emission estimate of 103,348 tons of SO_2. There is a discrepancy between the production values, emission factors, and reported emissions in the NAPAP inventory. The emissions for 95-96 percent recovery appear to be underestimated and the emissions for 99.9 percent recovery appear to be overestimated. Therefore there are probably errors in the NAPAP values, either in the reported production or in the reported emissions.

Additional research should be expended on this category to try and determine what types of sulfur recovery plants are in use in petroleum refineries and natural gas production fields. Once there is additional information, a new appropriately weighted emission factor could be developed for the TRENDS procedure.

3.8.5 Petroleum Refineries

The petroleum refining emission estimates in TRENDS and NAPAP are quite different. The TRENDS method estimates emissions for six categories for a combined estimate of 830,000 tons of SO_2. NAPAP estimates emissions for more than six categories of emissions. For the six categories that correspond to the TRENDS estimate, NAPAP estimates 520,445 tons of SO_2, however, NAPAP has a total estimate of 640,000 tons for petroleum refining.

Fluid catalytic cracking dominates the TRENDS estimate with 326,317 tons. The NAPAP estimate is significantly lower, 204,647 tons of SO_2. It is unclear why the NAPAP emission estimate is so much lower, the reported NAPAP activity is actually higher than the TRENDS activity (1,585 versus 1,324 million bbl/year fresh feed).

Thermal catalytic cracking activity relies on an annual survey conducted by the *Oil & Gas Journal.*[19] The NAPAP emission estimate and the NAPAP activity are both an order of magnitude higher than the TRENDS values, although the emissions are relatively insignificant relative to fluid catalytic cracking. The emissions are 7,273 tons versus 522 tons and the activity is 12 versus 17 million bbl/year fresh feed.

NAPAP reports significantly higher emissions for oil combustion at petroleum refineries. NAPAP has an emission estimate of 117,512 tons versus the TRENDS estimate of 44,360 tons of SO_2. The TRENDS procedure should be rewritten to reference the oil fired process heater SCC's. The sulfur content of the oil burned and consequently the emission factor used by TRENDS for oil-fired process heaters appears to be too low. The majority of the oil reported burned is actually crude oil (94 percent) and the distillate oil (5.4 percent) is far more significant than the residual oil (0.6 percent). Therefore the use of a residual oil emission factor is not very accurate. There is no emission factor for combustion of crude oil in process heaters at a petroleum refinery. Emission factors used in the industrial oil combustion section are 42.3 lbs/10^3 gallon burned for distillate oil and 258.5 lbs/10^3 gallon burned for residual oil. Using the residual oil emission factor, which appears to be the intent of the TRENDS procedure manual, would result in 76,911 tons of SO_2 from process heaters burning oil.

The emission estimates for gas-fired process heaters are 117,237 tons of SO_2 in NAPAP versus 231,106 tons of SO_2 in TRENDS. For gas-fired process heater emissions, the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] breaks out the emission factors for natural-gas fired 0.6 lbs/10^6 ft^3 versus 950.0S lbs/10^6 ft^3 process-gas fired. The TRENDS emission factor of 253.1 lbs/10^6 ft^3 appears to be somewhere in between the emission factors for the two fuels. The quantity of process gas combusted as a fuel is three times as high as the amount of natural gas combusted. The natural gas emissions are 146 tons of SO_2.

Finally, the emission estimates for sulfur recovery at petroleum refineries is also very different. The NAPAP inventory reports emissions of 29,117 tons of SO_2 and the TRENDS estimate is 202,125 tons of SO_2. Errors were discovered in the execution of the TRENDS method (as discussed in Section 2.3.3) and the TRENDS emission estimate should be 172,696 tons of SO_2, however the numbers are still very dissimilar. Research into the types of sulfur recovery units employed at petroleum refineries (and their consequent emissions) is warranted.

The data required to determine thermal catalytic cracking versus the fluid catalytic cracking are no longer available. The thermal catalytic cracking contributes 0.16 percent of the cracking emissions in the TRENDS estimate but contributes 3.4 percent in the NAPAP inventory. Significant effort to find a replacement source of data for thermal cracking may not be warranted, however, additional research into why the NAPAP activity rates for thermal catalytic cracking are so different from TRENDS may be warranted. Effort to determine why the fluid catalytic cracking estimate is so much lower in NAPAP is definitely warranted.

3.8.6 Natural Gas Production

The NAPAP and TRENDS estimates for this category are very different. The TRENDS estimate is made up of two numbers, emissions from combustion of natural gas during natural gas production and emissions from sulfur recovery units at natural gas plants.

Both NAPAP and TRENDS have small combustion estimates (460 versus 7,660 tons of SO_2). The estimates for sulfur recovery are very different (163,143 tons of SO_2 in TRENDS versus 59,498 tons of SO_2 in NAPAP). As stated earlier, errors were discovered in the TRENDS estimate and the value should be 139,374 according to the procedure manual. Research into the type of sulfur recovery units that are utilized in natural gas production should be conducted.

NAPAP reports an additional 264,911 tons of SO_2 from standard natural gas production processes including gas-sweetening amine process, gas stripping operations and flares. It is unclear why these processes are not accounted for in the TRENDS method.

3.8.7 Iron and Steel

All four of the iron and steel categories, coke manufacture, sintering, open hearth furnace, and roll and finish operations, have significantly different emission estimates in TRENDS and NAPAP. The four categories are discussed separately.

For coking emissions, TRENDS lists the six SCC categories that are used in their estimate. Using these six SCC categories provides coking emission estimates of 65,367 tons (NAPAP) versus 162,000 tons (TRENDS). Even if all of the NAPAP coke emissions are counted, the total NAPAP estimate for coke is only 74,629 tons of SO_2.

The TRENDS method appears to overestimate coking emissions. One possible cause for over estimation in the procedure is the inclusion of beehive process coke manufacturing in the activity number when beehive process coke production may not have any associated SO_2 emissions (there is a 0.0 as an emission factor in the SCC book and the NAPAP emission estimate is 1,599 tons of SO_2). Another possible disconnect is the accounting of SO_2 control techniques in the NAPAP inventory. Finally, the NAPAP inventory may have emissions from coke production reported in other iron and steel processing steps.

The sintering emission estimate is 21,000 tons of SO_2 in TRENDS versus 34,506 tons of SO_2 in NAPAP. The open hearth emission estimate is 4,650 tons of SO_2 in TRENDS versus 1,169 tons of SO_2 in NAPAP. For both these categories, the TRENDS method utilizes an emission factor that was derived from 1980 NEDS statistics.

The 1985 NAPAP inventory underwent significantly more review than the 1980 NEDS estimates. In addition, the 1985 numbers are more current. Therefore the 1985 values are more suitable for use to calculate sintering and open hearth emissions in the TRENDS method, although their absolute reliably for this purpose is unclear. Revising the emission factor based on the 1985 NAPAP emission estimate and utilizing the activity data that are available through the *Minerals Yearbook* would make the TRENDS and NAPAP emission estimates equivalent for these two categories of emissions. The overall sintering emission factor would increase from 2.5 lbs/ton steel produced to 4.11 lbs/ton of pig iron sintered. The overall emission factor for open hearth furnaces would decrease from 1.5 lbs/ton produced to 0.4 lbs/ton produced. These changes in the emission factors are so drastic that they cast doubt on this method of obtaining an emission factor.

The TRENDS roll and finish emission estimate of 168,000 tons of SO_2 is substantially higher than the NAPAP estimate of 25,304 tons of SO_2. The TRENDS category may be misnamed as it is really a sum of emissions from combustion of coke oven gas and residual oil. Although a long involved procedure is put forth to calculate the roll and finish emission factor, the factor has not changed from 1985 though 1991 and therefore the procedure has probably not been used. After following the procedure, a roll and finish emission factor of 4.04 was developed versus 3.8 lbs/ton of raw steel in the current TRENDS spreadsheets. Both of these emission factors are too high.

The reason the TRENDS roll and finish emission factor is so high is based on the ratio of residual oil used to produce steel. The TRENDS Procedures Manual uses a factor of 7.38 gal/ton of steel produced. Based on the data in Table 3 "Total Inputs of Energy for Heat, Power, and Electricity Generation by Census Region, Industry Group and Selected Industries, 1985" of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985*, the total residual oil used in blast furnaces and steel mills was 5,458,000 barrels in 1985.[8] Together, the changes in the coke oven gas and residual oil emission estimate would decrease the TRENDS roll and finish estimate from 168,000 tons to 87,000 tons SO_2.

3.8.8 Cement Manufacturing

There is a significant difference in the 620,000 tons of SO_2 estimated in the TRENDS method versus the 290,700 tons of SO_2 estimated in the NAPAP inventory for cement manufacture. The TRENDS method apparently double counts the fuel sulfur. The AP-42 emission factor of 10.2 lbs/ton cement produced that was used in the TRENDS method accounts for the fuel sulfur. The TRENDS method adds coal, residual oil, and distillate oil combustion emission estimates to the estimate made with the 10.2 lbs/ton cement produced emission factor. This is a significant error in the TRENDS method.

In the time since the TRENDS method was last revised and the NAPAP inventory was completed, the Portland cement section of AP-42 has been updated. AP-42 currently lists the uncontrolled SO_2 emission factor for the dry process as 7.0 lbs/ton of clinker produced and for the wet process as 6.0 lbs/ton of clinker produced when coal is the fuel. Coal dominates as the fuel of choice providing 93 percent of kiln fuel consumption. The dry production is overtaking wet production with a corresponding lower energy requirement per ton of clinker produced.

Statistics for manufacture of both (using all types of fuel) are available in *Minerals Yearbook "Cement"*.[4] Total 1985 production using the wet process was 26,066 10^3 tons of clinker and using the dry process was 37,797 10^3 tons of clinker. Assuming that the AP-42 emission factors (which are for coal burned) apply, emissions can be calculated as 210,500 tons of SO_2. These are uncontrolled emissions. AP-42 states that the use of a baghouse (for particulate control) would result in approximately 75 percent reduction in SO_2 due to the basic nature of the particulate (calcium). Assuming 75 percent control would result in emissions of 52,600 tons of SO_2.

3.8.9 Glass Manufacturing

The TRENDS estimate for glass manufacture is 30,000 tons of SO_2 and the NAPAP estimate is 23,000 tons of SO_2. The absolute difference between the TRENDS and NAPAP estimates is fairly small and there is no evidence that either is in error. However, the TRENDS method may benefit from two comments.

The purpose of averaging the production numbers and the emission factors in the TRENDS methodology is unclear. If pressed and blown glass represent 10 percent of the industry (both production and emission factor derivations assume this) the production and corresponding emission factors could be applied directly.

Based on the NAPAP production numbers, the 10 percent pressed and blown glass assumption may be a small overestimate. Because this type of production has the highest SO_2 emission factor, it would also skew the TRENDS estimate to an overestimation.

3.8.10 Lime Manufacturing

The TRENDS estimate for lime manufacture is 30,000 tons of SO_2 and the NAPAP estimate is 32,000 tons of SO_2. Statistically there is no difference in the emission estimate in TRENDS and NAPAP. Nevertheless, the TRENDS emission factor of 3.4 lbs SO_2/ton of lime produced may be too low. There are three emission factors in the *AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*[7] document with units of lbs SO_2 emissions/ton of lime produced. Calcining in a vertical kiln and multiple hearth calcining both have an emission factor of 8.2 lbs SO_2/ton of lime produced. Calcining in a rotary kiln has an emission factor of 5.1 lbs SO_2/ton of lime produced. In the NAPAP inventory, calcining with a rotary kiln is the dominant method 93 percent of production). Calcining in a vertical kiln or in a multiple hearth calciner is 7 percent of production. Using these production statistics results in a weighted average emission factor of 5.3 lbs/ton lime produced. Using this emission factor results in a revised uncontrolled TRENDS emission estimate of 42,000 tons of SO_2.

An investigation into the distribution of the three types of lime calcining operations and how they dominate the industry should be undertaken if an average emission factor is going to be used. In addition, an investigation into the use of control devices for the lime manufacturing industry should be undertaken. As discussed in cement, any particulate control device for this industry will have very good SO_2 control due to the properties of the lime particulate being captured.

SECTION 4

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APPENDIX A

EPA TRENDS PROCEDURE FOR INDUSTRIAL SO_2 EMISSIONS

The TRENDS Procedures Document was developed to support the TRENDS emission estimation method using spreadsheets to perform the calculations. As a result, the TRENDS Procedure as published, is somewhat disjointed and the user needs to jump around the document to obtain the values that are needed. During the development of the annual TRENDS estimate, the document works because once a number is developed, the spreadsheet automatically uses the number.

The following procedure was developed by compiling the appropriate sections into a sequential series of steps, thus avoiding jumping around the document. In addition, sections that do not pertain to the industrial SO_2 emission estimates are not included. This would include whole source categories such as highway vehicles as well as sources within a source category that are not part of the TRENDS SO_2 method, generally due to the emission cutoff level that was imposed on the TRENDS procedure (10,000 short tons per year).

The order of the source categories within this document follows the published TRENDS procedure manual. The procedures described below have not been edited under this effort. Interpretation of the procedure is described within the body of the report and this section has been left intact in order to allow the reader to develop a different interpretation if appropriate.

Two spreadsheets accompany the TRENDS procedure manual. One spreadsheet contains the emission factors for the source categories and is used to calculate current TRENDS estimates. The second spreadsheet contains historical activity data and is used in the projection of TRENDS estimates. On occasion, the emission factors reported in the text of the Procedures manual did not correspond to the emission factors located in the spreadsheets. The emission factors as they appear in the spreadsheet (in metric units) are included at the end of each section.

Anthracite Coal

Activity

From Coal Distribution, table entitled "Distribution of U.S. Coal by Origin and Consumer," obtain the distribution of anthracite from Pennsylvania to industrial less coke plants. State data is provided.

Emission Factors

Table 1.2-1, AP-42 Fourth Edition, Volume I

SCC	SO_x
1-02-001-01	39.0 S
1-02-001-04	39.0 S

Weight the emission factors based on the AIRS/FS AFP650 report (emissions by SCC report). Fuel totals and actual emissions are reported in this printout. Use an ash content of 11 percent and a sulfur content of 0.7 percent.

EF from print-out: 24.8 MLbs/tons

Bituminous Coal and Lignite

Activity

Obtain the total national consumption by "other industrial" (not including coke plants) from the Quarterly Coal Report. From this total, subtract the sum of the following three values:

1. Consumption by cement plants in Mineral Industry Survey, Cement.

2. Consumption by lime plants. Calculated from C&E News. Estimated coal consumption is lime production, multiplied by 0.1 ton coal/ton lime produced.

Emission Factors

Obtain a weighted average EF from AIRS/FS AFP650, for SCC 102002. AFP650 is used to obtain amounts of coal burned for each SCC. These are used as weighting factors with the emission factors obtained from the AIRS/FS SCC listing to calculate the weighted average EF. The value for SO_2 is 38.1(S) lbs SO_2/ ton. None of the emission factors need to be changed unless AP-42 changes. However, ash and sulfur content numbers may change. Therefore it may be necessary to change the emission factors.

Obtain the average percentage sulfur content from Coal Production (ref. 30) for shipments from each coal-producing state to other industrial consumers. Use the sulfur content data for the latest available year. As a first step it is necessary to determine an average sulfur content value for each coal production district. The reported sulfur contents in ref. 30 are for each state. Reference 30 also contains a description of the coal production districts. This information can be used to match the states to coal production districts. For those districts that represent only parts of states, ref. 30 also gives coal production by county for each state, which can be used to estimate the shipments from each district from component states. Compute a weighted average sulfur content value for each production district, as necessary. Weight these district averages by the shipments data from each district to destination contained in the Coal Distribution report. In this case the destination is "other industrial" consumers.

NOTE: This procedure is quite cumbersome, and thus has not been applied. The latest available data for sulfur content of coal by production district is for 1978. These data have been used for all TRENDS calculations for 1979-1985. (Assumes sulfur contents of coal from each production district have not changed since then.) In the future, DOE/EIA may produce new reports that give information on sulfur content in industrial coal shipment. The reader should make use of any new DOE reports to improve this procedure.

EF from print-out: 49.34 MLbs/tons (1990)
46.85 MLbs/tons (1991)

Residual Oil

Activity

Residual oil and distillate oil source categories can be done together for fuel consumption only.

Obtain the "adjusted" quantity of residual oil sales for industrial and oil company use from Fuel Oil and Kerosene Sales 19xx. Subtract the total of the following three statistics:

1. Quantity of oil consumed by cement plants reported in Mineral Industry Survey, Cement. Assume that 2/3 of the oil reported is residual oil; convert to gallons.

2. Quantity of residual oil consumed by petroleum refineries reported in Petroleum Supply Annual, table entitled, "Fuel Consumed at Refineries by PAD District." Convert to gallons.

3. Quantity of residual oil consumed by steel mills. From the Survey of Current Business, table containing information on Metals and Manufactures, obtain the quantity of raw steel production in short tons and multiply by 0.00738 x 10^6 gal/10^3 ton steel. (This value should be updated for 1982 and later years based on the 1982 Census of Manufactures, Fuels and Electric Energy Consumed).

Emission Factors

Table 1.3-1, AP-42 Fourth Edition, Volume I

SCC	SO_x
1-02-004-01	158.6S

S = 1.82

For SO_2, obtain a sulfur content value for No. 6 fuel oil from Heating Oils. An average value can be interpreted from the graphs presented in this report.

EF from print-out: 261.9 MLbs/10*3 Gal. (1990)
277.2 MLbs/10*3 Gal. (1991)

Control

SO_2: From ref. 33c.

NOTE: Ash and sulfur content numbers may change. Therefore, it may be necessary to change the emission factors

Distillate Oil

Activity

These values were derived simultaneously with residual oil consumption.

Obtain the "adjusted" quantity of distillate oil sales to industrial and to oil companies from Fuel Oil and Kerosene Sales 19xx. Subtract the total of the following statistics:

1. Quantity of oil consumed by cement plants reported in Mineral Industry Survey, Cement. Assume that 1/3 of the oil reported is distillate oil. Convert to gallons.

2. Quantity of distillate oil consumed by petroleum refineries reported in Petroleum Supply Annual, table entitled, "Fuel Consumed at Refineries by PAD District." Convert to gallons.

Emission Factors

Table 1.3-1, AP-42 Fourth Edition, Volume I

SCC	SO_x
1-02-005-01	143.6S
1-02-005-04	150.0S

Weight the factors above based on the AIRS/FS AFP650 report (see Table 3.9-1).

For SO_2, obtain average sulfur content values for No. 1, No. 2 and No. 4 oils reported in Heating Oils. Weight these values by the corresponding distribution to industrial reported in Fuel Oil and Kerosene Sales 19xx, to obtain a weighted average sulfur content value.

EF from print-out: 35.6 MLbs/10*3 Gal. (1990)
35.0 MLbs/10*3 Gal. (1991)

Control

SO_2: From ref. 33c.

NOTE: Ash and sulfur content numbers may change. Therefore, it may be necessary to change the emission factors.

Table 3.9-1. Weighted Average Emission Factors for Industrial Oil Combustion

Boiler Type	AIRS/FS Consumption	AP-42 Emission Factors (lbs/1000 gal)			
		CO	NO_x	SO_2	VOC*
Boilers burning No. 2	32758				
Boilers burning No. 4	3640				
Turbines	30193				
IC engines**	6536				
Weighted Average (lbs/1000 gal)					

* Use the nonmethane VOC EF.
** Internal combustion engines.

Natural Gas

Activity

Boilers: Obtain the total industrial consumption figure for natural gas from Natural Gas Annual. Subtract from this figure the sum of the following:

1. Total natural gas consumption by cement plants obtained from Mineral Industry Survey, Cement.

2. Total natural gas consumption by petroleum refineries obtained from Petroleum Supply Annual, (Table: Fuels Consumed at Refineries).

3. Total natural gas consumption by iron and steel industry. Obtain the raw steel production from Mineral Industry Survey, Iron and Steel. Multiply the production figure by 4.25 x 10^6 cu. ft. natural gas/1000 tons steel.*

4. Total natural gas consumption by glass manufacture industry. Take the total production as computed for glass production from Table 3.15.35, "Particulate Emissions from the Mineral Products Industry." Multiply this figure by 10.8 x 10^6 cu. ft. natural gas/1000 tons glass produced.*

*This value should be updated for 1982 and later years based on data from the 1982 Census of Manufactures and the Annual Survey of Manufactures, Fuel and Electricity Energy Consumed.

For glass activity data, see **Glass** below.

Glass: Table 8.13-1, AP-42 Fourth Edition

SCC	Description	TSP (lbs/Ton)	PM-10 (lbs/Ton)
3-05-014-02	Container Glass: Melting Furnace	1.4	1.32
3-05-014-03	Flat Glass: Melting Furnace	2.0	1.9
3-05-014-04	Pressed & Blown: Melting Furnace	17.4	16.5

Weight the EF's shown above by the factors shown in Table 3.15-4 [see **Glass** below].

Gas Pipelines and Plants: Obtain the total natural gas consumption for lease and plant fuel plus pipeline fuel from Natural Gas Annual.

Emission Factors

Table 1.4-1, AP-42 Fourth Edition, Volume I

SCC	SO_x
1-02-006-02	.6

EF from print-out:	Boilers	0.5 MLbs/10*6 CF
	Gas Pipelines & Plants	0.5 MLbs/10*6 CF

Control

SO_x: From ref. 33c.

NOTE: Ash and sulfur content numbers may change. Therefore, it may be necessary to change the emission factors.

Miscellaneous Fuel

Activity

Coke: The objective is to estimate coke consumption, in tons, outside the iron and steel industry. From the Quarterly Coal Report, obtain the following data:

1. Total breeze production at coke plants. Assume 24 percent is sold for use as boiler fuel. Multiply total breeze production by 0.24.

2. Coke sales to "other industrial plants;" if data for foundries and other industrial plants are combined, assume that 49 percent of the total is for other industrial plants.

Add 1 and 2 to obtain total coke produced from coal. Alternatively, if 1 and 2 are not available, assume 5.75 percent of total coke production represents coke consumption outside the iron and steel industry.

From the Cost & Quality, or Electric Power Annual, obtain the total quantity of petroleum coke consumed or received by power plants.

Add the values obtained in 1 and 2 above and petroleum coke receipts together to obtain the total coke consumption.

Coke Oven Gas: Obtain the total coke-oven gas production, in cubic feet from Quarterly Coal Report. Multiply this total by 0.188. It is assumed that 18.8 percent of total coke gas produced is consumed outside of the iron and steel industry. If not published, call National Energy Information Center (202) 586-8800. If not available, use previous year number.

Bagasse: Use the number from the previous year.

Kerosene: Obtain the "adjusted" quantity of kerosene sales in gallons, from Fuel Oil and Kerosene Sales 19xx. Add the "adjusted" sales figures reported for industrial and "all other."

LPG: Use LPG supplied to industrial use. American Petroleum Institute, Jim Tsiderdaos (202) 682-8498, table entitled, "LPG Supply and Disposition." The objective is to project the 1982 consumption figures, in gallons, to the update year based on the quantity of products supplied. The following equations can be used:

$$Industrial_i = \frac{5,397 * 10^6 \; gal_{1982} * LPG \; Supplied_i}{1,499 * 10^3 \; bbl/day} \qquad (eq. 48)$$

where,

i = year

$5,397 \times 10^6$ gal = total industrial sales in 1982.

$1,499 \times 10^3$ bbl/day = products supplied in 1982 obtained from Petroleum Supply Annual.

LPG Supplied = products supplied obtained from Petroleum Supply Annual

Wood: Obtain the consumption figures, in tons, from Estimates of U.S. Wood Energy Consumption, 1980-1983. This reference gives consumption in terms of oven-dried equivalent weight for the previous year. For example, for the 1984 update, the reference was available for 1983. Assume that 15 percent of the heating value is lost to moisture on a typical basis. Therefore, multiply the reported consumption figures in tons by 0.85. Do this for industrial and residential, separately. As of 1990, wood consumption was published in therms of Btu's and an average Btu content per oven-dried short ton was provided for both residential and industrial sectors. The ratio is:

$$\frac{17.2 \; million \; Btu}{oven\text{-}dried \; short \; ton}$$

No adjustment to the calculated tonnage is necessary.

Next, project the converted consumption figure to the update year. Assume that 75 percent of the industrial wood is consumed by the pulp and paper industry and 25 percent is used in lumber and wood products. Refer to Section 3.15.3.7 [below] to obtain the production figures for the base and update year. Then project as before (see LPG), but for pulp and paper and lumber and wood products, separately. Add the projected consumption figures.

Pulp and Paper.

Kraft: Use production found in Current Industrial Reports, Pulp, Paper and Board; use production value reported for "sulfate."

Sulfite: Same reference as for Kraft; use production value reported for "sulfite."

Lumber.

Obtain the total lumber production expressed in million board feet from Current Industrial Reports, Lumber Production and Mill Stocks. If not available, use Survey of Current Business.

Emission Factors

Coke:

Coke Type	LbsS/Ton SO_x
Petroleum Coke	38.8
Coal Coke	30.3

Calculate weighted average EF's based on the total coke produced from petroleum and the total coke produced from coal (breeze production plus coke sales to boilers) as shown in Table 3.11-1.

Use a sulfur content value of 3.25 percent for petroleum coke.

Table 3.11-1. Weighted Average Emission Factors for Coke

Coke Type	Consumption (from Part 3A)	EF (metric lbs/ton)			
		Part	SO_x	NO_x	PM-10
Petroleum Coke	554	1.4	114.3*	19	1.2
Coal Coke**	1384	4.2	27.5	12.7	?
Weighted Average (metric lbs/ton)					

* Assumes a constant sulfur content value of 3.25 percent for petroleum coke.
** Total of breeze production plus coke industrial boilers.

Coke Oven Gas:

SCC	LbsS/10^6 Cubic Feet Burned SO_x*
1-02-007-07	680.0S

*Assume a sulfur content value of 1.605 percent.

Bagasse: Table 1.8-1, AP-42 Fourth Edition, Volume I

SCC	LbsS/Ton SO_x
1-02-011-01	0

*Obtain percent control efficiency from AIRS AFP650, SCC 1-02-011-01. Currently this percent control = 69 percent.

Kerosene:

SCC	LbsS/10^3 Gal. SO_x
1-02-005-01	143.6S

*Assume a sulfur content value of 0.075 percent.

LPG: Table 1.5-1, AP-42 Fourth Edition, Volume I

SCC	SO_x*
1-02-010-02	86.5S

*Assume a sulfur content value of 0.0013 percent.

Wood: Table 1.6-1, AP-42 Fourth Edition, Volume I

SCC	SO_x
1-02-009-01	.15
1-02-009-02	.15
1-02-009-03	.15

EF from print-out:	Coke	47.8 MLbs/ton
	Coke oven Gas	990.0 10*9 cu ft.
	Kerosene	9.8 million gal.
	LPG	0.1 million gal.
	Wood	2.2 10*3 tons

Primary Copper

Activity

Roasting: Obtain the primary copper smelter production from domestic and foreign ores from the Minerals Yearbook, Copper. The Table is entitled, "Copper: World Smelter Production, by country." This figure is expressed in units of blister copper produced. Convert to short tons and multiply the reported number by 2. (This multiplier assumes that there are 4 tons of copper concentrate/ton of blister, but only half is roasted.)

Smelting, Converting: Same as above but instead multiply the reported number by 4.

Fugitive: Use the total new copper smelter production figure obtained from Minerals Yearbook, Copper. Total primary includes domestic and foreign ores. Convert to short tons.

Regional Fractions: Contact directly (i.e., telephone) the State or Regional Air Quality Bureaus for copper smelter activity within their area.

Emission Factors

Roasting: Table 7.3-2, AP-42 Fourth Edition

SCC	Description	LbsS/Ton SO_x
3-03-005-02	Multi-Hearth Roaster	280
3-03-005-09	Fluid-Bed Roaster	360

Calculate a weighted average EF based on the data in Table 3.15-9. Multiply each EF by the corresponding capacity. Add the products and divide by the total capacity. Then add 1 lbs/ton to the weighted average EF to account for fugitive emissions.

Table 3.15-9. Capacity Data

Type of Roaster	EF	1981 Capacity
Multihearth	280	430
Fluid Bed	360	230

Smelting: Table 7.3-2, AP-42 Fourth Edition

SCC	Description	LbsS/Ton SO_2
3-03-005-07	Reverb. Furnace + Convertors	320
3-03-005-03	Multi-Hearth + Reverb. Furnace + Convertors	180
	Fluid Bed Roaster + Reverb. Furn. + Convertors	160
3-03-005-10	Electric Furnace + Convertors	240
	Fluid Bed + Electric Arc + Convertors	90
3-03-005-26	Flash Furnace + Cleaning Furnace + Convertor	820

Calculate a weighted average EF based on the data in Table 3.15-10. Multiply each EF by the corresponding capacity. Add the products and divide by the total capacity. Then add 4 lbs/ton to the weighted average EF to account for fugitive emissions.

Table 3.15-10. Smelting Emission Factor Data

Type of Process	EF (lbs/ton)	1981 Capacity
Reverb. Furnace + Convertors	320	405
Multihearth + Reverb. Furnace + Convertors	180	430
Fluidized Bed Roasters + Reverb. Furnace + Convertors	160	212
Electric Furnace + Convertors	240	124
Fluidized Bed Roaster + Electric Arc + Convertors	90	18
Flash Furnace, Cleaning Furnace, Convertor	820	115

Converting: Table 7.3-2, AP-42 Fourth Edition

SCC	Description	LbsS/Ton SO_2
3-03-005-23	Reverberatory Furnace + Convertor	740
3-03-005-24	Multi-Hearth + Reverb. + Convertor	600
3-03-005-25	Fluid Bed Roaster + Reverb. + Convertor	540
3-03-005-26	Electric Arc + Convertor	820
3-03-005-27	Flash Furn. + Cleaning Furn. + Convertor	240
3-03-005-28	*Noranda Reactor + Convertor	600

*Assumed value used for Noranda Reactor emission factor.

Same procedure as for Roasting and Smelting except use the data in Table 3.15-11. Add 130 lbs/ton to the weighted average EF to account for fugitive emissions.

NOTE: For copper smelting, calculation of new weighted average emission factors is needed only if an existing smelter ceases operation or if a new smelter begins operation or if an existing smelter is modified. See Minerals Yearbook, Copper for information on such changes in capacity.

Table 3.15-11. Converting Emission Factor Data

Type of Process	EF (lbs/ton)	1981 Capacity
Reverb. Furnace + Convertors	740	405
Multihearth + Reverb. Furnace + Convertors	600	448
Fluidized Bed Roasters + Reverb. Furnace + Convertors	540	212
Electric Arc Furnace + Convertors	820	124
Flash Furnace, Cleaning Furnace, + Convertors	240	115
Noranda Reactor + Convertors	600	231

Primary Zinc

Activity

Roasting: Obtain the total slab zinc production from the Minerals Yearbook, Zinc. Convert the units to short tons and multiply by 2 to account for the fact that there are 2 units of concentrate/ton slab zinc.

Emission Factor

Zinc Roasting: Table 7.7-1, AP-42 Fourth Edition

SCC	LbsS/Ton SO_x
3-03-030-02	1,100

EF from print out: 998.0 MT Lbs/ton

Control

Control efficiency is derived from AIRS/FS (eq. 1) for all subcategories except **Zinc-Fugitive**. The control efficiency for this subcategory is obtained by best guess.

Primary Lead

Activity

For all subcategories, obtain the primary refined lead production from domestic and foreign ores from the Minerals Yearbook, Lead. Convert the units to short tons.

Lead Processing.

In order to calculate a production value for lead processing the following procedure should be used:

1. The total copper and zinc SO_2 emissions must be calculated first.

2. Then calculate SO_2 Removal in H_2SO_4 as follows:

Byproduct Sulfuric Acid - Copper: Obtain the quantity of byproduct sulfuric acid produced from Copper plants in the United States (Minerals Yearbook, Copper). Multiply this total by 0.6531. This is the ratio of the molecular weight of SO_2 (64) to the molecular weight of H_2SO_4 (98). Enter the result in the TRENDSXX.xls file "Sulfur Oxide Emissions from Non-Ferrous Smelters, SO_2 Removal in H_2SO_4," for Copper.

Byproduct Sulfuric Acid - Lead + Zinc (SO_2 lead+zinc): Add the quantity of byproduct sulfuric acid produced from Lead plants from Minerals Yearbook, Lead, to the quantity of byproduct sulfuric acid produced from Zinc plants. Again multiply this total by 0.6531. Enter the result in the TRENDSXX.xls file "Sulfur Oxide Emissions from Non-Ferrous Smelters, SO_2 Removal in H_2SO_4," for a total of Lead+Zinc byproduct sulfuric acid produced.

In the event the Minerals Yearbook, Copper is unavailable, one must estimate the byproduct sulfuric acid production from copper, lead, and zinc processing. The Bureau of Mines may also be able to supply preliminary numbers for these calculations.

3. Then calculate total lead SO_2 emission as follows:

In order to calculate 'Total SO_2 Lead Emissions' the following procedure should be used:

$$\text{Total } SO_2 \text{ Lead Emissions} = SO_2\text{(lead+zinc)} - SO_2\text{(zinc)} + [\text{AFS Lead Emissions} * .9072] \quad \text{(eq. 68)}$$

where:

SO_2(lead+zinc) is the total SO_2 removed in byproduct sulfuric acid production from lead + zinc processing, calculated above.

SO_2(zinc) = Total SO_2 removed in byproduct sulfuric acid production from zinc processing. Calculated as follows:

Byproduct sulfuric acid prod. from zinc plants * 0.6351 (eq. 69)

AIRS/FS Lead Emissions = the total SO_2 emissions from lead production, SCC 303 010 **. This is obtained from a AIRS/FS AFP650 report for the latest year available.

4. Once this is done, it is easy to back calculate a lead processing value.

Calculation is as follows:

$$\text{Lead Processing} = \frac{\text{Total } SO_2 \text{ Lead Emission} * 2000}{540} \quad \text{(eq. 70)}$$

The value for 'Lead Processing' may now be entered into TRENDSXX.xls.

Emission Factors

Lead Roasting: Table 7.6-1, AP-42 Fourth Edition

SCC	Description	*LbsS/Ton Lead Produced SO_2
3-03-010-01	Sintering	550
3-03-010-02	Blast Furnace	45

*AP-42 units are based on quantity of lead produced.
*NEDS SCC file units are based on tons of concentrated ore produced.

EF Lead Processing from print-out: 540.0 MT lbs/ton

Control

Control efficiency is derived from AIRS/FS (eq. 1) for all subcategories except **Lead-Fugitive**. The control efficiency for this subcategory is obtained by best guess.

Primary Aluminum

Activity

Material Handling: Use the total primary production figure obtained from the Minerals Yearbook, Aluminum.

Emissions Factors

Obtain an average EF based on NEDS, February 1980, for Washington State only.

EF from print-out: 33.5 MT lbs/ton

Control

Control efficiency is derived from AIRS/FS (eq. 1) for all subcategories <u>except</u> **Aluminum-Fugitive.** The control efficiencies for this subcategory is obtained by best guess.

Secondary Lead

Activity

Reverberatory Furnaces: Obtain the total consumption of lead scrap and multiply by the following fraction:

Lead recovered as soft lead/Total lead recovered from scrap
Convert to short tons.

Blast Furnaces: Same as for Reverberatory Furnaces except that the fraction is calculated as follows:

Lead recovered as antimonial lead/Total lead recovered from scrap
Convert to short tons.

Emission Factors

Table 7.11-1, AP-42 Fourth Edition

SCC	Description	LbsS/Ton SO_x
3-04-004-02	Reverberatory Furnace	80
3-04-004-03	Blast Furnace	53

EF from print-out:	Reverberatory Furnace	72.6 MT lbs/ton
	Blast Furnace	48.0 MT lbs/ton

Control

Control efficiency is derived from AIRS/FS (eq. 1) for all subcategories <u>except</u> **Lead-Fugitive.** The control efficiency for this subcategory is obtained by best guess.

Pulp and Paper

Activity

<u>Kraft Pulp Production</u>.

Obtain the production of sulfate and sulfite combined from <u>Current Industrial Reports, Pulp, Paper & Board</u>. Kraft process and Sulfite process are reported individually in this report.

Kraft: Use production found in Current Industrial Reports, Pulp, Paper and Board; use production value reported for "sulfate."

Sulfite: Same reference as for Kraft; use production value reported for "sulfite."

Emission Factors

Kraft Pulp Production: Table 10.1-1, AP-42 Fourth Edition

SCC	LbsS/Ton SO_x
3-07-001-04	7

The EF is obtained by adding the EF's for Kraft and Sulfite Mills. In the case of Kraft use the AP-42 EF of 7 lbs/ton (see above). In the case of Sulfite, the EF must be calculated as described below.

Sulfite Uncontrolled EF = 52 lbs/ton*
Sulfite Controlled EF = 20 lbs/ton*

If the sulfite particulate control efficiency is 90 percent (taken from Table 2.25), then assume 90 percent of production is at the controlled emission rate and 10 percent at the uncontrolled rate. Calculate SO_2 emissions from sulfite mills and add to the emissions for Kraft Mills (5 lbs/ton). Calculate the EF as follows:

EF = (Total Emissions, Kraft + Sulfite)/Production (eq. 63)

*Obsolete version of AP-42.

EF from print-out Kraft Pulp Prod. & Sulfite: 10.3 MT lbs/ton

Sulfuric Acid

Activity

Obtain the total production from Current Industrial Reports, Inorganic Chemicals.

Emission Factor

Calculate the EF as follows:

$$EF_t = \frac{(0.95 * EF_{t-1} * P_{t-1}) + (0.05 * EF_{NSPS} * P_{t-1}) + ((P_t - P_{t-1}) * EF_{NSPS})}{P_t}$$ (eq. 64

where,

i = Year
EF_{NSPS} = NSPS EF (4 lbs/ton)
P = Total Production

If the current year production is less than the previous year production, the last term (P_i - P_{i-1}) is zero. Only assume new capacity for production above the previous record high production level.

EF from print-out: 7.8 MT lbs/ton

Carbon Black Production

Activity

Obtain the total quantity of carbon black produced from C&E News.

Oil Process: Assume that 90 percent of total production is by oil process.

Gas Process: Assume that 10 percent of total production is by gas process.

Emission Factors

Table 5.3-3, AP-42 Fourth Edition

Description	LbsS/Ton SO_x
Flared Furnace Exhaust (Oil Process)	50

Calculate the EF as follows:

EF = (CO Control Efficiency / 0.913) * 50 lbs/ton (eq. 73)

where,

CO Control Efficiency = fraction.

EF from print-out: 20.6 MT lbs/ton

Sulfur Recovery Plants

Activity

Obtain the quantity of sulfur recovered by petroleum refineries and by natural gas plants, respectively, from the Minerals Industry Survey, Sulfur. Convert to short tons.

Emission Factors

Add the actual emissions reported in AIRS/FS for SCC 301-032-01 through 301-032-04. Divide the total by the sum of the operating rates.

Petroleum Refining

Activity

From the Oil and Gas Journal, obtain the total capacity of catalytic cracking fresh feed in bbl/stream day. Convert this number to bbl/calendar year by multiplying by 328.5 (365 days/year * 0.9 calendar day/stream day).

Prior to 1989, it was possible to obtain from Oil and Gas Journal, the sum of the catalytic cracking fresh feed capacity per plant for Thermofor and Houdriflow combined with the "other" category, as opposed to the "fluid" category, as designated by footnotes. This "other" category represented TCC. The total capacity was converted to bbl/calendar year by multiplying by 328.5. Then subtract this number from the total capacity above as follows:

$$\text{FCC Capacity} = \text{Total Catalytic Cracking Capacity} - \text{TCC Capacity} \quad \text{(eq. 64)}$$

Then it was necessary to convert capacity to throughput. From the Survey of Current Business, in table containing information on Petroleum, Coal, and Products, obtain the refinery operating ratio. Divide the ratio by 100 to convert it to percent, and multiply the estimated capacities for FCC and TCC by the relevant number to get an estimate of throughput.

Since 1989, the Oil and Gas Journal no longer gives catalytic cracking fresh feed for Thermofor and Houdriflow. Therefore, multiply the total capacity of catalytic cracking fresh feed in bbl/stream day by 328.5 and by the refinery operating ration. Also, add the total FCC and TCC reported in TRENDSXX.xls for the previous year. Then calculate FCC and TCC for the update year as follows:

$$FCC_t = FCC_{t-1} * \frac{cc(FF)_t}{cc(FF)_{t-1}} \quad \text{(eq. 65)}$$

$$TCC_t = TCC_{t-1} * \frac{cc(FF)_t}{cc(FF)_{t-1}} \quad \text{(eq. 66)}$$

Process Heaters.

Oil: Obtain the quantity of oil consumed at petroleum refineries by PAD District from Petroleum Supply Annual. Obtain the total of distillate, residual and crude oil. Divide by 1,000.

Gas: Obtain the total of natural gas and still (process) gas consumed at petroleum refineries from Petroleum Supply Annual. The quantity reported for still gas is expressed as thousand bbl equivalents. Multiply the reported number by 6.3 to get 10^6 cu. ft.

Emission Factors

SCC	Description	LbsS/10^3 BBL Fresh Feed SO_x
3-06-002-01	Fluid Catalytic Cracking	493
3-06-002-02	Thermal Catalytic Cracking	60
3-06-004-01	Flares (Blowdown System)	26.9
1-02-004-01	Process Heaters: Oil	158.6S
3-06-001-05	Process Heaters: Natural Gas	.6
3-06-001-06	Process Heaters: Process Gas	950.0S

The EF's for FCC, TCC, and Flares may be entered directly into the spreadsheet.

Process Heaters:

Oil: Obtain the EF from AP-42 for industrial- residual oil boilers. Estimate sulfur content from AIRS/FS AFP650 report for SCC 30600103.

Gas: Weight the EF's for Natural Gas (0.6 lbs/10^6 cu.ft.) and Refinery Gas (356.25 lbs/10^6 cu.ft.) by the natural gas and refinery gas consumption obtained from Petroleum Supply Annual. Convert bbl's of Refinery (Still) Gas to 10^6 cu. ft. by multiplying by 6.3.

EF from print-out:	MT lbs/ton
FCC	447.2
TCC	54.4
Flares	24.4
Process Heaters:	
Oil	5680.0
Gas	230.1

Iron and Steel

Activity

Use the same numbers as in the Megacalc Table 3.15.3.3, "Particulate Emissions from the Iron and Steel Industry", on coke, sintering, and open hearth, convert to thousand short tons from million short tons. For roll and finish, obtain the total raw steel production from the Survey of Current Business, in the table containing information on "metals and manufactures".

Coke.

Byproduct: Obtain the beehive and oven (byproduct) production figure, expressed in thousand short tons, from Survey of Current Business, in the table showing information on "Petroleum, Coal, and Products." SCC=3-03-003

Sintering.

Obtain the total production of pig iron from Mineral Industry Survey, Iron Ore, ref. 25 or use the total reported in the Survey of Current Business. Convert long tons to short tons: divide result by 3 and enter as 3 components of sintering (windbox, discharge, and sinter-fugitive).

Open Hearth.

From Mineral Industry Surveys, Iron and Steel Scrap, obtain the total scrap and pig iron consumed by open hearth, furnaces by manufacturers of pig iron and raw steel and castings. Calculate the fraction of scrap and pig iron (combined) that is consumed by the furnace types. Multiply the fraction by the total raw steel production, expressed in thousand short tons, obtained from the Survey of Current Business, in the table showing information on "Metals and Manufactures." Enter the calculated values both the "stack" and "fugitive" components of each furnace type. (Note: The fraction for open hearth furnace will be used in several tables of the OAQPS Data File. Once the Minerals Yearbook, Iron and Steel chapter, is available, values calculated above should be revised to agree with Minerals Yearbook final data.)

Emission Factors

Coking: *Table 7.2-1, AP-42 Fourth Edition
NED SCC and Emission Factor File

SCC	Description	LbsS/Ton SO_x
3-03-003-02	Charging	*0.02
3-03-003-03	Pushing	3.3
3-03-003-04	Quenching	0.4
3-03-003-06	Underfiring	*4
3-03-003-08	Oven/Door Leaks	0.1
3-03-003-14	Topside Leaks	0.1

Add the factors and divide by 0.7 to convert units. This is based on 0.7 tons coke produced/ton coal consumed.

Sintering: Divide the actual emissions reported in NEDS, February 1980, by the production rate.

Open Hearth: Same procedure as for Sintering.

Roll and Finish: The objective is to compute fuel use by process equipment. For SO_2, the fuels are coke oven gas and residual oil. Multiply the quantity of fuel use by the corresponding AP-42 EF. For example:

Quantity of Coke Oven Gas * 1,091 lbs/10^6 cu.ft.
Quantity of Residual Oil * 1,595 lbs/1,000 gal.

Coke oven gas used in iron and steel manufacturing is calculated as follows: (1) Obtain total annual coke oven gas production from Quarterly Coal Report, (2) Assume 40 percent of production is used in iron and steel process equipment. (3) The EF for coke oven gas (1,091 lbs/10^6 cu.ft.) is obtained from AP-42. (4) Multiply fuel quantity by the EF

Residual Oil used in iron and steel manufacturing is calculated as follows: (1) From the survey of Current Business, containing information on Metals and Manufactures, obtain the quantity of raw steel production in short tons and multiply by 0.00738 * 10^6 gal/10^3 ton steel. (This value should be updated for 1982 and later years based on the 1982 Census of Manufacturers, Fuels and Electric Energy Consumed). (2) The EF for industrial boilers (1,595 lbs/1,000 gal) is used as calculated for the TRENDSXX.XLS file "SO^F^Fmissions from Residual Oil Combustion." (3) Multiply fuel quantity by the EF. (4) Assume percent Sulfur for industrial-residential oil boilers calculated for the table on SO_2 emissions applies.

Add emissions together to obtain total SO_2 emissions. Then subtract the quantity of emissions from Open Hearth Furnaces shown in the TRENDSXX.xls file "SO_2 Emissions from Other Industrial Processes." Calculate the EF as follows:

EF = Emissions left over / Roll and Finish Operating Rate (eq. 74)

EF from print-out:

	MT lbs/ton
Coking	10.3
Sintering	2.3
Open Hearth	1.4
Roll & Finish	3.5

Cement Manufacturing

Activity

Obtain the total quantity of cement production from Mineral Industry Survey, Cement. Use the same figure for all subcategories.

Emission Factors

The first objective is to calculate total uncontrolled SO_2 emissions. These emissions are a function of mineral sources of SO_2 and sulfur in fuel used to fire kilns. Obtain total cement production from Minerals Industry Survey, Cement. The EF's shown in Table 3.15-12 are used to calculate uncontrolled emissions. Add these emissions and divide by the total cement production rate to get the uncontrolled EF.

At this point, it is convenient to estimate control efficiency. The baseline value of 13.75 percent SO_2 control corresponds to a cement kiln particulate control efficiency of 99 percent. The value of 12 percent SO_2 control corresponds to a cement kiln control efficiency of 92 percent. For other percent SO_2 control values, estimate the corresponding cement kiln SO_2 control efficiency value by linear interpolation/extrapolation from the particulate control efficiency.

Table 3.15-12. Emission Factors for Uncontrolled Emissions

Fuel	Emission Factor
Mineral Source	10.2 lbs/ton cement produced
Coal	30.45 lbs/ton coal consumed[1]
Residual Oil	124.5 lbs/1,000 gal residual oil consumed[2]
Distillate Oil	112.35 lbs/1,000 gal distillate oil consumed[3]

[1] S = value derived for industrial boilers, Section 3.7.
[2] S = value derived for industrial boilers, Section 3.8.
[3] S = 0.3

EF from print-out: 14.5 MT lbs/ton

Glass

Activity

Refer to Current Industrial Reports, Glass Containers and Current Industrial Reports, Flat Glass. Add the following quantities, after converting to thousands of short tons, as necessary:

1. Total production of flat glass (in short tons)
2. Net packed weight of glass containers (in thousands of pounds)

Multiply the total by 1.10 to account for miscellaneous glass products.

Emission Factors

Table 8.13-1, AP-42 Fourth Edition

SCC	Description	LbsS/Ton SO_x	Weighting Factor
3-05-014-02	Container Glass: Furnace	3.4	.75
3-05-014-03	Flat Glass: Furnace	3.0	.15
3-05-014-04	Blown Glass: Furnace	5.6	.1

Calculate a weighted average EF based on the weighting factors in the above table.

Table 3.15-13. Weighting Factors

Type of Glass	Weighting Factor
Container Glass	0.75
Flat Glass	0.15
Blown Glass	0.1

EF from print-out: 3.2 MT lbs/ton

Lime Manufacturing

Activity

Obtain the production figure from C & E News, for lime. Enter the obtained value for both kilns and fugitive.

Emission Factors

Divide the total actual SO_2 emissions reported in NEDS, February 1980, by the NEDS lime production rate.

EF from print-out: 3.1 MT lbs/ton

Control

Fugitive: Obtain a value for control efficiency by best guess.

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(Please read Instructions on the reverse before completing)

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2.	
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16. ABSTRACT

The report gives results of analyses of 1985 industrial sulfur dioxide (SO2) emissions from two data sources: the National Acid Precipitation Assessment Program (NAPAP) inventory and the EPA TRENDS report. These analyses conclude that the two data sources estimate comparable emissions in the aggregate, but that estimates for specific categories and for processes within those categories vary widely. The TRENDS method, limited to source categories that emit 10,000 tonnes of SO2 per year, generally overestimates emissions from these source categories, due primarily to the absence of SO2 control efficiency assumptions. Overestimating emissions in the TRENDS data set is offset by including additional source categories in the NAPAP inventory, with the final aggregate estimates within <10% of each other. Due to these findings, the TRENDS methodologies are being revised for 1993 and thereafter, using the 1985 NAPAP inventory as a base. (NOTE: The 1990 Clean Air Act Amendments (CAAA) require that EPA report to Congress by 1995 a national inventory of annual SO2 emissions from industrial sources, and emission projections for the next 20 years. This stems from the 5.6 million tons of industrial SO2 emissions cited in CAAA Title IV, and based on the estimated 1985 NAPAP emissions.)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Sulfur Dioxide	Stationary Sources	07B
Emission	NAPAP	14G
Inventories	TRENDS	15E

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