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**ANALYSIS OF POTENTIAL COMBUSTION
SOURCE IMPACTS ON ACID DEPOSITION USING
AN INDEPENDENTLY DERIVED INVENTORY**

Volume II: Appendices

December 1983

Work Performed Under Contract No.: DE-AC21-82MC19285

For
U. S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
PEDCo Environmental, Inc.
Cincinnati, Ohio
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DOCUMENTATION OF METHODOLOGIES USED TO ESTIMATE ENERGY CONSUMPTION AND COMBUSTION EMISSIONS FOR DIRECT-FIRED INDUSTRIAL PROCESSES

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INTRODUCTION

Background

This appendix documents the methodologies used to calculate production, unit energy consumption, fuel type and emission estimates for 16 industries and 35 types of facilities utilizing direct-fired industrial combustion processes, located in 26 states (and the District of Columbia) east of the Mississippi River. As discussed in the text of this report, a U.S. total of 16 industries and 45 types of facilities utilizing direct-fired combustion processes were identified by an elimination type method that was developed based on evaluation of fuel use in industrial SIC codes 20-39. The final population included only plants that have direct-fired fuel consumption $\geq 100 \times 10^9$ Btu/yr of equivalent energy consumption.

The goal for this analysis was to provide at least a 1980 base year for the data. This was achieved for all of the industries and in fact, 1981 data were used for a number of the industries evaluated.

The term direct-fired is used in this analysis to denote fuel combustion where the exhaust gases come into direct contact with the process gases (e.g., cement kilns, glass melting furnaces) as well as processes in which the exhaust gases from fuel combustion are not in contact with process off-gases, but are

direct-fired in that they do not involve the use of a heat transfer medium as boilers do. e.g., direct-fired atmospheric distillation units in refineries, firing of coke oven batteries, and firing of process heaters in chemical plants. Process steam produced from a boiler, however, is not considered to be direct-fired, and is accounted for within the category of industrial boilers.

One of the major objectives of this effort was to produce an independent industrial combustion source inventory that did not depend on survey type procedures [such as those employed in U.S. Environmental Protection Agency's National Emission Data System (NEDS)]. In most instances, however, individual plant data for production, direct-fired unit energy consumption, and fuel type utilized, are not available because the data are not reported. In addition, process specific emission factors for NO_x , SO_x , and HC are not available for a significant number of processes. It was possible, however, to devise other methods of estimating these parameters from data that was obtained from trade journals, and other literature sources.

The basic methodology employed to estimate fuel consumption and estimate emissions from individual direct-fired processes involved the following basic steps.

- 1) Estimation of plant and process production values. This was generally based on data for capacity and was estimated using a utilization factor.
- 2) Determination of unit energy consumption values using industry averages for the equipment being evaluated.
- 3) Determination of type of fuel used by process, based most often on industry average data, and plant specific fuel data where available.

- 4) Identification of emission factors and estimation of emissions by fuel for individual processes and plants. Emission factors for NO_x, SO_x, and HC were calculated based on the combustion^x portion of the emissions only, and thus do not include process related emissions.

These steps are discussed in further detail below.

PRODUCTION ESTIMATES

In addition to actual production data, which were available for 2 facility types, plant production was estimated using one of the following three methods: 1) actual plant capacity and an average national U.S. capacity factor (19 facility types), or an average regional U.S. capacity factor (3 facility types); 2) use of shipments data from Economic Information System^{*} reports (10 facility types). This method assumes that production is directly proportional to shipments and was utilized when plant capacity data were unavailable. The EIS data were cross-checked with other plant listings where available, however, since the EIS data were sometimes found to contain plants selling (not manufacturing) a product, manufacturing more than one product, or combining plants in close proximity; 3) the use of regional and state production data and the apportionment of equal production to each plant based on the average plant production (1 facility type). This method was used because plant capacity data were unavailable and EIS shipments data were found to be unreliable for the facility type analyzed in this manner.

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* These reports are based on data from Census Bureau reports, corporate annual reports, other published studies on company sales, acquisitions, plant openings and closings and industrial, trade, and telephone directories on plant locations employment, SIC code, and phone numbers.

UNIT ENERGY CONSUMPTION ESTIMATES

Fuel related unit energy consumption estimates, generally stated in 10^6 Btu/ton of product, are based on an industry average for the type of direct-fired equipment being evaluated. These factors can therefore be expected to accurately reflect unit energy consumption among a group of plants but are less accurate for individual plants. Data for estimating unit energy consumption factors were gathered from a number of sources, e.g., energy studies conducted since the oil embargo, Census data, and trade journals.

Total energy consumption is calculated by multiplying unit energy consumption in 10^6 Btu/ton by production in tons, and is therefore subject to the product of the uncertainties for these two parameters.

FUEL TYPE ESTIMATES

Generally, estimates of the fuel types utilized at individual plants were based on the average mix of fuels used for an industry on a national or regional basis. Minimal plant specific fuel type data were available but were included where available. For industries where one fuel type is overwhelmingly predominant, it was usually assumed that the predominant fuel was the only fuel utilized. This is a more accurate approach than assuming that each plant burns a national average mix of more than one fuel because most plants will likely use only the predominant fuel and thus, only a few plants will be improperly characterized.

In some instances, where a national mix of fuels was not available for a particular industry, 1977 or 1980 Census data was used as the basis of the fuel mix estimate.

EMISSION FACTOR ESTIMATES

Published combustion emission factors for SO_x , NO_x , and HC were used where available, but for a substantial number of industries evaluated, no combustion emission factors were available, and default values based on general industrial process combustion emission factors available in the literature, were substituted in order to provide an emission estimate. For many of the direct-fired processes, equations based on heat input per hour were used to calculate oil and gas NO_x emissions, instead of emission factors based on lb/ton of product which were unavailable.

SUMMARY OF UNCERTAINTIES ASSOCIATED WITH THE DIRECT-FIRED PROCESS METHODOLOGIES

It is obvious from the above discussions that there are a number of uncertainties associated with the methodologies developed for the population of industrial direct-fired process.

Although a quantitative estimated of uncertainty was not attempted in this analysis, it is possible to qualitatively indicate the relative uncertainty of different components of the methodologies.

For example, there is little uncertainty associated with locations of plants and the type of direct-fired processes employed for most of the plant types evaluated. In addition, plant capacity data that are available, are adequate for most of the industries considered.

Individual plant production, unit energy consumption, and fuel type utilized are generally not available, because the data are not reported, or are considered to be proprietary. For many industries, the resulting national or regional average values that are applied to calculate these parameters, adds a greater level of uncertainty than for the plant locations and types of processes employed. However, these uncertainties tend to average out over a number of plants.

The use of emission factors always carries a high uncertainty factor, since for the most part, the factors are not based on a large enough amount of test data, to establish accurate industry averages for individual processes. Therefore, they may not reflect the variation in emissions that can occur over a population of combustors.

CONCLUSIONS

Despite a number of areas of uncertainties, the knowledge of how these methodologies were developed, and where the uncertainties lie, is a strong endorsement for this type of a combustion source inventory. The methods used are well documented, and easily modified as more accurate data become available. It is felt that these data are adequate for use as both an energy data base and combustion inventory to support analysis of contributing sources to acid precipitation.

INDUSTRY: PETROLEUM REFINING

PLANT/FACILITY: PETROLEUM REFINERY

PLANT POPULATION

At the beginning of 1981, there were 301 operable refineries in the United States.¹ Since January of that year, 46 refineries have permanently closed and 47 refineries have remained "totally idle" (capable of reopening). Total operating crude distillation capacity in 1981 was 16.1 million barrels per calendar day. An additional 1.8 million barrels per calendar day stood idle (closed, but capable of coming on line within 90 days). The 61 refineries east of the Mississippi that were included in this analysis accounted for approximately 3.84×10^6 barrels per calendar day of operating crude distillation capacity.

The estimated 1981 capacities of the refineries in this analysis range from 1.6×10^6 to 117.5×10^6 barrels of crude oil per year and average 23.5×10^6 . The smallest refinery analyzed processed an estimated 1.6×10^6 barrels of crude oil in 1981 and consumed 170×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

Direct-fired energy in a petroleum refinery is consumed in the following processes: atmospheric distillation, vacuum

distillation, thermal operation, catalytic cracking, catalytic reforming, hydrocracking, hydrorefining, hydrotreating, alkylation, and aromatics (benzene, toluene, and xylenes) manufacture. In each case process heaters account for the direct-fired energy consumption. All of the crude oil passed through the atmospheric distillation process, and varying amounts of the resulting output are fed to the remaining processes, depending upon the configuration of the plant. Table A.1-1 summarizes the capacity and energy consumption ranges for each of these processes at the 61 refineries analyzed.

PRODUCTION AND FUEL CONSUMPTION

Production

The most recent capacity data available for refineries are for 1981. The capacity of each direct-fired process was obtained from the Department of Energy's Petroleum Supply Annual.¹ Refineries that ceased operations between January 1, and July 31, 1982, also were excluded from the list of study area plants.² Because plant capacity was expressed in barrels per stream day, the capacity factor was expressed in days per year. Regional capacity factors were used to calculate the days of operation because individual plant capacity factors are not available from the published literature.¹ Table A.1-2 presents the regional factors in percent capacity and in days of operation.

These capacity factors are calculated from crude distillation capacity, and it was assumed that the crude distillation

TABLE A.1-1. RANGE OF PROCESS CAPACITIES AND ENERGY CONSUMPTION
IN 61 PETROLEUM REFINERIES EAST OF MISSISSIPPI

	Atmos- pheric distil- lation	Vacuum distil- lation	Thermal opera- tion	Cata- lytic cracking	Cata- lytic reforming	Hydro cracking	Hydro refin- ing	Hydro treat- ing	Alkyla- tion	Aromatic manufacture
No. of plants ^a	61	47	15	35	45	11	13	39	31	10
Capacity 10 ³ bbl/day	5-405	2-180	3-44	7-145	1-90	2-68	4-104	1-186	1-24	4-28
Energy consumption 10 ¹² Btu/yr	0.17-12.1	0.1-6.1	0.2-12.0	0.2-4.8	0.1-49.0	0.2-6.7	0.1-8.0	0.03-4.6	0.1-2.3	0.7-5.2

^aNumber of plants containing the listed process.

TABLE A.1-2. REGIONAL CAPACITY FACTORS--BASED ON CRUDE DISTILLATION IN STATES IN THE STUDY AREA (1981)

	Crude capacity, ^a bbl/cd	Production, bbl/cd	Percent capacity	Annual days of operation
PAD District 1 ^b	1,663,141	1,420,462	85.4	312
PAD District 2 ^c	3,752,952	2,982,539	79.5	290
PAD District 3 ^d	7,278,696	5,920,472	81.3	297
Total United States	16,103,579	13,024,651	80.9	295

^a Does not include idle crude capacity; bbl/cd = barrels/calendar day.

^b Includes the following states: Connecticut, Delaware, Florida, Georgia, Maryland, Maine, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Vermont, Virginia, and West Virginia.

^c Includes the following states: Illinois, Indiana, Kentucky, Michigan, Ohio, Tennessee, and Wisconsin.

^d Includes the following states: Alabama and Mississippi.

capacity factors (days of operation) were applicable to all of the direct-fired processes in the refineries. This assumption was necessary because capacity factors for the direct-fired processes of individual refineries were not available. It is believed that the capacity factors for direct-fired refinery processes other than the atmospheric distillation unit would not differ substantially because of the way the industry as a whole operates its major processes, but no data were available to verify this belief.

Energy Consumption

Unit energy consumption factors (10^6 Btu/bbl) obtained from the Oil and Gas Journal³ were multiplied by individual process production estimates to obtain total energy consumption for each plant. In Table A.1-3 data from Ashland Oil's Buffalo, New York, plant are used to show how energy consumption was estimated for the industry.

Energy consumption at the plants included in the analysis range from 170×10^9 Btu/yr for a simple operation that practices only atmospheric distillation and catalytic reforming to $42,310 \times 10^9$ Btu/yr for a more complex operation that has 8 of the 10 major refinery combustion sources.

Fuel Types

In the petroleum refining industry, the type of fossil fuel consumed by process heaters not only varies from region to region, but often from plant to plant. The availability of specific fuels is a major factor in determining the ratio of oil and gas.

TABLE A.1-3. OPERATING AND ENERGY CONSUMPTION DATA FOR ASHLAND OIL, BUFFALO, NEW YORK

	Atmospheric distillation	Vacuum distillation	Thermal operation	Catalytic cracking	Catalytic reforming	Hydro- cracking	Hydro- refining	Hydro- treating	Alkylation	Aromatics manufacture
Crude capacity, bbl/sd	66,000	28,000	0	22,000	11,000	0	15,200	11,000	2,000	6,200
Days of operation, sd/yr	312	312	312 ^a	312	312	312 ^a	312	312	312	312
Energy consumption, 10 ³ Btu/bbl	103	125	300 ^a	113	314	333 ^a	57	85	336	600
Annual total con- sumption, 10 ¹² Btu/yr	2.12	1.09	0	0.78	1.08	0	0.27	0.29	0.21	1.16

^a Although this particular plant does not have any capacity in the indicated processes, the capacity and energy consumption factors are presented to serve as examples.

The following is an industrywide breakdown of fuel types consumed in process heaters:⁴

Refinery gas	Natural gas	Residual oil	CO gas
68.6%	24.9%	5.5%	1.1%

Because plant specific data are not available, this national breakdown was applied to each plant analyzed. As these data show, gaseous fuels account for 95 percent of the fuel used in refineries. Recently, many plants have retrofitted their process heaters with economizers for additional heat recovery, which allows them to burn lower Btu process gas. As this trend becomes more widespread, lower energy consumption should result, and even less residual oil will be used.

EMISSION ESTIMATES

Emission Factors

Emission factors for process heaters were obtained from AP-42.⁵ The NO_x emission factors are $55/\text{lb}/10^3$ gal for oil and $140 \text{ lb}/10^6 \text{ ft}^3$ for all gaseous fuels.⁵ The SO_x emission factors are $159 (S) \text{ lb}/10^3$ gal for oil (where S = sulfur content of oil in percent) and $0.6 \text{ lb}/10^6 \text{ ft}^3$ for gas.⁵

The average percent sulfur in residual oil, which varies by state, has been incorporated into the oil emission factor. The hydrocarbon emission factors used in this study are $1.6 \text{ lb}/10^3$ gal for oil and $8.0 \text{ lb}/10^6 \text{ ft}^3$ for gas. Emissions from refinery gas and CO gas are assumed to be the same as emissions from the combustion of natural gas in process heaters.

Weighted average emission factors were then developed by converting all emissions factors to lb/10⁶ Btu, based on their heat content, and then weighting these factors according to the industrywide relative proportion of fuels fired in process heaters. The heat content of each fuel is shown below, and the weighted emission factors for all fuels are summarized in Table A.1-4.

Refinery gas, Btu/ft ³	Natural gas, Btu/ft ³	Residual oil, Btu/gal	CO gas, Btu/ft ³
1,000	1,024	150,000	600

Plant Emissions

Emissions for each plant were then calculated by multiplying the weighted emission factor for SO_x, NO_x, and HC, by the total plant energy consumption.

These weighted average emission factors are much closer to the lower end of the range for NO_x and SO_x (because of the large percentage of gas use); therefore, plants that desulfurize and/or burn different quantities of residual oil from those assumed in the national fuel average breakdown could generate more or less combustion emissions than estimated in this analysis. Because residual oil accounts for only about 5 percent of the fuel burned in refineries, however, such potential variations are not expected to produce a significant error.

The range in annual emissions (in tons/yr) of NO_x, SO_x, and HC for the 61 plants analyzed is shown below.

TABLE A.1-4. ESTIMATED EMISSION FACTORS FOR REFINERY PLANTS

EMISSION FACTORS
(lb/10⁶ Btu)

	Residual oil	Natural gas	CO gas	Refinery gas	Weighted average
NO _x	0.37	0.14	0.23	0.14	0.153
SO _x	1.06(S) ^a	5.86 x 10 ⁻⁴	1 x 10 ⁻³	6 x 10 ⁻⁴	0.58(S) ^a + 5.70 x 10 ⁻⁴
HC	1 x 10 ⁻²	7.8 x 10 ⁻³	1.3 x 10 ⁻²	8 x 10 ⁻³	8.12 x 10 ⁻³

^a Where S equals the sulfur content of residual oil.

	<u>Low</u>	<u>High</u>
NO _x	13	3230
SO _x	7	2003
HC	1	145

Tables A.1-5 and A.1-6 summarize refinery crude production; fuel consumption; and NO_x, SO_x, and HC emissions by plant and county, respectively, for the 61 plants analyzed.

TABLE A.1-5. SUMMARY OF 1981 INDIVIDUAL PETROLEUM REFINERY PRODUCTION,
FUEL USE AND SO_x, NO_x, HC EMISSIONS FOR PLANTS
IN 27 STATES EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Crude Prod 1000 Bbl	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coal	Other	Total	NOx	SOx	HC
AL	MOBILE	MOBILE BAY REF	8,316	0.00	0.07	0.31	0.00	0.86	1.23	94	69	5
AL	MOBILE	LOUIS LAND&EXP	12,771	0.00	0.17	0.75	0.00	2.10	3.01	230	170	12
AL	MOBILE	MARION CORP	8,019	0.00	0.08	0.37	0.00	1.04	1.50	114	85	6
AL	TUSCALOOSA	WARRIOR ASPHALT	1,782	0.00	0.01	0.06	0.00	0.18	0.26	20	15	1
AL	TUSCALOOSA	CORAL PETROLEUM	3,416	0.00	0.03	0.14	0.00	0.40	0.58	44	32	2
AL	TUSCALOOSA	MUNT OIL	10,395	0.00	0.14	0.86	0.00	2.42	3.47	265	196	14
Total - AL			44,699	0.00	0.55	2.50	0.00	6.99	10.05	767	567	41
DE	NEW CASTLE	GETTY REF&MARK	46,800	0.00	1.39	6.30	0.00	17.62	25.31	1,932	1,046	103
GA	CHATTAHOOCHIE	AMOCO OIL	8,424	0.00	0.05	0.22	0.00	0.60	0.87	66	49	4
GA	DOUGLAS	YOUNG REFINING	1,622	0.00	0.01	0.04	0.00	0.12	0.17	13	9	1
Total - GA			10,046	0.00	0.06	0.26	0.00	0.72	1.04	79	59	4
IL	COOK	CLARK OIL&REF	20,300	0.00	0.48	2.19	0.00	6.14	8.81	673	339	36
IL	COOK	UNION OIL OF CA	45,530	0.00	0.96	4.36	0.00	12.20	17.53	1,338	674	71
IL	CRAWFORD	MARATHON OIL	36,250	0.00	0.96	4.33	0.00	12.11	17.40	1,328	669	71
IL	LAWRENCE	TEIACO	25,520	0.00	0.51	2.31	0.00	6.46	9.28	708	357	38
IL	MADISON	CLARK OIL&REF	19,430	0.00	0.40	1.83	0.00	5.12	7.36	562	285	30
IL	MADISON	SHELL OIL	85,350	0.00	1.90	8.60	0.00	24.06	34.56	2,638	1,328	141
IL	WILL	MOBIL OIL	58,000	0.00	1.40	6.32	0.00	17.70	25.42	1,941	977	104
Total - IL			290,580	0.00	6.61	29.94	0.00	83.81	120.36	9,188	4,626	491
IN	ALLEN	GLADIEUX REFIN	4,785	0.00	0.03	0.12	0.00	0.34	0.49	39	19	2
IN	LAKE	AMOCO OIL	117,450	0.00	2.32	10.53	0.00	29.46	42.31	3,236	1,626	173
IN	MARION	ROCK ISLAND REF	13,050	0.00	0.24	1.06	0.00	2.98	4.28	327	164	17
IN	POSEY	IND FARM COOP	6,554	0.00	0.09	0.41	0.00	1.15	1.65	126	63	7
IN	WABASH	LAKETON ASPHALT	2,813	0.00	0.07	0.12	0.00	0.33	0.47	36	18	2
Total - IN			144,652	0.00	2.70	12.24	0.00	34.26	49.21	3,756	1,891	201
KY	BOYD	ASHLAND OIL	63,800	0.00	1.34	6.06	0.00	16.97	24.37	1,860	922	99
KY	JEFFERSON	ASHLAND OIL	7,540	0.00	0.10	0.46	0.00	1.29	1.85	141	74	8
KY	PULASKI	SOMERSET REFIN	1,827	0.00	0.02	0.08	0.00	0.22	0.31	24	12	1
Total - KY			73,167	0.00	1.46	6.60	0.00	18.47	26.52	2,025	1,058	108
MI	GRATIOT	TOTAL PETROL	12,180	0.00	0.20	0.88	0.00	2.47	3.55	271	147	14
MI	KALAMAZOO	LAKEVIEW REFIN	1,624	0.00	0.02	0.09	0.00	0.24	0.35	27	14	1
MI	MONTCALM	CRYSTAL REFIN	1,798	0.00	0.01	0.05	0.00	0.13	0.19	14	7	1
MI	WAYNE	MARATHON OIL	20,590	0.00	0.36	1.62	0.00	4.55	6.53	498	260	27
Total - MI			36,192	0.00	0.58	2.64	0.00	7.39	10.62	810	423	43

(Continued)

TABLE A.1-5 (Continued)

St	County	Facility	Crude	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			Prod 1000 Bbl	Coal	Oil	Nat Gas	Coke	Other	Total	NO _x	SO _x	HC
MS	JACKSON	CHEVRON USA	89,100	0.00	1.95	8.82	0.00	24.69	35.45	2,706	2,003	145
MS	JONES	SOUTHLAND OIL	3,713	0.00	0.04	0.16	0.00	0.44	0.64	49	36	3
MS	LAMAR	SOUTHLAND OIL	1,931	0.00	0.01	0.05	0.00	0.14	0.20	15	11	1
MS	LAMAR	AMERADA HESS	8,910	0.00	0.22	1.01	0.00	2.81	4.04	309	228	16
MS	WARREN	ERSON	6,569	0.00	0.06	0.28	0.00	0.78	1.12	86	63	5
MS	WARREN	VICKSBURG REFIN	2,507	0.00	0.01	0.06	0.00	0.18	0.26	20	15	1
Total - MS			112,729	0.00	2.29	10.38	0.00	29.05	41.71	3,184	2,356	176
NJ	GLOUCESTER	MOBIL OIL	31,886	0.00	0.72	3.24	0.00	9.07	13.03	994	539	53
NJ	GLOUCESTER	SEAVIEW PETROL	14,882	0.00	0.16	0.72	0.00	2.01	2.89	221	119	12
NJ	GLOUCESTER	TEXACO	29,640	0.00	0.53	2.42	0.00	6.78	9.73	743	462	40
NJ	MIDDLESEX	CHEVRON USA	56,160	0.00	0.95	4.30	0.00	12.05	17.30	1,321	715	71
NJ	UNION	EXXON USA	65,520	0.00	1.78	8.06	0.00	22.57	32.41	2,474	1,346	132
Total - NJ			198,089	0.00	4.14	18.75	0.00	52.47	75.36	5,752	3,116	307
NY	ALBANY	CIBCO PETROL	12,480	0.00	0.13	0.58	0.00	1.63	2.34	179	97	10
NY	ERIE	ASHLAND OIL	20,592	0.00	0.38	1.74	0.00	4.88	7.01	535	290	29
Total - NY			33,072	0.00	0.51	2.32	0.00	6.51	9.35	713	386	38
OH	ALLEN	STANDARD OIL OH	51,530	0.00	0.86	3.91	0.00	10.95	15.72	1,200	650	64
OH	HAMILTON	GULF OIL	13,050	0.00	0.25	1.12	0.00	3.14	4.51	344	187	18
OH	LUCAS	STANDARD OIL OH	36,540	0.00	1.00	4.51	0.00	12.62	18.12	1,382	749	74
OH	LUCAS	SUN	37,700	0.00	0.85	3.84	0.00	10.74	15.42	1,177	637	63
OH	STARKE	ASHLAND OIL	19,720	0.00	0.42	1.91	0.00	5.35	7.68	586	317	31
Total - OH			158,340	0.00	3.38	15.29	0.00	42.79	61.45	4,691	2,541	251
PA	BEAVER	ASHLAND OIL	2,184	0.00	0.02	0.09	0.00	0.25	0.36	28	15	1
PA	DELAWARE	BP OIL	55,224	0.00	1.23	5.56	0.00	15.56	22.35	1,706	924	91
PA	DELAWARE	SUN	56,160	0.00	1.04	4.72	0.00	13.21	18.97	1,448	784	77
PA	MCKEAN	WITCO CHEMICAL	2,340	0.00	0.03	0.13	0.00	0.35	0.50	38	21	2
PA	MCKEAN	QUAKER ST OIL	2,184	0.00	0.03	0.15	0.00	0.43	0.62	47	26	3
PA	PHILADELPHIA	ARCO	40,560	0.00	1.13	5.13	0.00	14.37	20.64	1,575	853	84
PA	PHILADELPHIA	GULF OIL	56,160	0.00	1.08	4.89	0.00	13.68	19.64	1,499	812	80
PA	VENANGO	PENNZOIL	4,867	0.00	0.08	0.35	0.00	0.97	1.40	107	58	6
PA	WARREN	CORAL PETROL	13,416	0.00	0.30	1.34	0.00	3.76	5.40	412	223	22
Total - PA			233,095	0.00	4.94	22.36	0.00	62.58	89.88	6,860	3,716	367
TN	SHELBY	DELTA REFIN	14,471	0.00	0.27	1.20	0.00	3.36	4.83	369	273	20
VA	YORR	AMOCO OIL	17,160	0.00	0.38	1.72	0.00	4.83	6.93	529	287	28

(Continued)

TABLE A.1-5 (Continued)

St	County	Facility	Crude Prod 1000 Bbl	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MI	HANDCOCK	QUAKER ST OIL	3,744	0.00	0.08	0.35	0.00	0.97	1.40	107	58	6
MI	KANAWHA	ELK REFIN	1,903	0.00	0.02	0.10	0.00	0.27	0.39	30	16	2
MI	PLEASANTS	QUAKER ST OIL	1,560	0.00	0.02	0.07	0.00	0.21	0.30	23	12	1
Total = MI			7,207	0.00	0.11	0.52	0.00	1.45	2.09	159	86	9
MI	DOUGLAS	MURPHY OIL	11,600	0.00	0.19	0.88	0.00	2.46	3.53	269	136	14
Total Study Area			1431,899	0.00	29.57	133.88	0.00	374.77	538.22	41,084	22,567	2,196

TABLE A.1-6. SUMMARY BY COUNTY OF 1981 PETROLEUM REFINERY PRODUCTION,
FUEL USE AND SO_x, NO_x, HC EMISSIONS FOR COUNTIES
IN 27 STATES^x EAST^x OF THE MISSISSIPPI RIVER

St	County	Facility	Crude Prod 1000 Bbl	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NO _x	SO _x	HC
AL	MOBILE	All	29,106	0.00	0.32	1.43	0.00	4.00	5.74	438	324	23
AL	TUSCALOOSA	All	15,593	0.00	0.24	1.07	0.00	3.00	4.31	329	243	18
Total - AL			44,699	0.00	0.55	2.50	0.00	6.99	10.05	767	567	41
DE	NEW CASTLE	All	46,800	0.00	1.39	6.30	0.00	17.62	25.31	1,932	1,046	103
GA	CHATHAM	All	8,424	0.00	0.05	0.22	0.00	0.60	0.87	66	49	4
GA	DOUGLAS	All	1,622	0.00	0.01	0.04	0.00	0.12	0.17	13	9	1
Total - GA			10,046	0.00	0.06	0.26	0.00	0.72	1.04	79	59	4
IL	COOK	All	65,830	0.00	1.45	6.55	0.00	18.34	26.34	2,011	1,012	107
IL	CRAWFORD	All	36,250	0.00	0.96	4.33	0.00	12.11	17.40	1,328	669	71
IL	LAWRENCE	All	25,520	0.00	0.51	2.31	0.00	6.46	9.28	708	357	38
IL	MADISON	All	104,980	0.00	2.30	10.43	0.00	29.19	41.92	3,200	1,611	171
IL	MILL	All	58,000	0.00	1.40	6.32	0.00	17.70	25.42	1,941	977	104
Total - IL			290,580	0.00	6.61	29.94	0.00	83.81	120.36	9,188	4,626	491
IN	ALLEN	All	4,785	0.00	0.03	0.12	0.00	0.34	0.49	38	19	2
IN	LAKE	All	117,450	0.00	2.32	10.53	0.00	29.46	42.31	3,230	1,626	173
IN	MARION	All	13,050	0.00	0.24	1.06	0.00	2.98	4.28	327	164	17
IN	POSEY	All	6,554	0.00	0.09	0.41	0.00	1.15	1.65	126	63	7
IN	WABASH	All	2,813	0.00	0.03	0.12	0.00	0.33	0.47	36	18	2
Total - IN			144,652	0.00	2.70	12.24	0.00	34.26	49.21	3,756	1,891	201
KY	BOYD	All	63,800	0.00	1.34	6.06	0.00	16.97	24.37	1,860	972	99
KY	JEFFERSON	All	7,540	0.00	0.10	0.46	0.00	1.29	1.85	141	74	8
KY	PULASKI	All	1,827	0.00	0.02	0.08	0.00	0.22	0.31	24	12	1
Total - KY			73,167	0.00	1.46	6.60	0.00	18.47	26.53	2,025	1,058	108
MI	GRATIOT	All	12,180	0.00	0.20	0.88	0.00	2.47	3.55	271	142	14
MI	KALAMAZOO	All	1,624	0.00	0.02	0.09	0.00	0.24	0.35	27	14	1
MI	MONTCALM	All	1,798	0.00	0.01	0.05	0.00	0.13	0.19	14	7	1
MI	WAYNE	All	20,590	0.00	0.36	1.62	0.00	4.55	6.53	498	260	27
Total - MI			36,192	0.00	0.58	2.64	0.00	7.39	10.62	810	423	43
MS	JACKSON	All	89,100	0.00	1.95	8.82	0.00	24.69	35.45	2,706	2,003	145
MS	JONES	All	3,713	0.00	0.04	0.16	0.00	0.44	0.64	49	36	3
MS	LAMAR	All	10,841	0.00	0.23	1.06	0.00	2.95	4.24	324	240	17
MS	WARREN	All	9,076	0.00	0.08	0.34	0.00	0.96	1.38	105	78	6
Total - MS			112,729	0.00	2.29	10.38	0.00	29.05	41.71	3,184	2,356	170

(Continued)

TABLE A.1-6 (Continued)

St	County	Facility	Crude Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Bbl	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NJ	GLoucester	All	76,409	0.00	1.41	6.38	0.00	17.86	25.65	1,958	1,060	105
NJ	MIDDLESEX	All	56,160	0.00	0.95	4.30	0.00	12.05	17.30	1,321	715	71
NJ	UNION	All	65,520	0.00	1.78	8.06	0.00	22.57	32.41	2,474	1,340	132
Total - NJ			198,089	0.00	4.14	18.75	0.00	52.47	75.36	5,752	3,116	307
NY	ALBANY	All	12,480	0.00	0.13	0.58	0.00	1.63	2.34	179	97	10
NY	ERIE	All	20,592	0.00	0.38	1.74	0.00	4.88	7.01	535	290	29
Total - NY			33,072	0.00	0.51	2.32	0.00	6.51	9.35	713	386	38
OH	ALLEN	All	51,330	0.00	0.86	3.91	0.00	10.95	15.72	1,200	650	64
OH	HAMILTON	All	13,050	0.00	0.25	1.12	0.00	3.14	4.51	344	187	18
OH	LUCAS	All	74,240	0.00	1.84	8.34	0.00	23.35	33.54	2,560	1,387	127
OH	STARK	All	19,720	0.00	0.42	1.91	0.00	5.35	7.68	586	317	31
Total - OH			158,340	0.00	3.38	15.29	0.00	42.79	61.45	4,691	2,541	251
PA	BEAVER	All	2,184	0.00	0.02	0.09	0.00	0.25	0.36	28	15	1
PA	DELAWARE	All	111,384	0.00	2.27	10.28	0.00	28.77	41.32	3,154	1,708	169
PA	MCKEAN	All	4,524	0.00	0.06	0.28	0.00	0.78	1.12	86	46	5
PA	PHILADELPHIA	All	96,720	0.00	2.21	10.02	0.00	28.05	40.28	3,074	1,665	164
PA	VENANGO	All	4,867	0.00	0.08	0.35	0.00	0.97	1.40	107	58	6
PA	WARREN	All	13,416	0.00	0.30	1.34	0.00	3.76	5.40	412	223	22
Total - PA			233,095	0.00	4.94	22.36	0.00	62.58	89.88	6,860	3,716	367
TN	SHELBY	All	14,471	0.00	0.27	1.20	0.00	3.36	4.83	369	273	20
VA	YORK	All	17,160	0.00	0.38	1.72	0.00	4.83	6.93	529	287	28
WV	HANCOCK	All	3,744	0.00	0.08	0.35	0.00	0.97	1.40	107	58	6
WV	KANAWHA	All	1,903	0.00	0.02	0.10	0.00	0.27	0.39	30	16	2
WV	PLEASANTS	All	1,560	0.00	0.02	0.07	0.00	0.21	0.30	23	12	1
Total - WV			7,207	0.00	0.11	0.52	0.00	1.45	2.09	159	86	9
WI	DOUGLAS	All	11,600	0.00	0.19	0.88	0.00	2.46	3.53	269	136	14
Total Study Area			1431,899	0.00	29.57	133.88	0.00	374.77	538.22	41,084	22,567	2,196

REFERENCES FOR APPENDIX A.1

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2. U.S. Department of Energy. Petroleum Supply Monthly. Washington, D.C. DOE/EIA-0109(82/09), 1982.
3. Nelson, W. C. What Are Utility Needs? Oil and Gas Journal. 75(45):118-119, 1977.
4. Cherry, S. S. Draft Emissions Control by Advanced Combustion Modifications Techniques for Industrial Combustion Equipment Task 1 - Equipment Survey. Research Triangle Park, N.C. EPA 68-02-3690, 1982.
5. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. Supplements 1 through 13. 3d Ed. Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: ETHYLENE/PROPYLENE

PLANT POPULATION

In 1981, 35 ethylene plants operated in the United States, but only the 5 plants located east of the Mississippi River were included in this analysis.¹ Propylene is coproduced at 28 ethylene plants and 35 U.S. petroleum refineries with no additional direct-fired energy above and beyond that required for the product ethylene. Two of these five plants included in this study produce propylene as a coproduct, and the estimated 1981 capacity at these plants ranged from 50,000 to 470,000 tons. These five plants produced an estimated 711,300 tons in 1981, compared with a national total of 14.4×10^6 tons. The estimated 1981 production at the smallest of the five ethylene plants was 35,300 tons, and direct-fired energy consumption was 610×10^9 Btu.

COMBUSTION PROCESSES

During pyrolysis (hydrocarbon cracking), byproduct fuels are fired into a tubular furnace. The primary byproduct fuel used is hydro-methane residue gas.

PRODUCTION AND FUEL CONSUMPTION

Production

Plant capacity data were obtained from published sources,² and production was estimated by multiplying each plant's production capacity by a national average capacity factor. The 1981 national average capacity factor was based on the most recent available capacity and production data.^{1,2} These data estimate 1981 ethylene capacity at 20.5 million tons.¹ Based on a total 1981 U.S. production of 14.4 million tons,² an average capacity factor of 70.6 percent was calculated. The total estimated 1981 plant production for the five plants evaluated was 711,300 tons; individual plant production ranged from 35,300 to 331,800 tons.

Energy Consumption - Fuel Type

The tubular furnace consumes approximately 17.2×10^6 Btu/ton of direct-fired energy.³ Total plant energy consumption was calculated by multiplying production by the unit energy consumption. Both hydro-methane residue gas and pyrolysis fuel oil are fired in the tubular furnace. Because hydro-methane residue gas accounts for 97 percent of the direct-fired fuel, however, it was assumed to be the only fuel fired.³

Total estimated 1981 energy consumption for the five plants evaluated was 12.2×10^{12} Btu; individual plant consumption ranged from 610×10^9 to $5,710 \times 10^9$ Btu.

EMISSION ESTIMATES

Emission Factors

Because the tubular furnace is very similar to that used in the ammonia industry, the SO_x , NO_x , and HC emission factors used

in the ammonia methodology (Appendix A.3) in lb/10⁶ Btu have been used for this methodology. In addition, the hydro-methane residue gas was assumed to have the same emission rate as natural gas.³ Based on a heat input of 1024 Btu/ft³ of natural gas and a direct-fired energy consumption of 17.2 x 10⁶ Btu/ton, the NO_x, SO_x, and HC emission factors were converted to 2.35, 1.01 x 10⁻², and 1.34 x 10⁻¹ lb/ton, respectively.⁴

Plant Emissions

The range in annual emissions (in tons/year) for the five plants evaluated is shown below:

	<u>Low</u>	<u>High</u>
NO _x	41	390
SO _x	<0	2
HC	2	22

Table A.2-1 summarizes annual production; energy consumption; and NO_x, SO_x, and HC emissions for each of the five plants. Table A.2-2 summarizes this information by county. It should be noted that these tables show only ethylene production because propylene is coproduced and does not require any additional direct-fired energy.

TABLE A.2-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 5 ETHYLENE/PROPYLENE PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
DE	NEW CASTLE	All	79.4	0.00	0.00	0.00	0.00	1.37	1.37	93	0	5
IL	DOUGLAS	All	141.2	0.00	0.00	0.00	0.00	2.43	2.43	166	1	9
IL	GRUNDY	All	331.8	0.00	0.00	0.00	0.00	5.71	5.71	390	2	22
Total - IL			473.0	0.00	0.00	0.00	0.00	8.14	8.14	556	2	32
KY	MARSHALL	All	123.6	0.00	0.00	0.00	0.00	2.13	2.13	145	1	8
KY	MEADE	All	35.3	0.00	0.00	0.00	0.00	0.61	0.61	41	0	2
Total - KY			158.9	0.00	0.00	0.00	0.00	2.73	2.73	187	1	11
Total Study Area			711.3	0.00	0.00	0.00	0.00	12.23	12.23	836	4	48

TABLE A.2-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 5 ETHYLENE/PROPYLENE
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
DE	NEW CASTLE	SUN OLIN CHEM	79.4	0.00	0.00	0.00	0.00	1.37	1.37	93	0	5
IL	DOUGLAS	WATL DISTILLERS	141.2	0.00	0.00	0.00	0.00	2.43	2.43	166	1	9
IL	BRUNDY	INTERNORTH INC	331.8	0.00	0.00	0.00	0.00	5.71	5.71	390	2	22
Total - IL			473.0	0.00	0.00	0.00	0.00	8.14	8.14	556	2	32
KY	MARSHALL	BF GOODRICH	123.6	0.00	0.00	0.00	0.00	2.13	2.13	145	1	8
KY	MEADE	OLIN CORP	35.3	0.00	0.00	0.00	0.00	0.61	0.61	41	0	2
Total - KY			158.9	0.00	0.00	0.00	0.00	2.73	2.73	187	1	11
Total Study Area			711.3	0.00	0.00	0.00	0.00	12.23	12.23	836	4	48

REFERENCES

1. SRI International. 1982 Directory of Chemical Producers. Menlo Park, California, 1982.
2. Layman, P. L. Big-Volume Chemicals' Output Fell Again in '81. Chemical and Engineering News ():10-13, May 1982.
3. Energy and Environmental Analysis, Inc. The Technical Feasibility of Coal Use in Industrial Process Heat Applications. Prepared for the Department of Energy, Washington, D.C. 1978.
4. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. Supplements 1-13. 3d Ed. Research Triangle Park, North Carolina. AP-42, 1978.

INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: AMMONIA PLANTS

PLANT POPULATION

In 1981, approximately 77 domestic ammonia plants were operated in the United States. Of this total, 21 were located east of the Mississippi River.¹ All of these 21 met the minimum established energy consumption of 100×10^9 Btu/yr. The capacities of these plants ranged from 33,000 to 474,000 tons. The smallest plant evaluated provided an estimated 29,700 tons of ammonia in 1981 and consumed 480×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

In the manufacture of ammonia, direct-fired energy is consumed in the tubular furnace to heat the natural gas feedstock to produce the hydrogen needed for ammonia manufacture. Natural gas is the primary fuel utilized.

PRODUCTION AND ENERGY CONSUMPTION

Production

Chemical and Engineering News estimated the 1981 U.S. production of ammonia to be 19.2 million tons² versus an estimated capacity of approximately 20.1 million tons.¹ According to these data, the ammonia industry utilized 90 percent of their production capacity.^{1,2} Individual plant capacity data were

also obtained from Chemical Engineering News,² and production estimates were calculated by multiplying each plant's capacity by the national average capacity factor. Total estimated 1981 production for the 21 plants was 4.2 million tons, and the capacities of individual plants ranged from 29,700 to 426,000 tons.

Energy Consumption - Fuel Type

Estimated unit energy consumption attributable to the tubular furnace is 16.1×10^6 Btu/ton.³ Natural gas, the primary fuel consumed by the direct-fired furnace, was assumed to be the only fuel burned. Total estimated 1981 energy consumption for the 21 plants was $67,480 \times 10^9$ Btu, and the capacities of individual plants ranged from 480 to 7590×10^9 Btu/year.

EMISSION ESTIMATES

The emission factors selected for estimating combustion-related emissions in this industry are 0.0048 lb/ton, 0.024 lb/ton, and 5.8 lb/ton for SO_x , HC, and NO_x , respectively.⁴

Plant Emissions

The 1981 emissions from the 21 plants evaluated were as follows: NO_x , 86 to 1368 tons/yr; SO_x , 1 ton/yr (high and low); HC, 1 to 6 tons/yr.

Table A.3-1 summarizes production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by plant; Table A.3-2 summarizes this information by county.

TABLE A.3-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 21 AMMONIA PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NO _x	SO _x	HC
AL	COLBERT	US STEEL CORP	158.4	0.00	0.00	2.55	0.00	0.00	2.55	459	0	2
AL	COLBERT	TVA	59.4	0.00	0.00	0.96	0.00	0.00	0.96	172	0	1
Total - AL			217.8	0.00	0.00	3.51	0.00	0.00	3.51	632	1	3
FL	ESCAMBIA	AIR PRODUCTS	89.1	0.00	0.00	1.43	0.00	0.00	1.43	258	0	1
FL	HILLSBOROUGH	GARDINIER	124.2	0.00	0.00	2.00	0.00	0.00	2.00	360	0	1
Total - FL			213.3	0.00	0.00	3.43	0.00	0.00	3.43	619	1	2
GA	CHATHAM	KAISER ALUMINUM	89.1	0.00	0.00	1.43	0.00	0.00	1.43	258	0	1
GA	RICHMOND	COLUMBIA NITRO	471.6	0.00	0.00	7.59	0.00	0.00	7.59	1,368	1	6
Total - GA			560.7	0.00	0.00	9.03	0.00	0.00	9.03	1,626	1	7
IL	JO DAVIES	M-REN CORP	213.3	0.00	0.00	3.43	0.00	0.00	3.43	619	1	3
IN	VISC	CF INDUSTRIES	134.1	0.00	0.00	2.16	0.00	0.00	2.16	389	0	2
MS	JACKSON	MISS CHEMICAL	173.7	0.00	0.00	2.80	0.00	0.00	2.80	504	0	2
MS	JACKSON	STANDARD OIL	426.6	0.00	0.00	6.87	0.00	0.00	6.87	1,237	1	5
MS	LOWNDES	CARGILL INC	59.4	0.00	0.00	0.96	0.00	0.00	0.96	172	0	1
MS	YALCO	MISS CHEMICAL	371.7	0.00	0.00	5.98	0.00	0.00	5.98	1,076	1	4
Total - MS			1,031.4	0.00	0.00	16.61	0.00	0.00	16.61	2,991	2	12
NY	CATTARAUGUS	FELMONT OIL	74.7	0.00	0.00	1.20	0.00	0.00	1.20	217	0	1
NE	NEPTUNE	CF INDUSTRIES	153.9	0.00	0.00	2.48	0.00	0.00	2.48	446	0	2
OH	ALLEN	STANDARD OIL	421.2	0.00	0.00	6.78	0.00	0.00	6.78	1,221	1	5
PA	ALLEGHENY	US STEEL CORP	367.2	0.00	0.00	5.91	0.00	0.00	5.91	1,065	1	4
PA	CARRON	WJ ZINC CO	35.1	0.00	0.00	0.57	0.00	0.00	0.57	102	0	0
Total - PA			402.3	0.00	0.00	6.48	0.00	0.00	6.48	1,167	1	5
TN	HAMILTON	CF INDUSTRIES	118.6	0.00	0.00	1.91	0.00	0.00	1.91	345	0	1
TX	SHELBY	MP GRACE & CO	307.8	0.00	0.00	4.96	0.00	0.00	4.96	897	1	4
Total - TN			426.4	0.00	0.00	6.87	0.00	0.00	6.87	1,237	1	5
VA	HOPEWELL	ALLIED FIBERS	312.3	0.00	0.00	5.03	0.00	0.00	5.03	906	1	4
WV	OHIO	PPG INDUSTRIES	29.7	0.00	0.00	0.48	0.00	0.00	0.48	86	0	0
Total Study Area			4,191.3	0.00	0.00	67.48	0.00	0.00	67.48	12,155	10	50

TABLE A.3-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS, BY COUNTY, FOR 21 AMMONIA PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St:	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	COLBERT	All	217.8	0.00	0.00	3.51	0.00	0.00	3.51	632	1	3
FL	ESCAMBIA	All	89.1	0.00	0.00	1.43	0.00	0.00	1.43	258	0	1
FL	MILLSBOROUGH	All	124.2	0.00	0.00	2.00	0.00	0.00	2.00	360	0	1
Total - FL			213.3	0.00	0.00	3.43	0.00	0.00	3.43	619	1	3
GA	CHATHAM	All	89.1	0.00	0.00	1.43	0.00	0.00	1.43	258	0	1
GA	RICHMOND	All	471.6	0.00	0.00	7.59	0.00	0.00	7.59	1,368	1	6
Total - GA			560.7	0.00	0.00	9.03	0.00	0.00	9.03	1,626	1	7
IL	JO DAVIES	All	213.3	0.00	0.00	3.43	0.00	0.00	3.43	619	1	3
IN	VIGO	All	134.1	0.00	0.00	2.16	0.00	0.00	2.16	389	0	2
MS	JACKSON	All	600.3	0.00	0.00	9.66	0.00	0.00	9.66	1,741	1	7
MS	LOWNDES	All	59.4	0.00	0.00	0.96	0.00	0.00	0.96	172	0	1
MS	YALCO	All	371.7	0.00	0.00	5.98	0.00	0.00	5.98	1,078	1	4
Total - MS			1,031.4	0.00	0.00	16.61	0.00	0.00	16.61	2,991	2	12
MI	CATTARAUGUS	All	74.7	0.00	0.00	1.20	0.00	0.00	1.20	217	0	1
NC	HEATFORD	All	152.9	0.00	0.00	2.48	0.00	0.00	2.48	446	0	2
OH	ALLEN	All	421.2	0.00	0.00	6.78	0.00	0.00	6.78	1,221	1	5
PA	ALLEGHENY	All	367.2	0.00	0.00	5.91	0.00	0.00	5.91	1,065	1	4
PA	CARBON	All	35.1	0.00	0.00	0.57	0.00	0.00	0.57	102	0	0
Total - PA			402.3	0.00	0.00	6.48	0.00	0.00	6.48	1,167	1	5
TN	HAMILTON	All	118.8	0.00	0.00	1.91	0.00	0.00	1.91	345	0	1
TN	SHELBY	All	307.8	0.00	0.00	4.96	0.00	0.00	4.96	893	1	4
Total - TN			426.6	0.00	0.00	6.87	0.00	0.00	6.87	1,237	1	5
VA	NOPEWELL	All	312.3	0.00	0.00	5.03	0.00	0.00	5.03	906	1	4
WV	OHIO	All	29.7	0.00	0.00	0.48	0.00	0.00	0.48	66	0	0
Total Study Area			4,191.3	0.00	0.00	67.48	0.00	0.00	67.48	12,155	10	50

REFERENCES

1. SRI International. 1982 Directory of Chemical Producers, United States of America. Menlo Park, California. 1982.
2. Kiefer, D. M. Chemical Output is Sliding Following A Short-Lived Recovery. Chemical and Engineering News, 59(51):32-41, 1981.
3. Energy and Environment Analysis, Inc. The Technical Feasibility of Coal Use in the Industrial Process Heat Application. Prepared for the Department of Energy, Washington, D.C. 1978.
4. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. Supplements 1-13. Research Triangle Park, North Carolina. AP-42, 1977.

INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: BTX PLANTS

PLANT POPULATION

Benzene, toluene, and xylenes (BTX) are produced at chemical plants, coking plants, and petroleum refineries. In 1981, the 53 benzene, 44 toluene, and 53 xylene plants in the United States yielded total capacities of 9.43×10^6 , 5.96×10^6 , and 8.59×10^6 tons, respectively.¹ Most of this capacity, however, represents the manufacture of BTX at coking plants and petroleum refineries; because direct-fired energy attributable to BTX production was accounted for in these two industries, it is excluded here.

As of 1981, one plant located east of the Mississippi (in Decatur, Alabama) produced BTX (p-xylene). In 1981 this plant produced an estimated 396,500 tons and consumed $1,570 \times 10^9$ Btu of direct-fired energy.¹

COMBUSTION PROCESSES

The direct-fired energy in the production of p-xylene at the Alabama plant was consumed in a tubular preheater used to heat the p-xylene feedstocks, which is fired by byproduct gases from the plant.²

PRODUCTION AND FUEL CONSUMPTION

Production

A 1981 production figure of 400,000 tons/year was obtained for the plant by applying a national average utilization factor of 61 percent³ to its reported 1981 plant capacity of 650,000 tons in the literature.

Energy Consumption - Fuel Type

The energy consumption attributed to the process gas-fired tubular preheater is estimated to be 3.97×10^6 Btu/ton,⁴ and the total 1981 energy consumption for the plant was estimated to be approximately $1,570 \times 10^9$ Btu. Plant byproduct gases, which have an approximate heating value equivalent to that of natural gas, was assumed to be the only fuel utilized.²

EMISSION ESTIMATES

Emission Factors

Because of similarities in operation and fuel type, the emission factors for the process gas-fired tubular preheater were assumed to be equivalent to those for natural gas-fired process heaters used in light hydrocarbon refineries. The specific emission factors obtained from the AP-42 are 140, 0.6, and 5.8 lb/10⁶ natural gas for NO_x, SO_x, and HC, respectively.⁵ Based on the energy consumption factor of 3.97×10^6 Btu/ton and a heating value of 1024 Btu/ft³ for natural gas,⁶ the emission factors converted to pounds per ton are 5.43×10^{-1} for NO_x, 2.33×10^{-3} for SO_x, and 2.25×10^{-2} for HC.

Plant Emissions

Table A.4-1 summarizes the 1981 estimated production, fuel consumption, and NO_x , SO_x , and HC emissions by county for the single BTX plant evaluated.

TABLE A.4-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x, SO_x, AND HC EMISSIONS, BY COUNTY, FOR ONE BTX PLANT
 LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MORGAN	All	396.5	0.00	0.00	0.00	0.00	1.57	1.57	108	0	4
Total Study Area			396.5	0.00	0.00	0.00	0.00	1.57	1.57	108	0	4

REFERENCES

1. SRI International. 1982 Directory of Chemical Producers United States of America. Menlo Park, California. 1982.
2. Personal communication from G. Christianson, Standard Oil Company (Indiana) to R. S. McKibben, PEDCo Environmental, Inc. March 1983.
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5. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3d Edition (including Supplements 1 through 13; Final). AP-42, 1977.
6. State Energy Data Report, U.S. Department of Energy. Average Industrial Consumption in U.S., 1980. DOE/EPA - 0214(80), July 1982.

INDUSTRY: CARBON BLACK

PLANT/FACILITY: CARBON BLACK PLANTS

PLANT POPULATION

In 1981, 25 carbon black plants operated in the U.S., 4 of which were located east of the Mississippi and were included in this analysis.¹ The estimated 1981 capacity range for the four plants is 25,000 to 80,000 tons. The estimated 1981 production of the 4 plants analyzed was 186,000 tons, compared with a 1981 national total of 1.3×10^6 tons. The smallest plant had a 1981 production estimate of 18,800 tons of carbon black and a direct-fired energy consumption estimate of $2,060 \times 10^9$ Btu.

COMBUSTION PROCESSES

Carbon black is the product of incomplete combustion of oil or natural gas. Ninety-six percent is manufactured using the furnace process with oil feed.^{1,2*} The combustion processes involved are reactor and pellet dryer, which are direct fired, and are reported to be exclusively fired with natural gas.^{2,3}

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* The oil feed is considered feedstock and is not a part of the direct-fired estimate.

PRODUCTION AND FUEL CONSUMPTION

Production

Since individual plant production values could not be obtained, production for the plants being investigated was obtained by applying a national average utilization factor (based on 1981 production), to the plant capacities reported in the literature. The 1981 production (1.3×10^6 tons) divided by the capacity of 1.7×10^6 tons yields a factor of 0.75 which was used to calculate individual plant capacities.⁴

Energy Consumption - Fuel Type

Total energy requirements (including the partial combustion of oil feedstock) for carbon black by the oil furnace process are in the range of 5 to 7×10^4 Btu/lb, with an average of 5.5×10^4 Btu/lb (110×10^6 Btu/ton).² However, the direct-fired energy consumption averages only 52.4×10^6 Btu/ton.⁵ The distribution of direct-fired energy consumption between the reactor and dryer was not reported but the reactor was indicated to account for most of the consumption.² Natural gas was reported to be the only direct-fired fuel.^{2,4} Total 1981 energy consumption for the 4 plants analyzed was estimated to be 9740×10^9 Btu/yr, with a plant range of 980 to 3140×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Emission factors applied to plant production were based on combined factors from the reactor and the dryer. These are 0.56, 0.10, and 0.36 lb/ton for NO_x , SO_x and HC respectively.^{3,6}

The HC emission factor is a default value that accounts for direct-fired combustion emissions only.³

Plant Emissions

The range in annual emissions for plants east of the Mississippi River is:

	Low	High
NO _x	5	17
SO _x	1	3
HC	3	11

Tables A.5-1 and A.5-2 summarize fuel consumption and SO_x, NO_x and HC emissions by plant and county respectively.

TABLE A.5-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY PLANT FOR FOUR CARBON BLACK PLANTS EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	RUSSELL	EI DUPONT	18.8	0.00	0.00	0.98	0.00	0.00	0.98	5	1	3
OH	WASHINGTON	ASHLAND OIL	48.8	0.00	0.00	2.55	0.00	0.00	2.55	14	2	9
WV	MARSHALL	CITIES SERVICE	58.5	0.00	0.00	3.06	0.00	0.00	3.06	16	3	10
WV	WOOD	CABOT CORP	60.0	0.00	0.00	3.14	0.00	0.00	3.14	17	3	11
Total - WV			118.5	0.00	0.00	6.21	0.00	0.00	6.21	33	6	21
Total Study Area			186.0	0.00	0.00	9.74	0.00	0.00	9.74	52	9	33

TABLE A.5-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR FOUR CARBON BLACK PLANTS EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	RUSSELL	All	18.3	0.00	0.00	0.98	0.90	0.00	0.98	5	1	3
OH	WASHINGTON	All	48.8	0.00	0.00	2.55	0.10	0.00	2.55	14	2	9
WV	MARSHALL	All	58.5	0.00	0.00	3.06	0.90	0.00	3.96	16	3	10
WV	WOOD	All	60.9	0.00	0.00	3.14	0.10	0.00	3.14	17	3	11
Total - WV			118.5	0.00	0.00	6.21	0.00	0.00	6.21	33	6	21
Total Study Area			186.0	0.00	0.00	9.74	0.00	0.00	9.74	52	9	33

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INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: ETHANOL PLANTS

PLANT POPULATION

In 1981, there were 15 ethanol plants in the U.S., with 5 being located east of the Mississippi.¹ Only one of these plants produces ethanol synthetically via a direct-fired process. The remainder of the plants either produces ethanol via the non direct-fired 1) fermentation/distillation process (3 plants) or 2) refining of low grade ethanol (1 plant).^{1,2} The one direct-fired plant analyzed had an estimated 1981 capacity of 208,000 tons, production of 156,000 tons, and a direct-fired energy consumption of 310×10^9 Btu.

COMBUSTION PROCESSES

In the synthetic ethanol process, a direct-fired tubular preheater is utilized to preheat the ethylene feedstock to desired temperature and pressure.³ The preheater is normally fired by plant by-product gases in a manner similar to that found in refineries.⁴

PRODUCTION AND FUEL CONSUMPTION

Production

Production for the process analyzed was obtained by applying a national average utilization factor to the reported plant

capacity of 66 million gallons.¹ Applying a density of 6.3 lb/gal (95% ethanol)⁵ and a utilization factor of 75 percent,⁶ the plant's 1981 production was estimated to be approximately 156,000 tons.

Energy Consumption - Fuel Type

Energy consumption was assumed to be 2.0×10^6 Btu/ton of ethanol.⁷ The total 1981 energy consumption for the single plant was estimated to be approximately 310×10^9 Btu. Plant by-product gas, having an approximate heating value equivalent to that of natural gas, was assumed to be the only fuel utilized.⁴

EMISSION ESTIMATES

Emission Factors

Based on similarities in operation and fuel type, the emission factors for the process gas-fired tubular preheater were assumed to be equivalent to that of natural gas-fired process heaters utilized by light hydrocarbon refineries. The specific emission factors, as obtained from the U.S. EPA's AP-42 publication are: 140.0, 0.6, and $5.8 \text{ lb}/10^6 \text{ ft}^3$ of natural gas for NO_x , SO_x , and HC respectively.⁸ Utilizing the energy consumption factor of 1.984×10^6 Btu/ton and a heating value of $1024 \text{ Btu}/\text{ft}^3$ for natural gas,⁹ the emission factors converted to lb/ton are: 0.271, 1.16×10^{-3} , and 1.12×10^{-2} for NO_x , SO_x , and HC respectively.

Plant Emissions

Table A.6-1 summarizes the 1981 estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by county for the single ethanol plant evaluated.

TABLE A.6-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x , SO_x , AND HC EMISSIONS BY COUNTY, FOR 1 ETHANOL PLANT
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
IL	BOUCLAS	All	156.0	0.00	0.00	0.00	0.00	0.31	0.31	21	0	1
Total Study Area			156.0	0.00	0.00	0.00	0.00	0.31	0.31	21	0	1

REFERENCES

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9. State Energy Data Report, U.S. DOE. July 1982. DOE/EIA-0214(80). Average Industrial Consumption in U.S. 1980.

INDUSTRY: PETROCHEMICALS

PLANT/FACILITY: METHANOL PLANTS

PLANT POPULATION

The total U.S. capacity for methanol production in 1981 was 4.97×10^6 tons/year, with 11 methanol plants in the U.S., and one plant being located east of the Mississippi.¹ This plant had an estimated 1981 capacity of 148,750 tons, estimated production of approximately 107,100 tons and direct-fired energy consumption of 166×10^9 Btu.

COMBUSTION PROCESSES

In the manufacture of methanol, direct-fired energy is consumed in a tubular reformer. The tubular reformers are fired by either natural gas or naphtha.²

PRODUCTION AND FUEL CONSUMPTION

Production

Production for the plant analyzed was obtained by applying a national average utilization factor to its reported plant capacity of 45 million gal/yr.¹ Applying a density of 6.61 lb/gal³ and a utilization factor of 72 percent,⁴ the plant's 1981 production was estimated to be approximately 107,100 tons.

Energy Consumption - Fuel Type

The unit energy consumption attributed to the tubular reformer is estimated to be 15.5×10^6 Btu/ton.⁵ The total 1981 energy consumption for this single plant was estimated to be approximately 1.66×10^{12} Btu. Natural gas was assumed to be the only fuel utilized.²

EMISSION ESTIMATES

Emission Factors

Industrial combustion default emission factors for tubular reformers as reported by the U.S. EPA's AP-40 publication are:⁶ 0.42 and $7.0 \text{ lb}/10^6 \text{ ft}^3$ natural gas for SO_x and HC, respectively. Utilizing the energy consumption factor of 15.5×10^6 Btu/ton and a heating value of $1024 \text{ Btu}/\text{ft}^3$ for natural gas,⁷ the emission factors converted to lb/ton are: 6.36×10^{-3} and 1.06×10^{-1} for SO_x and HC, respectively.

Nitrogen dioxide emissions were estimated using an equation derived by Mills et al.⁸ The plant is assumed to operate on an average of 6310 hours/year. This was obtained by multiplying the total available hours in a year by the utilization factor of 72 percent.

Plant Emissions

Table A.7-1 summarizes the 1981 estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by county for the single methanol plant evaluated.

TABLE A.7-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x , SO_x , AND HC EMISSIONS BY COUNTY, FOR 1 METHANOL PLANT
 LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
FL	ESCAMBIA	All	107.1	0.00	0.00	1.66	0.00	0.00	1.66	203	0	6
Total Study Area			107.1	0.00	0.00	1.66	0.00	0.00	1.66	203	0	6

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INDUSTRY: INDUSTRIAL ORGANIC CHEMICALS

PLANT/FACILITY: DIMETHYL TEREPHTHALATE PLANTS

PLANT POPULATION

The five dimethyl terephthalate (DMT) plants in the U.S. are all located east of the Mississippi. In 1981 their total capacity for DMT production was 2.12×10^6 tons.¹ Plant capacities ranged from 270,000 to 675,000 tons. The smallest plant analyzed had an estimated 1981 production of 156,600 tons and consumed 560×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

There are two process routes being used to manufacture DMT with both being based on the use of p-xylene as the starting material.

In the first process, DMT is produced through the intermediate production of crude terephthalic acid by direct air-oxidation of p-xylene.^{2,3} This acid is subsequently esterified with methanol to produce DMT. In this process, direct-fired heaters are used to heat a high temperature transfer fluid.³ This transfer fluid is in turn then used to preheat the feedstocks. The heaters are normally fired with natural gas.³

The second process involves stepwise indirect oxidation/esterification of p-xylene. In this process, a direct-fired

tubular preheater is utilized to preheat the p-xylene feedstock to the desired temperature and pressure.⁴ The preheater was assumed to fire natural gas.

PRODUCTION AND FUEL CONSUMPTION

Production

Production for the five plants was obtained by applying a national average utilization factor to their reported plant capacities found in the literature. As mentioned previously, the 1981 U.S. total capacity was 2.12×10^6 tons. Applying a utilization factor of 58 percent,⁵ the total 1981 production of the five plants was estimated to be approximately 1.23×10^6 tons, with a plant range of 156,600 to 391,500 tons.

Energy Consumption - Fuel Type

Energy consumption for all five plants was assumed to be equivalent i.e., 3.6×10^6 Btu/ton.⁴ The total energy consumption for the five plants was estimated to be approximately 4.43×10^{12} Btu, with a plant range of 560×10^9 to $1,410 \times 10^9$ Btu. Natural gas was assumed to be the only fuel utilized.³

EMISSION ESTIMATES

Emission Factors

Based on similarities in operation and fuel type, the emission factors for the natural gas-fired tubular preheater were assumed to be equivalent to that of natural gas-fired process heaters utilized by light hydrocarbon refineries. The

specific emission factors, as obtained from the U.S. EPA's AP-42 publication are: 140.0, 0.6, and 5.8 lb/10⁶ft³ natural gas for NO_x, SO_x and HC respectively.⁶ Utilizing the energy consumption factor of 3.6 x 10⁶ Btu/ton and a heating value of 1024 Btu/ft³ for natural gas,⁷ the emission factors converted to lb/ton are: 4.92 x 10⁻¹, 2.11 x 10⁻³, and 2.04 x 10⁻² for NO_x, SO_x, and HC respectively.

Plant Emissions

The range in annual emissions (in tons/year) for the five plants is shown below:

	Low	High
NO _x	39	96
SO _x	negligible	
HC	2	4

Tables A.8-1 and A.8-2 summarize the plants estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county respectively.

TABLE A.8-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS FOR 5 DMT PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	NEW HAMOVER	EI DUPONT	362.5	0.00	0.00	1.31	0.00	0.00	1.31	89	0	4
NC	NEW HAMOVER	MERCOFINA	391.5	0.00	0.00	1.41	0.00	0.00	1.41	96	0	4
Total - NC			754.0	0.00	0.00	2.71	0.00	0.00	2.71	185	1	8
SC	RICHLAND	EASTMAN KODAK	156.6	0.00	0.00	0.56	0.00	0.00	0.56	39	0	2
TN	DAVIDSON	EI DUPONT	159.5	0.00	0.00	0.57	0.00	0.00	0.57	39	0	2
TN	SULLIVAN	EASTMAN KODAK	159.5	0.00	0.00	0.57	0.00	0.00	0.57	39	0	2
Total - TN			319.0	0.00	0.00	1.15	0.00	0.00	1.15	78	0	3
Total Study Area			1,229.6	0.00	0.00	4.43	0.00	0.00	4.43	302	1	13

TABLE A.8-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 5 DMT PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	NEW HAMPSHIRE	All	754.0	0.00	0.00	2.71	0.00	0.00	2.71	185	1	8
SC	RICHLAND	All	156.6	0.00	0.00	0.56	0.00	0.00	0.56	39	0	2
TN	DAVIDSON	All	159.5	0.00	0.00	0.57	0.00	0.00	0.57	39	0	2
TN	SULLIVAN	All	159.5	0.00	0.00	0.57	0.00	0.00	0.57	39	0	2
Total - TN			319.0	0.00	0.00	1.15	0.00	0.00	1.15	78	0	3
Total Study Area			1,229.6	0.00	0.00	4.43	0.00	0.00	4.43	302	1	13

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INDUSTRY: INDUSTRIAL ORGANIC CHEMICALS

PLANT/FACILITY: STYRENE PLANTS

PLANT POPULATION

In 1981, there were 13 styrene plants located in the U.S., with 2 being located east of the Mississippi. As of 1981, their total annual capacity was 260,000 tons, compared to a national total of about 4.5×10^6 tons. The individual plant capacities for the two facilities are 110,000 and 150,000 tons/year.¹ The smaller of the two facilities had a 1981 production estimate of 86,900 tons of styrene and consumed 570×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

Polymer grade styrene monomer is manufactured by alkylating benzene and ethylene to form ethylbenzene which is then dehydrogenated to form styrene. In converting the ethylbenzene to styrene, a direct-fired steam superheater is utilized.² The superheaters are fired by by-product gases produced from other on-site plant processes.²

PRODUCTION AND FUEL CONSUMPTION

Production

Production for the plants being investigated was obtained by applying a national average utilization factor of 79 percent

to the plant capacities of 260,000 tons, yielding a 1981 production estimate for the two plants of 205,400 tons.³

Energy Consumption - Fuel Type

Energy consumption was assumed to be 3294 Btu/lb (6.6×10^6 Btu/ton).² The estimated 1981 energy consumption for the two plants was 572×10^9 and 781×10^9 Btu. Plant by-product gas, having an approximate heating value equivalent to that of natural gas, was assumed to be the only fuel utilized.²

EMISSION ESTIMATES

Emission Factors

Based on similarities in operation and fuel type, the emission factors for the by-product gas-fired steam superheater were assumed to be equivalent to that of natural gas-fired process heaters utilized by light hydrocarbon refineries. The specific emission factors, as obtained from the U.S. EPA's AP-42 publication, are: 140.0, 0.6, and 5.8 lb/10⁶ft³ of natural gas for NO_x, SO_x, and HC respectively.⁴ Utilizing the energy consumption factor of 3294 Btu/lb and a heating value of 1024 Btu/ft³ for natural gas,⁵ the emission factors converted to lb/ton are: 9.01×10^{-1} , 3.86×10^{-3} , and 3.73×10^{-2} for NO_x, SO_x, and HC respectively.

Plant Emissions

The range in annual emissions in tons/year for the two plants are shown below:

	Low	High
NO _x	39	53
SO _x	negligible	
HC	2	2

Summarized in Tables A.9-1 and A.9-2 are the two plants' estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county, respectively.

TABLE A.9-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x, SO_x, AND HC EMISSIONS FOR 2 STYRENE PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Total	Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other		NO _x	SO _x	PM	HC
MI	MIDLAND	BOW CHEMICAL	118.5	0.00	0.00	0.00	0.00	0.78	0.78	53	28.0	0	2
PA	BEAVER	ATLAN RICHFIELD	86.9	0.00	0.00	0.00	0.00	0.57	0.57	39	0	0	2
Total Study Area			205.4	0.00	0.00	0.00	0.00	1.35	1.35	93	0	0	4

TABLE A.9-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x , SO_x , AND HC EMISSIONS BY COUNTY, FOR 2 STYRENE PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other	Total	NO_x	SO_x	HC
MI	MIDLAND	All	118.5	0.00	0.00	0.00	0.00	0.78	0.78	53	0	2
PA	BEAVER	All	86.9	0.00	0.00	0.00	0.00	0.57	0.57	39	0	2
Total Study Area			205.4	0.00	0.00	0.00	0.00	1.35	1.35	93	0	4

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INDUSTRY: INORGANIC CHEMICALS

PLANT/FACILITY: ALUMINA

PLANT POPULATION

In 1980, there were approximately 13 calcined alumina plants in the U.S., with 2 being located east of the Mississippi.¹ The two plants had reported capacities of 199×10^3 and $1,089 \times 10^3$ tons per year, respectively. Total estimated 1980 production of these two plants was 1.05×10^6 tons, compared to a national 1980 production of 6.94×10^6 tons.^{1,2} The smaller of the two plants had an estimated 1980 production of 162.4×10^3 tons, and a direct-fired energy consumption of 670×10^9 Btu.

COMBUSTION PROCESSES

In the Bayer process, alumina is produced from bauxite. The final step in this process is the transformation of trihydroxide to anhydrous alumina by calcination in rotary kilns or fluid bed calciners.³ Currently, rotary kilns are more prevalent, but are being replaced by the energy-efficient fluid bed calciner. Both the rotary kiln and the fluid bed calciner are direct fired. Natural gas is the predominant fuels fired in this industry.^{4,5,6}

PRODUCTION AND FUEL CONSUMPTION

Production

The 1980 production for plants east of the Mississippi was calculated by applying a national average utilization factor to individual plant capacities.^{1,2} The national 1980 production (6.94×10^6 tons)⁴ and capacity (8.49×10^6 tons)¹ data yield a utilization factor of 0.82. Based on this calculation, it was assumed that all plants utilize 82 percent of their capacity.

Energy Consumption - Fuel Type

The energy required to produce calcined alumina is approximately 4.1×10^6 Btu/ton.^{4,7,8} This energy consumption factor was applied to individual plant production to determine each plant's total energy consumption. Estimated 1980 energy consumption for the two plants east of the Mississippi was 670×10^9 and $3,640 \times 10^9$ Btu.

Although oil and natural gas are fired during calcination,⁴ precise data on the fuels consumed by individual plants are not available.⁵ Natural gas was assumed to be the primary fuel utilized, based on the fact that the 2 plants analyzed are near adequate supplies of natural gas.

EMISSION ESTIMATES

Emission Factors

Emission factors for NO_x , SO_x , and HC are based on industrial combustion source default factors from the literature.^{8,9} Nitrogen oxide emissions are estimated by equations derived from Mills, et al.⁹ Operating time for the kiln was

assumed to be 7183 hrs/yr, based on the 87 percent capacity factor discussed previously. The SO_x and HC emission factors are shown below (in lb/ton):¹⁰

	SO_x	HC
Natural gas	1.35×10^{-3}	2.24×10^{-2}
Oil	$6.31(S) \times 10^{-1}$	1.66×10^{-2}
Total	6.32×10^{-1}	3.90×10^{-2}

Plant Emissions

The range in emissions for 2 eastern U.S. plants evaluated (in tons/year), is shown below:

	Low	High
NO_x	498	566
SO_x	Negligible	1
HC	2	12

Tables A.10-1 and A.10-2 summarize production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by plant and county, respectively for the 2 alumina plants analyzed.

TABLE A.10-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR TWO ALUMINA PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

=====												
			Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility		Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MOBILE	ALCOA	888.6	0.00	0.00	3.64	0.00	0.00	3.64	498	1	12
TN	GREENE	COMBUSTION ENGR	162.4	0.00	0.00	0.67	0.00	0.00	0.67	566	0	2
Total Study Area			1,051.0	0.00	0.00	4.31	0.00	0.00	4.31	1,063	1	15
=====												

TABLE A.10-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR TWO ALUMINA PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MOBILE	All	888.6	0.00	0.00	3.64	0.00	0.00	3.64	498	1	12
TN	GREENE	All	162.4	0.00	0.00	0.67	0.00	0.00	0.67	566	0	2
Total Study Area			1,051.0	0.00	0.00	4.31	0.00	0.00	4.31	1,063	1	15

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INDUSTRY: INDUSTRIAL INORGANIC CHEMICALS

PLANT/FACILITY: LITHIUM CARBONATE PLANTS

PLANT POPULATION

In 1981, there were 3 lithium carbonate plants in the U.S., with 2 being located east of the Mississippi.^{1,2} The total U.S. capacity for lithium carbonate production in 1981 was 34,000 tons.² The capacities of the two plants were 9,000 and 18,000 tons. The smaller of the two plants analyzed had an estimated 1981 plant production of 7,500 tons of lithium carbonate and consumed 188×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

Presently in the U.S., only the sulfuric acid process is being employed to manufacture lithium carbonate from spodumene ore.³ In this process, direct-fired energy is consumed in the 1) calcination kiln and 2) sulfuric acid roaster.^{4,5} The first relevant step in the manufacture of lithium carbonate is calcination. The second involves roasting of the ore once it has been acidified by sulfuric acid. Presently, natural gas is the only fuel used today by the industry to fire both the kiln and acid roaster.³

PRODUCTION AND FUEL CONSUMPTION

Production

Production in 1981 for the two plants as reported by the literature was 7,500 and 14,454 tons, respectively.²

Energy Consumption - Fuel Type

The average unit energy consumptions of natural gas attributed to 1) the kiln for calcination and 2) the acid roaster for roasting (in Btu per ton of lithium carbonate produced) are 2.34×10^7 and 1.62×10^6 , respectively.⁵ The estimated 1981 energy consumption for the two plants was 187.7×10^9 and 361.6×10^9 Btu, respectively. Natural gas was assumed to be the only fuel utilized.³

EMISSION ESTIMATES

Emission Factors

Industrial combustion default emission factors for the kiln and acid roaster were assumed because no other process-specific factors were available from published literature.

Nitrogen oxide emissions were estimated using an equation derived by Mills et al.⁶ The two plants analyzed were assumed to have operated 7300 and 7030 hours in 1981. Operating hours were obtained by multiplying the total available hours in a year by the given ratio of the individual plant's production to capacity.

The SO_x and HC emission factors as obtained from the U.S. EPA's AP-40 publication are: 0.42 and $7.0 \text{ lb}/10^6 \text{ ft}^3$ natural gas, respectively. The emission factors converted to lb/ton for the kiln, based on its energy consumption factor of 2.34×10^7 Btu/ton and a heating value of $1024 \text{ Btu}/\text{ft}^3$ for natural gas are: 9.6×10^{-3} and 1.6×10^{-1} for SO_x and HC, respectively. Similarly for the acid roaster, the emission factors converted to

lb/ton based on its energy consumption factor of 1.62×10^6 Btu/ton and a heating value of 1024 Btu/ft³ for natural gas, are: 6.64×10^{-3} and 1.11×10^{-2} for SO_x and HC, respectively.

Plant Emissions

The range in total annual emissions (kiln and acid roaster) in tons/year for the two plants are shown below:

	Low	High
NO _x	15	32
SO _x	negligible	
HC	1	1

Tables A.11-1 and A.11-2 summarize the plants estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county, respectively.

TABLE A.11-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 2 LITHIUM CARBONATE PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

		Prod 1000	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	CLEVELAND	FOOTE MINERAL	7.5	0.00	0.00	0.19	0.00	0.00	0.19	15	0	1
NC	GASTON	GULF RES & CHEM	14.4	0.00	0.00	0.36	0.00	0.00	0.36	32	0	1
Total - NC			21.9	0.00	0.00	0.55	0.00	0.00	0.55	47	0	2
Total Study Area			21.9	0.00	0.00	0.55	0.00	0.00	0.55	47	0	2

TABLE A.11-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 2 LITHIUM CARBONATE PLANTS^x LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	CLEVELAND	All	7.5	0.00	0.00	0.19	0.00	0.00	0.19	15	0	1
NC	GASTON	All	14.4	0.00	0.00	0.36	0.00	0.00	0.36	32	0	1
Total - NC			21.9	0.00	0.00	0.55	0.00	0.00	0.55	47	0	2
Total Study Area			21.9	0.00	0.00	0.55	0.00	0.00	0.55	47	0	2

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INDUSTRY: INDUSTRIAL INORGANIC CHEMICALS

PLANT/FACILITY: TITANIUM DIOXIDE PLANTS

PLANT POPULATION

In 1982, there were 10 titanium dioxide plants in the U.S., with 9 being located east of the Mississippi.^{1,2} However, only three out of the nine plants met the established energy consumption criteria of 100×10^9 Btu/year. Therefore, the remaining six plants were excluded from further consideration. The total capacity of the three plants in 1982 was 146,065 tons, compared with a national total of about 170,000 tons.^{1,2} The 1982 capacity range for the three plants was 41,970 to 60,000 tons. The smallest plant had an estimated 1982 plant production of 25,600 tons with a direct-fired energy consumption of $1,190 \times 10^9$ Btu.

COMBUSTION PROCESSES

Titanium dioxide is produced in the U.S. by the chloride process and the sulfate process. Two of the three plants located east of the Mississippi produce titanium dioxide via both processes.¹ The remaining plant uses only the sulfate process to produce titanium dioxide.¹ Since direct-fired energy requirements of the chloride process are very low in comparison with the sulfate process, the chloride process was excluded from further analysis.

The sulfate process uses ilmenite ore concentrate from placer or open-pit mines, or titanium slag, chiefly from Sorel, Canada. Direct-fired energy is consumed by this process in the ore dryer and calciner.^{3,4} The ore dryer and the calciner are fired by fuel oil and natural gas, respectively.⁴

PRODUCTION AND FUEL COMBUSTION

Production

Production for the three plants was obtained by applying a national average utilization factor to their reported plant sulfate capacities provided in the literature and updated to 1982 by a leading expert knowledgeable in the industry. As mentioned previously, the 1982 sulfate capacity for the three plants was 146,065 tons. Applying a utilization factor of 61 percent,⁵ the three plants' 1982 production was estimated to be approximately 89,100 tons with a plant range of 25,600 to 36,600 tons.

Energy Consumption - Fuel Type

For the sulfate process, based on the use of sorel slag as the starting material by the three plants, the unit energy consumptions for the drying and calcination operations are:^{2,4}

2.5 gallons of residual fuel oil per ton of titanium dioxide and 43,000 ft³ of natural gas per ton of titanium dioxide. Utilizing heating values of 150,000 Btu/gal for residual fuel oil⁶ and 1024 Btu/ft³ for natural gas,⁶ the energy consumption in Btu/ton for the two equipment items are approximately: 3.75×10^5 and 44.0×10^6 for the ore dryer and calciner, respectively, for a total of 47.73×10^6 Btu/ton.

Therefore, the total energy consumption in 1982 for the three plants was estimated at 4.6×10^{12} Btu sulfate produced titanium dioxide, respectively. Total 1981 energy consumption was estimated to be $4,630 \times 10^9$ Btu, with a plant range of $1,190 \times 10^9$ to $1,800 \times 10^9$ Btu.

EMISSION ESTIMATES

Emission Factors

Nitrogen oxide emissions for the oil and natural gas fired equipment items were estimated using equations derived by Mills et al.⁷ The plants were assumed to operate 5340 hours/year. This was obtained by multiplying the total available hours in a year by the utilization factor of 61 percent.

The SO_x and HC emission factors were obtained from the U.S. EPA's AP-40 publication. The SO_x emission factors for oil and natural gas are $7000 (S) \text{ lb}/10^3 \text{ bbl}$ (where S = sulfur content of oil in percent) and $0.42 \text{ lb}/10^6 \text{ ft}^3$, respectively.⁸ The average percent sulfur in residual oil varies by state and is therefore incorporated into the oil emission factor. Utilizing the previously mentioned oil and natural gas consumption rates given for the sulfate equipment items, the emission factors converted to lb/ton are: $4.17 \times 10^{-1} (S)$ and 1.806×10^{-2} for the soral slag dryer and calciner, respectively.

The HC emission factors for oil and natural gas are $127.0 \text{ lb}/10^3 \text{ bbl}$ and $7.0 \text{ lb}/10^6 \text{ ft}^3$, respectively.⁸ Utilizing the oil and natural gas consumption rates given for the sulfate equipment items, the emission factors converted to lb/ton are:

7.56×10^{-3} and 3.01×10^{-1} for the sored slag dryer and calciner, respectively.

Plant Emissions

The range in total annual emissions in tons/year for the three plants are shown below:

	Low	High
NO _x	141	227
SO _x	8	15
HC	4	6

Tables A.12-1 and A.12-2 summarize the three plants estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county, respectively.

TABLE A.12-1. SUMMARY OF 1980 PRODUCTION ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR THREE TITANIUM DIOXIDE PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Total	Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other		NO _x	SO _x	HC
GA	CHATNAM	AMEF CYANAMID	36.6	0.00	0.01	1.63	0.00	0.00	1.64	204	15	6
MD	BALTIMORE	SCM CORP	25.6	0.00	0.02	1.79	0.00	0.00	1.80	227	12	6
NJ	CAMDEN	GULF & WESTERN	26.8	0.00	0.01	1.18	0.00	0.00	1.19	141	8	4
Total Study Area			89.1	0.00	0.04	4.59	0.00	0.00	4.63	572	35	16

TABLE A.12-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR THREE TITANIUM DIOXIDE
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Total	Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other		NO _x	SO _x	HC
GA	CHATNAM	All	36.6	0.00	0.01	1.63	0.00	0.00	1.64	204	15	6
MD	BALTIMORE	All	25.6	0.00	0.02	1.79	0.00	0.00	1.80	227	12	6
NJ	CAMDEN	All	26.8	0.00	0.01	1.18	0.00	0.00	1.19	141	8	4
Total Study Area			89.1	0.00	0.04	4.59	0.00	0.00	4.63	572	35	16

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INDUSTRY: PHOSPHATE ROCK AND BASIC FERTILIZER

PLANT/FACILITY: SODIUM PHOSPHATE

PLANT POPULATION

Sodium phosphate plants generally produce a wide variety of products. These chemical products can be subdivided into two groups: orthophosphates and polyphosphates. Only polyphosphate manufacture, however, employs direct-fired combustion equipment.

Eight out of the twenty U.S. sodium phosphate plants operating in 1981, were located east of the Mississippi and consumed direct-fired energy $\geq 100 \times 10^9$ Btu/year. Two other plants were eliminated because their energy consumption was below 100×10^9 Btu/yr. For the 8 plants investigated, 1981 sodium phosphate capacity ranged between 50,000 and 250,000 tons.¹ Total estimated 1981 production of the 8 plants was 638,500 tons, compared to a national production of 983,175 tons. The smallest plant produced 33,500 tons of sodium phosphates in 1981 and consumed 290×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

During polyphosphate manufacture, direct-fired energy is consumed in a spray dryer, rotary kiln (for product calcination), and fusion furnaces (for product fusion).² Natural gas accounts for approximately 91 percent of the fuel fired in this industry.³

PRODUCTION AND ENERGY CONSUMPTION

Production

Sodium phosphate production capacity (1981) was reported for each of the 8 plants evaluated, and totalled 953,000 tons.¹ Industry experts indicated that domestic plants operated at 67 percent of their capacity in 1981.⁴ The national capacity factor was applied to each of the 8 plants located east of the Mississippi. Total estimated 1981 production for the 8 plants was 638,500 of sodium phosphate with a plant range of 33,500 to 167,500 tons.

Since only polyphosphate production consumed direct-fired energy, it was then necessary to apportion plant production to each individual product. First, it was determined which polyphosphate chemicals were produced at each plant.¹ The next step was to apportion production to individual polyphosphate products using domestic 1980 production of individual sodium phosphate products (ortho and polyphosphates) and their corresponding share of the market. Results are shown in Table A.13-1.⁵ Since this product breakdown was not available for 1981, the ratio between products was assumed to remain constant to estimate 1981 production of individual sodium phosphate products.

Energy Consumption - Fuel Type

The polyphosphate (sodium metaphosphate, sodium acid pyrophosphate, tetrasodium pyrophosphate, and sodium tripolyphosphate) whose manufacture involves significant quantities of direct-fired energy utilize different processes. A fusion furnace is used in

TABLE A.13-1. 1980 PRODUCTION OF SODIUM PHOSPHATE⁵

	1980 production, tons/year	Share of the market, percent
Orthophosphates		
Monosodium phosphate	43,687	4.4
Disodium phosphate	28,552	2.9
Trisodium phosphate	62,786	6.4
Other ^a	Confidential	
Polyphosphates		
Sodium metaphosphate	60,985	6.2
Sodium acid pyrophosphate	28,953	3.0
Tetrasodium pyrophosphate	30,772	3.1
Sodium tripolyphosphate	727,440	74.0
Total	983,175	100.0

^a Includes certain chemicals of limited production, e.g., aluminum and chlorinated phosphates.

the production of metaphosphate. Both spray dryers and rotary kilns are used in the production of sodium acid pyrophosphate, tetrasodium pyrophosphate, and sodium tripolyphosphate. The direct-fired energy factors are as follows:²

Fusion furnace: 7.20×10^6 Btu/ton

Dryer: 3.60×10^6 Btu/ton

Rotary kiln: 5.05×10^6 Btu/ton

Using these factors, the individual product production at each plant was multiplied by the appropriate direct-fired energy consumption factor. Thus, plant production of metaphosphate was multiplied by the energy consumption factor for the fusion furnace (7.2×10^6 Btu/ton), and the individual product production for the remaining three polyphosphates was multiplied by the energy consumption factors for the spray dryer and rotary kiln (totals 8.65×10^6 Btu/ton).

Total estimated 1981 plant energy consumption for the 8 plants evaluated was 500×10^9 Btu, with a plant range of 290×10^9 to $1,230 \times 10^9$ Btu. Natural gas is the predominate fuel (91 percent) fired in this industry.³ Although small quantities of oil are consumed, it has been assumed for purpose of emission estimates that natural gas is fired exclusively.

EMISSION ESTIMATES

Emission Factors

The factors used to estimate emissions from metaphosphates (fusion furnace) are 0.238, 2.95×10^{-3} , and 4.92×10^{-2} lb/ton for NO_x , SO_x and HC, respectively.^{6,7} Emission factors for

the spray dryer and rotary kiln combined are 0.473 , 3.55×10^{-3} , and 5.91×10^{-2} lb/ton for NO_x , SO_x and HC, respectively.^{6,7} Both the SO_x and HC emission factors are default values calculated from estimated industrial emission rates.

Plant Emissions

The range in annual emissions for the 8 plants investigated is shown below (in tons/year).

	Low	High
NO_x	8	33
SO_x	Negligible	
HC	1	4

Tables A.13-2 and A.13-3 summarize plant production, energy consumption by fuel, and emissions by plant and county respectively for the 8 plants investigated. The production shown in these tables includes all sodium phosphate chemicals and thus may show a higher production value than the one used for calculating direct-fired energy consumption and emissions.

TABLE A.13-2. SUMMARY OF 1981 PRODUCTION ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 8 SODIUM PHOSPHATE PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER.

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
GA	RICHMOND	MONSANTO CO	50.3	0.00	0.00	0.43	0.00	0.00	0.43	12	0	1
IL	COOK	STAUFFER CHEM	33.5	0.00	0.00	0.29	0.00	0.00	0.29	8	0	1
IL	WILL	OLIN CORP	138.7	0.00	0.00	1.02	0.00	0.00	1.02	27	0	3
Total - IL			172.2	0.00	0.00	1.31	0.00	0.00	1.31	35	0	4
IN	CLARK	OCCIDENTAL PETR	52.3	0.00	0.00	0.40	0.00	0.00	0.40	11	0	1
MI	WAYNE	MONSANTO CO	167.5	0.00	0.00	1.23	0.00	0.00	1.23	33	0	4
NJ	HUDSON	MONSANTO CO	73.7	0.00	0.00	0.63	0.00	0.00	0.63	17	0	2
NJ	MIDDLESEX	FMC CORP	57.6	0.00	0.00	0.42	0.00	0.00	0.42	11	0	1
Total - NJ			131.3	0.00	0.00	1.05	0.00	0.00	1.05	28	0	4
TN	DAVIDSON	STAUFFER CHEM	65.0	0.00	0.00	0.56	0.00	0.00	0.56	15	0	2
Total Study Area			638.5	0.00	0.00	5.00	0.00	0.00	5.00	134	1	17

TABLE A.13-3. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 8 SODIUM PHOSPHATE PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
GA	RICHMOND	All	50.3	0.00	0.00	0.43	0.00	0.00	0.43	12	0	1
IL	COOK	All	33.5	0.00	0.00	0.29	0.00	0.00	0.29	8	0	1
IL	MILL	All	138.7	0.00	0.00	1.02	0.00	0.00	1.02	27	0	3
Total - IL			172.2	0.00	0.00	1.31	0.00	0.00	1.31	35	0	4
IN	CLARK	All	52.3	0.00	0.00	0.40	0.00	0.00	0.40	11	0	1
MI	WAYNE	All	167.5	0.00	0.00	1.23	0.00	0.00	1.23	33	0	4
NJ	HUDSON	All	73.7	0.00	0.00	0.63	0.00	0.00	0.63	17	0	2
NJ	MIDDLESEX	All	57.6	0.00	0.00	0.42	0.00	0.00	0.42	11	0	1
Total - NJ			131.3	0.00	0.00	1.05	0.00	0.00	1.05	28	0	4
TN	DAVIDSON	All	65.0	0.00	0.00	0.56	0.00	0.00	0.56	15	0	2
Total Study Area			638.5	0.00	0.00	5.00	0.00	0.00	5.00	134	1	17

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INDUSTRY: PULP AND PAPER

PLANT/FACILITY: KRAFT PULP MILLS

PLANT POPULATION

In 1980, there were approximately 120 kraft pulp mills in the U.S., with 75 being located east of the Mississippi.¹ The 1980 capacity range for the regeneration of lime* in kilns at the 75 plants evaluated was approximately 17,200 to 191,625 tons. Total estimated 1980 production for the 75 plants evaluated was 6.8×10^6 tons. The smallest plant analyzed had an estimated 1980 production of 16,400 tons, and consumed 140×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

Rotary kilns generally fired with natural gas or oil, are used for regeneration of lime.^{4,5}

PRODUCTION AND FUEL COMBUSTION

Production

Production for the 75 plants was estimated by first obtaining the total capacity for the kiln(s) in tons/day for the individual plants. These were obtained either directly from literature sources or, if not available, estimated using the plant's

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* The only major direct-fired process in Kraft Pulp Mills.^{2,3}

kiln(s) dimensions or the plant's bleached and/or unbleached production capacity provided by the literature. For plants in which only the kiln(s) dimensions were available in the literature, kiln design data were utilized to estimate the plant's capacity.² For those plants for which a capacity figure or kiln size were both not available in the literature, capacity was estimated by multiplying the plant's bleached and/or unbleached kraft pulp capacity by a conversion factor of 0.24, an average ratio of lime kiln capacity to bone dry pulp input for kraft pulp mills.⁶ Using this approach, the total estimated 1980 daily capacity for the 75 kraft pulp mills was determined to be approximately 18,700 tons.

Estimated production for 1980 was then obtained by multiplying capacity times the number of operating days. Generally, pulp mills operate about 348 days per year.⁷ Utilizing the 348 operating days a year factor, total production for the 75 plants in 1980 was estimated to be approximately 6.5×10^6 tons. Estimated 1980 production for the 75 plants ranged from 16,400 to 182,700 tons.

Energy Consumption - Fuel Type

On an industry-wide basis the breakdown of fuel types consumed in lime kilns are: natural gas (50%), No. 5 residual fuel oil (25%), and No. 6 residual fuel oil (25%).⁵ Because plant specific data were not available, the above national breakdown was applied to each plant analyzed.

Lime kilns generally consume 8.58×10^6 Btu/ton of lime.^{3,8} This direct-fired process represents approximately 12 percent of the total energy consumption at a kraft pulp mill.⁹ Total estimated 1980 energy consumption for lime kilns in the 75 plants is estimated to be 55.7×10^{12} Btu, with a plant range of 140×10^9 to $1,570 \times 10^9$ Btu.

EMISSION ESTIMATES

Emission Factors

Based on similarities in equipment and fuel usage, the NO_x (natural gas or oil fired) and SO_x (oil fired only) emission factors were assumed to be equivalent to that of kilns used in the lime manufacturing industry. The specific emission factor for NO_x as obtained from the U.S. EPA's AP-42 publication is 3.0 lb/ton of lime.¹⁰ This factor was utilized for both natural gas and oil fired kilns. For SO_x , according to AP-42, when a low-sulfur fuel (less than 1 percent by weight) is fired, about 10 percent of the fuel sulfur is emitted as SO_x . When a high-sulfur fuel (greater than 1 percent by weight) is fired, approximately 50 percent of the oil sulfur is emitted as SO_x . Since kilns used by kraft pulp mills fire both light residual (No. 5 fuel oil) and residual (No. 6 fuel oil) oils, three separate emission factors for SO_x were determined in order to incorporate the varying range of sulfur contents found in these fuel oils. For residual fuel oil (No. 6), having a heat value of 150,000 Btu/gal,¹¹ a density of 8.212 lb/gal,¹¹ and an average sulfur content greater than 1 percent by weight found in states east of the Mississippi,¹²

the emission factor converted to lb/ton utilizing the total energy consumption factor of 8.58×10^6 Btu/ton of lime is 2.35 (S). The (S) represents the sulfur content of the oil in percent.

Similarly, for light residual fuel oil (No. 5), with a heat value of 148,000 Btu/gal,¹¹ a density of 7.935 lb/gal,¹¹ and a sulfur content ranging from less than to greater than 1 percent by weight,¹² the following emission factors, based on low and high sulfur contents and the total energy consumption factor of 8.58×10^6 Btu/ton of lime are: 0.46 (S) and 2.30 (S), respectively. As before, the (S) represents the sulfur content of the oil in percent.

For natural gas the SO_x emission factor as obtained from the U.S. EPA's AP-40 publication is $0.42 \text{ lb}/10^6 \text{ ft}^3$.¹³ Utilizing the total energy consumption factor of 8.58×10^6 Btu/ton of lime and a heating value of $1024 \text{ Btu}/\text{ft}^3$ for natural gas,¹⁴ the SO_x emission factor for natural gas fired kilns converted to lb/ton is 3.519×10^{-3} . The HC emission factors as obtained from AP-40 are: $7.0 \text{ lb}/10^6 \text{ ft}^3$ natural gas and $127.0 \text{ lb}/10^3 \text{ bbl}$ fuel oil (light or residual). These emission factors converted to lb/ton based on a total energy consumption factor of 8.58×10^6 Btu/ton of lime and heating values at $1024 \text{ Btu}/\text{ft}^3$ for natural gas and 150,000 Btu/gal for fuel oil are: 5.865×10^{-2} and 1.73×10^{-1} , respectively.

Plant Emissions

The range in annual emissions in tons/year for the 75 plants is shown below:

	Low	High
NO _x	25	274
SO _x	8	169
HC	1	11

Tables A.14-1 and A.14-2 summarize the 75 plant's estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county respectively.

TABLE A.14-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 75 KRAFT PULP MILL PLANTS
(TIME FILMS) LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	AUTAUGA	UNION CAMP CORP	160.1	0.00	0.69	0.69	0.00	0.00	1.37	240	148	9
AL	CHOCTAW	AMERICAN CAN CO	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
AL	CLARKE	ALLIED PAPER	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	DALLAS	HAMMERMILL PAP	43.5	0.00	0.19	0.19	0.00	0.00	0.37	65	40	3
AL	ESCAMBIA	CONTAINER CORP	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	LAWRENCE	CHAMPION INTL	153.1	0.00	0.66	0.66	0.00	0.00	1.31	230	142	9
AL	MARENGO	GULF STATES PAP	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	MOBILE	INTL PAPER CO	114.8	0.00	0.49	0.49	0.00	0.00	0.99	172	106	7
AL	MOBILE	SCOTT PAPER CO	125.3	0.00	0.54	0.54	0.00	0.00	1.07	188	116	7
AL	MONROE	ALABAMA RIVER	114.8	0.00	0.49	0.49	0.00	0.00	0.99	172	106	7
AL	RUSSELL	GEORGIA KRAFT	81.4	0.00	0.35	0.35	0.00	0.00	0.70	122	75	5
AL	TALLADEGA	KIMBERLY-CLARK	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
AL	WILCOX	MACMILLAN BLOED	78.3	0.00	0.34	0.34	0.00	0.00	0.67	117	72	5
Total - AL			1,198.5	0.00	5.14	5.14	0.00	0.00	10.28	1,798	1,108	69
FL	BAY	SW FOREST IND	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	129	8
FL	DUVAL	ALTON BOX BOARD	111.4	0.00	0.48	0.48	0.00	0.00	0.96	167	103	6
FL	DUVAL	ST REGIS PAPER	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
FL	ESCAMBIA	ST REGIS PAPER	76.9	0.00	0.33	0.33	0.00	0.00	0.66	115	71	4
FL	GULF	ST JOE PAPER	83.5	0.00	0.36	0.36	0.00	0.00	0.72	125	77	5
FL	NASSAU	CONTAINER CORP	116.9	0.00	0.50	0.50	0.00	0.00	1.00	175	108	7
FL	PUTNAM	GEORGIA PACIFIC	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
FL	TAYLOR	BUCKEYE CELLUL	174.0	0.00	0.75	0.75	0.00	0.00	1.49	261	161	10
Total - FL			903.8	0.00	3.88	3.88	0.00	0.00	7.75	1,356	835	52
GA	BIBB	GEORGIA KRAFT	55.7	0.00	0.24	0.24	0.00	0.00	0.48	84	51	3
GA	CAMDEN	GILMAN PAPER CO	95.7	0.00	0.41	0.41	0.00	0.00	0.82	144	88	6
GA	CHATHAM	CONTINENTAL FOR	114.8	0.00	0.49	0.49	0.00	0.00	0.99	172	106	7
GA	CHATHAM	UNION CAMP CORP	182.7	0.00	0.78	0.78	0.00	0.00	1.57	274	169	11
GA	EARLY	GREAT SOUTHERN	156.6	0.00	0.67	0.67	0.00	0.00	1.34	235	145	9
GA	FLOYD	GEORGIA KRAFT	118.0	0.00	0.51	0.51	0.00	0.00	1.01	177	109	7
GA	GLYNN	BRUNSWICK PULP	130.5	0.00	0.56	0.56	0.00	0.00	1.12	196	121	8
GA	LIBERTY	INTERSTATE PAP	38.6	0.00	0.17	0.17	0.00	0.00	0.33	58	36	2
GA	LOWNDES	OWENS-ILLINOIS	74.5	0.00	0.32	0.32	0.00	0.00	0.64	112	69	4
GA	RICHMOND	CONTINENTAL FOR	38.3	0.00	0.16	0.16	0.00	0.00	0.33	57	35	2
GA	WAYNE	ITT RAYONIER	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
Total - GA			1,109.8	0.00	4.76	4.76	0.00	0.00	9.52	1,665	1,026	64
KY	BALLARD	WESTVACO CORP	20.9	0.00	0.09	0.09	0.00	0.00	0.18	31	15	1
KY	HANCOCK	WILLAMETTE IND	45.2	0.00	0.19	0.19	0.00	0.00	0.39	68	33	3
Total - KY			66.1	0.00	0.28	0.28	0.00	0.00	0.57	99	48	4

(continued)

TABLE A.14-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
ME	CUMBERLAND	MAHVEN CO	31.3	0.00	0.13	0.13	0.00	0.00	0.27	47	15	2
ME	FRANKLIN	INTL PAPER CO	94.0	0.00	0.40	0.40	0.00	0.00	0.81	141	44	5
ME	OXFORD	BOISE CASCADE	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	19	2
ME	PENOBSCOT	LINCOLN PULP	34.8	0.00	0.15	0.15	0.00	0.00	0.30	52	16	2
ME	PENOBSCOT	DIAMOND INTL	43.5	0.00	0.19	0.19	0.00	0.00	0.37	65	20	3
ME	SOMERSET	SCOTT PAPER CO	90.5	0.00	0.34	0.39	0.00	0.00	0.78	136	42	5
ME	WASHINGTON	GEORGIA PACIFIC	52.2	0.00	0.22	0.22	0.00	0.00	0.45	78	24	3
Total - ME			388.0	0.00	1.66	1.66	0.00	0.00	3.33	582	181	22
MD	ALLEGANY	WESTVACO CORP	64.4	0.00	0.28	0.28	0.00	0.00	0.55	97	30	4
MI	DELTA	MEAD PUBL PAPER	76.6	0.00	0.33	0.33	0.00	0.00	0.66	115	55	4
MI	MUSKEGON	WARREN CO	24.4	0.00	0.10	0.10	0.00	0.00	0.21	37	18	1
Total - MI			100.9	0.00	0.43	0.43	0.00	0.00	0.87	151	73	6
MS	ADAMS	INTL PAPER CO	92.2	0.00	0.40	0.40	0.00	0.00	0.79	138	85	5
MS	JACKSON	INTL PAPER CO	79.0	0.00	0.34	0.34	0.00	0.00	0.68	118	73	5
MS	LAWRENCE	ST REGIS PAPER	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	129	8
MS	WARREN	INTL PAPER CO	96.7	0.00	0.42	0.42	0.00	0.00	0.83	145	89	6
Total - MS			407.2	0.00	1.75	1.75	0.00	0.00	3.49	611	376	24
NH	COOS	BROWN CO	61.9	0.00	0.27	0.27	0.00	0.00	0.53	93	29	4
NY	ESSEX	INTL PAPER CO	47.0	0.00	0.20	0.20	0.00	0.00	0.40	70	22	3
NC	COLUMBUS	FED PAPER BOARD	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
NC	CrAVEN	MEYERHAEUSER CO	76.6	0.00	0.33	0.33	0.00	0.00	0.66	115	71	4
NC	HALIFAX	CHAMPION INTL	83.5	0.00	0.36	0.36	0.00	0.00	0.72	125	77	5
NC	HAYWOOD	CHAMPION INTL	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
NC	MARTIN	MEYERHAEUSER CO	174.0	0.00	0.75	0.75	0.00	0.00	1.49	261	161	10
Total - NC			535.9	0.00	2.30	2.30	0.00	0.00	4.60	804	495	31
OH	ROSS	MEAD CORP	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	41	5
PA	BLAIR	APPLETON PAPERS	35.1	0.00	0.14	0.14	0.00	0.00	0.28	50	15	2
PA	ELK	PENNTech PAPERS	17.4	0.00	0.07	0.07	0.00	0.00	0.15	26	8	1
PA	ERIE	HAMMERMILL PAP	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	41	5
PA	YORK	PH GLATFELTER	52.2	0.00	0.22	0.22	0.00	0.00	0.45	78	24	3
Total - PA			189.7	0.00	0.81	0.81	0.00	0.00	1.63	284	88	11
SC	CHARLESTOWN	WESTVACO CORP	167.0	0.00	0.72	0.72	0.00	0.00	1.43	251	154	10

(continued)

TABLE A.14-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
SC	FLORENCE	SC INDUSTRIES	111.4	0.00	0.48	0.48	0.00	0.00	0.96	167	103	6
SC	GEORGETOWN	INTL PAPER CO	134.3	0.00	0.58	0.58	0.00	0.00	1.15	201	124	8
SC	YORK	BOWATER CAROL	90.5	0.00	0.39	0.39	0.00	0.00	0.78	136	84	5
Total - SC			503.2	0.00	2.16	2.16	0.00	0.00	4.32	755	465	29
TN	HARDIN	TENN RIVER PULP	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
TN	MCMINN	BOWATER SOUTH	43.5	0.00	0.19	0.19	0.00	0.00	0.37	65	40	3
TN	SULLIVAN	MEAD CORP	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	80	5
Total - TN			227.9	0.00	0.98	0.98	0.00	0.00	1.96	342	211	13
VA	ALLEGHENY	WESTVACO CORP	91.9	0.00	0.39	0.39	0.00	0.00	0.79	138	43	5
VA	ISLE WIGHT	UNION CAMP CORP	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	65	8
VA	KING WILLIAM	CHESAPEAKE CORP	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	49	6
VA	PRINCE GEORGE	CONTINENTAL FOR	154.9	0.00	0.66	0.66	0.00	0.00	1.33	232	72	9
Total - VA			490.3	0.00	2.10	2.10	0.00	0.00	4.21	735	229	28
WI	MARATHON	MOSINEE PAPER	16.4	0.00	0.07	0.07	0.00	0.00	0.14	25	13	1
WI	DUTAGAMIE	THILMANY PULP	33.4	0.00	0.14	0.14	0.00	0.00	0.29	50	27	2
WI	WOOD	NEKOOSA PAPERS	27.5	0.00	0.12	0.12	0.00	0.00	0.24	41	22	2
WI	WOOD	CONSOL PAPERS	39.3	0.00	0.17	0.17	0.00	0.00	0.34	59	31	2
Total - WI			116.6	0.00	0.50	0.50	0.00	0.00	1.00	175	93	7
Total Study Area			6,498.2	0.00	27.88	27.88	0.00	0.00	55.75	9,747	5,349	376

TABLE A.14-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR 75 KRAFT PULP MILL PLANTS
(LIME KILNS) LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	AUTAUGA	All	160.1	0.00	0.69	0.69	0.00	0.00	1.37	240	148	9
AL	CHOCTAW	All	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
AL	CLARKE	All	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	DALLAS	All	43.5	0.00	0.19	0.19	0.00	0.00	0.37	65	40	3
AL	ESCAMBIA	All	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	LAWRENCE	All	153.1	0.00	0.66	0.66	0.00	0.00	1.31	230	142	9
AL	MARENGO	All	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	39	2
AL	MOBILE	All	240.1	0.00	1.03	1.03	0.00	0.00	2.06	360	222	14
AL	MONROE	All	114.8	0.00	0.49	0.49	0.00	0.00	0.99	172	106	7
AL	RUSSELL	All	81.4	0.00	0.35	0.35	0.00	0.00	0.70	122	75	5
AL	TALLADEGA	All	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
AL	WILCOX	All	78.3	0.00	0.34	0.34	0.00	0.00	0.67	117	72	5
Total - AL			1,198.5	0.00	5.14	5.14	0.00	0.00	10.28	1,798	1,108	69
FL	BAY	All	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	129	8
FL	DUVAL	All	208.8	0.00	0.90	0.90	0.00	0.00	1.79	313	193	12
FL	ESCAMBIA	All	76.9	0.00	0.33	0.33	0.00	0.00	0.66	115	71	4
FL	GULF	All	83.5	0.00	0.36	0.36	0.00	0.00	0.72	125	77	5
FL	MASSAU	All	116.9	0.00	0.50	0.50	0.00	0.00	1.00	175	108	7
FL	PUTNAM	All	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
FL	TAYLOR	All	174.0	0.00	0.75	0.75	0.00	0.00	1.49	261	161	10
Total - FL			903.8	0.00	3.88	3.88	0.00	0.00	7.75	1,356	835	52
GA	BIBB	All	55.7	0.00	0.24	0.24	0.00	0.00	0.48	84	51	3
GA	CAMDEN	All	95.7	0.00	0.41	0.41	0.00	0.00	0.82	144	88	6
GA	CHATHAM	All	297.5	0.00	1.28	1.28	0.00	0.00	2.55	446	275	17
GA	EARLY	All	156.6	0.00	0.67	0.67	0.00	0.00	1.34	235	145	9
GA	FLOYD	All	118.0	0.00	0.51	0.51	0.00	0.00	1.01	177	109	7
GA	GLYNN	All	130.5	0.00	0.56	0.56	0.00	0.00	1.12	196	121	8
GA	LIBERTY	All	38.6	0.00	0.17	0.17	0.00	0.00	0.33	58	36	2
GA	LOWNDES	All	74.5	0.00	0.32	0.32	0.00	0.00	0.64	112	69	4
GA	RICHMOND	All	38.3	0.00	0.16	0.16	0.00	0.00	0.33	57	35	2
GA	WAYNE	All	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
Total - GA			1,109.8	0.00	4.76	4.76	0.00	0.00	9.52	1,665	1,026	64
KY	BALLARD	All	20.9	0.00	0.09	0.09	0.00	0.00	0.18	31	15	1
KY	HANCOCK	All	45.2	0.00	0.19	0.19	0.00	0.00	0.39	68	33	3
Total - KY			66.1	0.00	0.28	0.28	0.00	0.00	0.57	99	48	4
ME	CUMBERLAND	All	31.3	0.00	0.13	0.13	0.00	0.00	0.27	47	15	2
ME	FRANKLIN	All	94.0	0.00	0.40	0.40	0.00	0.00	0.81	141	44	5

(continued)

TABLE A.14-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
ME	OXFORD	All	41.8	0.00	0.18	0.18	0.00	0.00	0.36	63	19	2
ME	PENOBSCOT	All	78.3	0.00	0.34	0.34	0.00	0.00	0.67	117	37	5
ME	SOMERSET	All	90.5	0.00	0.39	0.39	0.00	0.00	0.78	136	42	5
ME	WASHINGTON	All	52.2	0.00	0.22	0.22	0.00	0.00	0.45	78	24	3
Total - ME			388.0	0.00	1.66	1.66	0.00	0.00	3.33	582	181	22
MD	ALLEGANY	All	64.4	0.00	0.28	0.28	0.00	0.00	0.55	97	30	4
MI	DELTA	All	76.6	0.00	0.33	0.33	0.00	0.00	0.66	115	55	4
MI	MUSKEGON	All	24.4	0.00	0.10	0.10	0.00	0.00	0.21	37	18	1
Total - MI			100.9	0.00	0.43	0.43	0.00	0.00	0.87	151	73	6
MS	ADAMS	All	92.2	0.00	0.40	0.40	0.00	0.00	0.79	138	85	5
MS	JACKSON	All	79.0	0.00	0.34	0.34	0.00	0.00	0.68	118	73	5
MS	LAWRENCE	All	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	129	8
MS	WARREN	All	96.7	0.00	0.42	0.42	0.00	0.00	0.83	145	89	6
Total - MS			407.2	0.00	1.75	1.75	0.00	0.00	3.49	611	376	24
NH	COOS	All	61.9	0.00	0.27	0.27	0.00	0.00	0.53	93	29	4
NY	ESSEX	All	47.0	0.00	0.20	0.20	0.00	0.00	0.40	70	22	3
NC	COLUMBUS	All	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
NC	CRAVEN	All	76.6	0.00	0.33	0.33	0.00	0.00	0.66	115	71	4
NC	HALIFAX	All	83.5	0.00	0.36	0.36	0.00	0.00	0.72	125	77	5
NC	HAYWOOD	All	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	96	6
NC	MARTIN	All	174.0	0.00	0.75	0.75	0.00	0.00	1.49	261	161	10
Total - NC			535.9	0.00	2.30	2.30	0.00	0.00	4.60	804	495	31
OH	ROSS	All	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	41	5
PA	BLAIR	All	33.1	0.00	0.14	0.14	0.00	0.00	0.28	50	15	2
PA	ELK	All	17.4	0.00	0.07	0.07	0.00	0.00	0.15	26	8	1
PA	ERIE	All	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	41	5
PA	YORK	All	52.2	0.00	0.22	0.22	0.00	0.00	0.45	78	24	3
Total - PA			189.7	0.00	0.81	0.81	0.00	0.00	1.63	284	88	11
SC	CHARLESTOWN	All	167.0	0.00	0.72	0.72	0.00	0.00	1.43	251	154	10
SC	FLORENCE	All	111.4	0.00	0.48	0.48	0.00	0.00	0.96	167	103	6
SC	GEORGETOWN	All	134.3	0.00	0.58	0.58	0.00	0.00	1.15	201	124	8

(continued)

TABLE A.14-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
SC	YORK	All	90.5	0.00	0.39	0.39	0.00	0.00	0.78	136	84	5
Total - SC			503.2	0.00	2.16	2.16	0.00	0.00	4.32	755	465	29
TN	HARDIN	All	97.4	0.00	0.42	0.42	0.00	0.00	0.84	146	90	6
TN	MCMINN	All	43.5	0.00	0.19	0.19	0.00	0.00	0.37	65	40	3
TN	SULLIVAN	All	87.0	0.00	0.37	0.37	0.00	0.00	0.75	131	80	5
Total - TN			227.9	0.00	0.98	0.98	0.00	0.00	1.96	342	211	13
VA	ALLEGHENY	All	91.9	0.00	0.39	0.39	0.00	0.00	0.79	138	43	5
VA	ISLE WIGHT	All	139.2	0.00	0.60	0.60	0.00	0.00	1.19	209	65	8
VA	KING WILLIAM	All	104.4	0.00	0.45	0.45	0.00	0.00	0.90	157	49	6
VA	PRINCE GEORGE	All	154.9	0.00	0.66	0.66	0.00	0.00	1.33	232	72	9
Total - VA			490.3	0.00	2.10	2.10	0.00	0.00	4.21	735	229	28
WI	MARATHON	All	16.4	0.00	0.07	0.07	0.00	0.00	0.14	25	13	1
WI	OUTAGAMIE	All	33.4	0.00	0.14	0.14	0.00	0.00	0.29	50	27	2
WI	WOOD	All	66.8	0.00	0.29	0.29	0.00	0.00	0.57	100	53	4
Total - WI			116.6	0.00	0.50	0.50	0.00	0.00	1.00	175	93	7
Total Study Area			6,498.2	0.00	27.88	27.88	0.00	0.00	55.75	9,747	5,349	376

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INDUSTRY: GYPSUM

PLANT/FACILITY: GYPSUM PLANTS

PLANT POPULATION

In 1981, there were 72 gypsum plants operating in the U.S., with 32 plants being located east of the Mississippi. However, only 20 out of the 32 plants met the established energy consumption criteria of 100×10^9 Btu/year. The total 1981 U.S. capacity at approximately 16.3×10^6 tons/year.² Total plant production in the U.S. was 11.7×10^6 tons of calcined gypsum in 1981. Capacity data were not available for the 20 plants analyzed. Hence, plant production was estimated from the shipments data that indicated that 1981 production for the 20 plants analyzed was 4.3×10^6 tons, with a plant range of 145,000 to 345,000 tons. The smallest plant analyzed had an estimated direct-fired energy consumption of 110×10^9 Btu.

COMBUSTION PROCESSES

The calciner is the major direct-fired equipment used in gypsum production. Natural gas is the primary fuel.²

PRODUCTION AND FUEL CONSUMPTION

Production

Production data were available in the literature by state or group of states.² Apportioning the total state(s) production

to an industrial plant was accomplished by using the EIS report on shipments.³ Assuming that shipments in dollars for each plant is directly equatable with production, the share or percentage of the total sales for each plant was first determined for that given state or group of states in which the plant was located and then applied to the total production of that state(s) to estimate plant specific production.

Since shipment data was not available in EIS for one of the plants, an average production of 162,000 tons/year was calculated for this plant.² In calculating production for the other plants in which this single plant was grouped, total production for this grouping was first adjusted downward by the average production assumed for the single plant mentioned above. Total 1981 production of the 20 plants was estimated to be approximately 4.3×10^6 tons, with a plant range of 145,000 to 354,000 tons.

Energy Consumption - Fuel Type

The gypsum calciner has a direct-fired energy consumption of 0.75×10^6 Btu/ton.⁴ Natural gas is the primary fuel fired in gypsum calciners.² Total 1981 energy consumption for the 20 plants is estimated to be 3.23×10^{12} Btu, with a plant range of 110×10^9 to 270×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Nitrogen oxide emissions were estimated using an equation developed by Mills, et al.⁵ The plants were assumed to operate 6310 hours/ year. This was obtained by multiplying the total

available hours in a year by the 1981 utilization factor of 72 percent.²

The SO_x and HC emission factors as obtained from the U.S. EPA's AP-40 publication are:⁶ 0.42 and 7.0 lb/10⁶ ft³ natural gas, respectively. The emission factors converted to lb/ton for the calciner based on its energy consumption of 0.75 x 10⁶ Btu/ton and a heating value of 1024 Btu/ft³ for natural gas⁷ are: 3.08×10^{-4} and 5.13×10^{-3} for SO_x and HC, respectively.

Plant Emissions

The range in total annual emissions for the 20 plants, (in tons/yr) is shown below:

	Low	High
NO_x	8	24
SO_x	negligible	
HC	1	1

Tables A.15-1 and A.15-2 summarize estimated production, energy consumption by fuel, and NO_x , SO_x and HC emissions for the 30 plants analyzed by plant and county, respectively.

TABLE A.15-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 20 GYPSUM PLANTS
*LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
DE	NEW CASTLE	GEORGIA PACIFIC	166.0	0.00	0.00	0.12	0.00	0.00	0.12	10	0	0
FL	DUVAL	US GYPSUM CO	307.0	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
FL	HILLSBOROUGH	NATL GYPSUM CO	205.0	0.00	0.00	0.15	0.00	0.00	0.15	13	0	1
Total - FL			512.0	0.00	0.00	0.38	0.00	0.00	0.38	33	0	1
GA	CHATHAM	GENSTAR BLDE PR	168.0	0.00	0.00	0.13	0.00	0.00	0.13	10	0	0
GA	CHATHAM	NATL GYPSUM CO	215.0	0.00	0.00	0.16	0.00	0.00	0.16	13	0	1
GA	BLANTA	GEORGIA PACIFIC	230.0	0.00	0.00	0.17	0.00	0.00	0.17	14	0	1
Total - GA			613.0	0.00	0.00	0.46	0.00	0.00	0.46	37	0	2
IL	LAKE	NATL GYPSUM CO	162.0	0.00	0.00	0.12	0.00	0.00	0.12	10	0	0
IN	LAKE	US GYPSUM CO	231.0	0.00	0.00	0.17	0.00	0.00	0.17	14	0	1
IN	MARTIN	NATL GYPSUM CO	290.0	0.00	0.00	0.22	0.00	0.00	0.22	19	0	1
IN	MARTIN	US GYPSUM CO	180.0	0.00	0.00	0.14	0.00	0.00	0.14	11	0	0
Total - IN			701.0	0.00	0.00	0.53	0.00	0.00	0.53	44	0	2
MD	BALTIMORE	NATL GYPSUM CO	233.0	0.00	0.00	0.17	0.00	0.00	0.17	15	0	1
MD	BALTIMORE	US GYPSUM CO	162.0	0.00	0.00	0.12	0.00	0.00	0.12	10	0	0
Total - MD			395.0	0.00	0.00	0.30	0.00	0.00	0.30	24	0	1
NJ	CAMDEN	GENSTAR BLDE PR	145.0	0.00	0.00	0.11	0.00	0.00	0.11	8	0	0
NY	GENESEE	US GYPSUM CO	354.0	0.00	0.00	0.27	0.00	0.00	0.27	24	0	1
NY	ROCKLAND	US GYPSUM CO	271.0	0.00	0.00	0.20	0.00	0.00	0.20	17	0	1
Total - NY			625.0	0.00	0.00	0.47	0.00	0.00	0.47	41	0	2
NC	NEW HANOVER	NATL GYPSUM CO	195.0	0.00	0.00	0.15	0.00	0.00	0.15	12	0	1
OH	OTTAWA	US GYPSUM CO	185.0	0.00	0.00	0.14	0.00	0.00	0.14	11	0	0
PA	PHILADELPHIA	US GYPSUM CO	175.0	0.00	0.00	0.13	0.00	0.00	0.13	10	0	0
VA	NORFOLK	US GYPSUM CO	224.0	0.00	0.00	0.17	0.00	0.00	0.17	14	0	1
VA	WASHINGTON	US GYPSUM CO	212.0	0.00	0.00	0.16	0.00	0.00	0.16	13	0	1
Total - VA			436.0	0.00	0.00	0.33	0.00	0.00	0.33	27	0	1
Total Study Area			4,310.0	0.00	0.00	3.23	0.00	0.00	3.23	267	1	11

TABLE A.15-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 20 GYPSUM PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
DE	NEW CASTLE	All	166.0	0.00	0.00	0.12	0.00	0.00	0.12	10	0	0
FL	DUVAL	All	307.0	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
FL	HILLSBOROUGH	All	205.0	0.00	0.00	0.15	0.00	0.00	0.15	13	0	1
Total - FL			512.0	0.00	0.00	0.38	0.00	0.00	0.38	33	0	1
GA	CHATHAM	All	383.0	0.00	0.00	0.29	0.00	0.00	0.29	23	0	1
GA	GLYNN	All	230.0	0.00	0.00	0.17	0.00	0.00	0.17	14	0	1
Total - GA			613.0	0.00	0.00	0.46	0.00	0.00	0.46	37	0	2
IN	LAKE	All	393.0	0.00	0.00	0.29	0.00	0.00	0.29	24	0	1
IN	MARTIN	All	470.0	0.00	0.00	0.35	0.00	0.00	0.35	30	0	1
Total - IN			863.0	0.00	0.00	0.65	0.00	0.00	0.65	53	0	2
MD	BALTIMORE	All	395.0	0.00	0.00	0.30	0.00	0.00	0.30	24	0	1
NJ	CAMDEN	All	145.0	0.00	0.00	0.11	0.00	0.00	0.11	8	0	0
NY	GENESEE	All	354.0	0.00	0.00	0.27	0.00	0.00	0.27	24	0	1
NY	ROCKLAND	All	271.0	0.00	0.00	0.20	0.00	0.00	0.20	17	0	1
Total - NY			625.0	0.00	0.00	0.47	0.00	0.00	0.47	41	0	2
NC	NEW HANOVER	All	195.0	0.00	0.00	0.15	0.00	0.00	0.15	12	0	1
OH	OTTAWA	All	185.0	0.00	0.00	0.14	0.00	0.00	0.14	11	0	0
PA	PHILADELPHIA	All	175.0	0.00	0.00	0.13	0.00	0.00	0.13	10	0	0
VA	NORFOLK	All	224.0	0.00	0.00	0.17	0.00	0.00	0.17	14	0	1
VA	WASHINGTON	All	212.0	0.00	0.00	0.16	0.00	0.00	0.16	13	0	1
Total - VA			436.0	0.00	0.00	0.33	0.00	0.00	0.33	27	0	1
Total Study Area			4,310.0	0.00	0.00	3.23	0.00	0.00	3.23	267	1	11

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INDUSTRY: LIME

PLANT/FACILITY: LIME PLANTS

PLANT POPULATION

In 1981, 69 out of 150 lime plants operating in the U.S., were located east of the Mississippi River. One of the 69 plants was eliminated because its energy consumption was below 100×10^9 Btu/yr. Capacity data were not available for the 68 plants evaluated. Hence, production was estimated using regional or state data from the Bureau of Mines. Total estimated 1981 production for the 68 plants was 807,000 tons compared to a national total of 18.9×10^6 tons. The smallest plant analyzed had an estimated 1981 production of 16,000 tons of lime and consumed 140×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

Lime is calcined from limestone in direct-fired kilns. During 1981, 483 lime kilns operated: 70 vertical, 187 rotary, and 26 other (mostly calcimatic).² The rotary kilns account for approximately two thirds of total lime output. Lime kilns generally burn either natural gas or coal.³

PRODUCTION AND FUEL CONSUMPTION

Production

In 1981, domestic lime plants produced 18.9×10^6 tons of lime.² Plant-specific production and capacity data are not

available. Using Bureau of Mines data however, 1981 plant production can be estimated. In addition to providing production data on a regional, or in some cases, a state basis, the Bureau of Mines indicated that: 1) the top ten plants accounted for 32 percent of total lime production; 2) the seven largest of these produced 27 percent (hence, the remaining three plants produced 5 percent of the total output); and 3) the top 10 companies, operating 30 plants, accounted for 48 percent of production.^{1,2} From this, it can be determined that the 20 plants out of this group that are not among the 10 largest plants account for 16 percent of the total production.

Using these data, an average production rate was calculated for each plant in the above size categories. Remaining 1981 production in each state or region was averaged and apportioned to plants not covered in the above mentioned categories. This methodology resulted in a total 1981 production estimate of 807,000 tons for the 69 plants analyzed, with a plant range of 30 to 690×10^3 tons.

Energy Consumption - Fuel Type

Unit energy consumption ranges between 5 and 15×10^6 Btu/ton.^{2,4} On the average, however, lime kilns consume approximately 8.58×10^6 Btu/ton.^{4,5} This energy consumption factor was applied to each plant's estimated production to calculate total plant energy consumption. Total 1981 energy consumption for the 69 plants was estimated to be $105,150 \times 10^9$ Btu with a plant range of 260 to $5,920 \times 10^9$ Btu.

Natural gas and coal are the two primary fuels consumed by this industry. Generally vertical kilns (mostly used in the captive chemical and sugar industries) are fired with natural gas while rotary kilns are usually fired with coal.³ It was thus assumed that captive sugar and chemical plants burned natural gas and all other plants burned coal.

EMISSION ESTIMATES

Emission Factors

Emission factors for NO_x and SO_x for coal were obtained from EPA's AP-42.⁶ Default emission factors were used to estimate HC emissions from coal and NO_x , SO_x , and HC emissions from natural gas. The coal and gas emission factors in lb/ton are shown in Table A.16-1.

TABLE A.16-1. ESTIMATED NO_x , SO_x , AND HC EMISSION FACTORS FOR COAL- AND GAS-FIRED LIME KILNS (lb/ton).

	NO_x	SO_x	HC
Coal	3.0 ⁶	a ⁶	0.135 ⁷
Natural gas	1.79 ⁷	0.003 ⁷	0.058 ⁷

^a 3.04(S) for high sulfur coal or 0.61(S) for low sulfur coal (less than 1% by weight).

Plant Emissions

The range in emissions for the 69 eastern U.S. plants follows (in tons/yr):

	<u>Low</u>	<u>High</u>
NO_x	45	1035
SO_x	103	2612
HC	2	47

Tables A.16-2 and A.16-3 provide data on lime production, energy consumption and emissions by plant and county, respectively.

TABLE A.16-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 69 LIME PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	SHELBY	ALLIED PRODUCTS	300.0	2.57	0.00	0.00	0.00	0.00	2.57	450	725	20
AL	SHELBY	ALLIED PRODUCTS	250.0	2.15	0.00	0.00	0.00	0.00	2.15	375	604	17
AL	SHELBY	CHENEY LIME	200.0	1.72	0.00	0.00	0.00	0.00	1.72	300	483	14
AL	SHELBY	MARTIN MARIETTA	300.0	2.57	0.00	0.00	0.00	0.00	2.57	450	725	20
AL	SHELBY	SI LIME CO	170.0	1.46	0.00	0.00	0.00	0.00	1.46	255	411	11
Total - AL			1,220.0	10.47	0.00	0.00	0.00	0.00	10.47	1,830	2,946	82
CT	LITCHFIELD	PFIZER INC	16.0	0.14	0.00	0.00	0.00	0.00	0.14	24	49	1
FL	BULF	BASIC INC	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
FL	HERNANDO	CHEMICAL LIME	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
FL	SUMTER	DIXIE LIME	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
Total - FL			192.0	1.65	0.00	0.00	0.00	0.00	1.65	288	636	13
IL	COOK	MARBLEHEAD LIME	450.0	3.86	0.00	0.00	0.00	0.00	3.86	675	1,259	30
IL	COOK	MARBLEHEAD LIME	385.0	3.30	0.00	0.00	0.00	0.00	3.30	578	1,077	26
IL	COOK	VULCAN MATERIAL	35.0	0.30	0.00	0.00	0.00	0.00	0.30	53	98	2
Total - IL			870.0	7.46	0.00	0.00	0.00	0.00	7.46	1,305	2,433	59
IN	LAKE	INLAND STEEL	350.0	3.00	0.00	0.00	0.00	0.00	3.00	525	1,394	24
IN	LAKE	MARBLEHEAD LIME	695.0	5.96	0.00	0.00	0.00	0.00	5.96	1,043	2,768	47
Total - IN			1,045.0	8.97	0.00	0.00	0.00	0.00	8.97	1,568	4,162	71
KY	MASON	DRAVO LIME CO	700.0	6.01	0.00	0.00	0.00	0.00	6.01	1,050	2,671	47
KY	PENDLETON	BLACK RIVER	635.0	5.45	0.00	0.00	0.00	0.00	5.45	953	2,423	43
Total - KY			1,335.0	11.45	0.00	0.00	0.00	0.00	11.45	2,003	5,093	90
MA	BERKSHIRE	LEE LIME CORP	85.0	0.73	0.00	0.00	0.00	0.00	0.73	128	150	6
MA	BERKSHIRE	PFIZER INC	85.0	0.73	0.00	0.00	0.00	0.00	0.73	128	150	6
Total - MA			170.0	1.46	0.00	0.00	0.00	0.00	1.46	255	300	11
MI	BAY	MONITOR SUGAR	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	MURON	MICHIGAN SUGAR	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	MASON	DOW CHEMICAL	92.0	0.79	0.00	0.00	0.00	0.00	0.79	138	182	6
MI	SAGINAW	MICHIGAN SUGAR	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	SANILAC	MICHIGAN SUGAR	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	TUSCOLA	MICHIGAN SUGAR	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	WAYNE	DETROIT LIME CO	92.0	0.79	0.00	0.00	0.00	0.00	0.79	138	182	6
MI	WAYNE	MARBLEHEAD LIME	163.0	1.40	0.00	0.00	0.00	0.00	1.40	245	322	11
Total - MI			807.0	2.98	0.00	3.95	0.00	0.00	6.92	932	686	37

(continued)

TABLE A.16-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NY	ERIE	BETHLEHEM STEEL	200.0	1.72	0.00	0.00	0.00	0.00	1.72	300	559	14
NY	OWONDABA	ALLIED CHEMICAL	690.0	0.00	0.00	5.92	0.00	0.00	5.92	618	1	20
Total - NY			890.0	1.72	0.00	5.92	0.00	0.00	7.64	918	560	34
OH	ASHTABULA	ELKEM METALS CO	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	CUYAHOGA	CUYAHOGA LIME	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	ERIE	HURON LIME CO	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	LAKE	REPUBLIC STEEL	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	LORAIN	US STEEL CORP	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	OTTAWA	US GYPSUM CO	200.0	1.72	0.00	0.00	0.00	0.00	1.72	300	757	14
OH	SANDUSKY	JE BAKER CO	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	SANDUSKY	MARTIN MARIETTA	690.0	5.92	0.00	0.00	0.00	0.00	5.92	1,035	2,512	47
OH	SANDUSKY	NORTHERN OHIO	145.0	0.00	0.00	1.24	0.00	0.00	1.24	130	0	4
OH	SANDUSKY	OHIO LIME CO	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	SANDUSKY	OHIO LIME CO	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	SANDUSKY	PFIZER INC	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	SANDUSKY	WOODVILLE LIME	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	SENECA	CE BASIC INC	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	WYANDOT	NATIONAL LIME	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
Total - OH			2,775.0	22.57	0.00	1.24	0.00	0.00	23.81	4,075	9,954	182
PA	ADAMS	BETHLEHEM STEEL	165.0	1.42	0.00	0.00	0.00	0.00	1.42	248	529	11
PA	BUTLER	MERCER LIME	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	CENTRE	DOMTAR INDUSTR	70.0	0.60	0.00	0.00	0.00	0.00	0.60	105	225	5
PA	CENTRE	MARBLEHEAD LIME	165.0	1.42	0.00	0.00	0.00	0.00	1.42	248	529	11
PA	CENTRE	WARNER CO	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	CHESTER	WARNER CO	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	LEBANON	BETHLEHEM STEEL	370.0	3.35	0.00	0.00	0.00	0.00	3.35	585	1,251	26
PA	MIFFLIN	HONEYCREEK LIME	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	MONTGOMERY	CORSON LIME CO	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	YORK	JE BAKER CO	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
Total - PA			1,690.0	14.50	0.00	0.00	0.00	0.00	14.50	2,535	5,426	114
TN	MCMINN	BOWATER SOUTH	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	103	2
TN	UNION	TENN-LUTTRELL	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	103	2
Total - TN			60.0	0.51	0.00	0.00	0.00	0.00	0.51	90	206	4
VA	FREDERICK	WS FREY CO	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	FREDERICK	GENSTAR STONE	165.0	1.42	0.00	0.00	0.00	0.00	1.42	248	44	11
VA	GILES	NATL GYPSUM CO	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	GILES	VIRGINIA LIME	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7

(continued)

TABLE A.16-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SO2	HC
VA	SHENANDOAH	CHEMSTONE CORP	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	SMYTH	GREER LIME CO	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	WARREN	RIVERTON CORP	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
Total - VA			795.0	6.82	0.00	0.00	0.00	0.00	6.82	1,193	213	54
WV	BERKELEY	RIVERTON CORP	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	82	2
WV	PENDLETON	GERMANY VALLEY	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	82	2
Total - WV			60.0	0.51	0.00	0.00	0.00	0.00	0.51	90	163	4
WI	BROWN	WESTERN LIME	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	DODGE	WESTERN LIME	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	DOUGLASS	CLM CORP	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	FOND DU LAC	WESTERN LIME	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	MANITOWOC	ROCKWELL LIME	130.0	1.12	0.00	0.00	0.00	0.00	1.12	195	370	9
Total - WI			330.0	2.83	0.00	0.00	0.00	0.00	2.83	495	938	22
Total Study Area			12,255.0	94.04	0.00	11.11	0.00	0.00	105.15	17,599	33,764	777

TABLE A.16-3. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR 69 LIME PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prnd 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	SHELBY	All	1,220.0	10.47	0.00	0.00	0.00	0.00	10.47	1,830	2,948	82
CT	LITCHFIELD	All	16.0	0.14	0.00	0.00	0.00	0.00	0.14	24	49	1
FL	GULF	All	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
FL	HERNANDU	All	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
FL	SUNTER	All	64.0	0.55	0.00	0.00	0.00	0.00	0.55	96	212	4
Total - FL			192.0	1.65	0.00	0.00	0.00	0.00	1.65	288	636	13
IL	COOK	All	870.0	7.46	0.00	0.00	0.00	0.00	7.46	1,305	2,433	59
IN	LAKE	All	1,045.0	8.97	0.00	0.00	0.00	0.00	8.97	1,568	4,162	71
KY	MASON	All	700.0	6.01	0.00	0.00	0.00	0.00	6.01	1,050	2,671	47
KY	PENDLETON	All	635.0	5.45	0.00	0.00	0.00	0.00	5.45	953	2,423	43
Total - KY			1,335.0	11.45	0.00	0.00	0.00	0.00	11.45	2,003	5,093	90
MA	BERKSHIRE	All	170.0	1.46	0.00	0.00	0.00	0.00	1.46	255	300	11
MI	BAY	All	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	HURON	All	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	MASON	All	92.0	0.79	0.00	0.00	0.00	0.00	0.79	138	182	6
MI	SAGINAW	All	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	SANILAC	All	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	TUSCOLA	All	92.0	0.00	0.00	0.79	0.00	0.00	0.79	82	0	3
MI	WAYNE	All	255.0	2.19	0.00	0.00	0.00	0.00	2.19	383	504	17
Total - MI			807.0	2.98	0.00	3.95	0.00	0.00	6.92	932	686	37
NY	ERIE	All	200.0	1.72	0.00	0.00	0.00	0.00	1.72	300	559	14
NY	ONONDAGA	All	690.0	0.00	0.00	5.92	0.00	0.00	5.92	618	1	20
Total - NY			890.0	1.72	0.00	5.92	0.00	0.00	7.64	918	560	34
OH	ASHTABULA	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	CUYAHOGA	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	ERIE	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	LAKE	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	LORAIN	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	OTTAWA	All	200.0	1.72	0.00	0.00	0.00	0.00	1.72	300	757	14
OH	SANDUSKY	All	1,560.0	12.14	0.00	1.24	0.00	0.00	13.38	2,252	5,356	100
OH	SENECA	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
OH	WYANDOT	All	145.0	1.24	0.00	0.00	0.00	0.00	1.24	218	549	10
Total - OH			2,775.0	22.57	0.00	1.24	0.00	0.00	23.81	4,075	9,954	182

(continued)

TABLE A.16-3 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	ADAMS	All	165.0	1.42	0.00	0.00	0.00	0.00	1.42	248	529	11
PA	BUTLER	All	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	CENTRE	All	385.0	3.30	0.00	0.00	0.00	0.00	3.30	578	1,235	26
PA	CHESTER	All	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	LEBANON	All	390.0	3.35	0.00	0.00	0.00	0.00	3.35	585	1,251	26
PA	MIFFLIN	All	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	MONTGOMERY	All	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
PA	YOFL	All	150.0	1.29	0.00	0.00	0.00	0.00	1.29	225	481	10
Total - PA			1,690.0	14.50	0.00	0.00	0.00	0.00	14.50	2,535	5,420	114
TN	MCMINN	All	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	103	2
TN	UNION	All	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	103	2
Total - TN			60.0	0.51	0.00	0.00	0.00	0.00	0.51	90	206	4
VA	FREDERICK	All	270.0	2.32	0.00	0.00	0.00	0.00	2.32	405	72	18
VA	GILES	All	210.0	1.80	0.00	0.00	0.00	0.00	1.80	315	56	14
VA	SHENANDOAH	All	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	SMYTH	All	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
VA	WARREN	All	105.0	0.90	0.00	0.00	0.00	0.00	0.90	158	28	7
Total - VA			795.0	6.82	0.00	0.00	0.00	0.00	6.82	1,193	213	54
WV	BERKELEY	All	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	82	2
WV	PENDLETON	All	30.0	0.26	0.00	0.00	0.00	0.00	0.26	45	82	2
Total - WV			60.0	0.51	0.00	0.00	0.00	0.00	0.51	90	163	4
WI	BROWN	All	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	DODGE	All	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	DOUGLASS	All	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	FOND DU LAC	All	50.0	0.43	0.00	0.00	0.00	0.00	0.43	75	142	3
WI	MANITOWOC	All	130.0	1.12	0.00	0.00	0.00	0.00	1.12	195	370	9
Total - WI			330.0	2.83	0.00	0.00	0.00	0.00	2.83	495	938	22
Total Study Area			12,255.0	94.04	0.00	11.11	0.00	0.00	105.15	17,599	33,764	777

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INDUSTRY: CLAY PRODUCTS

PLANT/FACILITY: BRICK AND STRUCTURAL CLAY TILE

PLANT POPULATION

In 1980, the brick and structural clay tile industry was composed of approximately 214 operating plants, 134 of which are located east of the Mississippi River.^{2,3} Capacity data were not available for the 134 plants evaluated. Hence, production was estimated from shipments data which indicated the total estimated 1980 production of the 134 plants analyzed was 19.7×10^6 tons, compared to a national total of 29.7×10^6 tons. The range in 1980 plant production was 32,700 to 816,800 tons, and the smallest plant consumed an estimated 110×10^9 Btu.

COMBUSTION PROCESSES

The brick and structural clay tile industry utilizes kilns to fire their product. Two direct-fired kilns predominate; the tunnel kiln and periodic or beehive kiln. The tunnel kiln accounts for 65 percent of total production.¹ Use of the periodic kiln has been declining over the last decade because this kiln is more energy- and labor-intensive. Natural gas is the predominate fuel fired in this industry.

PRODUCTION AND ENERGY CONSUMPTION

Production

Individual plant capacity or production data are not available for this industry. Although 1977 U.S. production is the most current year available,^{4,5} 1980 production estimates have been made by applying a growth factor to the 1977 production estimates. U.S. production for 1977 was estimated to be 4.24×10^7 tons of brick or brick equivalent using Department of Commerce data.^{4,5} Unfortunately, not all subcategories within the brick and tile industry reported production. If available, 1972 production data were substituted for missing 1977 data. The subcategories for which no data could be located appeared to be small (based on their product value) and were not included in the total U.S. production estimates.

Next, 1980 shipments of brick and structural clay tile were examined, and were shown to have declined approximately 30 percent from 1977 levels.⁶ Production was assumed to decline in direct proportion to shipments, and the resulting 1980 production estimate was 29.7×10^6 tons.

Plant production was apportioned to the individual plant level using data derived from the EIS shipments report.³ This report listing was checked by cross referencing it with a manufacturing plant listing.² Each manufacturing plant's share of the market was determined based on its shipments, and total U.S. 1980 production has been apportioned using each plant's share of the market. This apportioning method assumes that production is directly proportional to shipments.

Total estimated 1980 production for the 134 plants evaluated was 19.7×10^6 tons, with a plant range of 32,700 to 816,800 tons.

Energy Consumption - Fuel Type

As mentioned previously, the industry uses two basic types of kilns, the continuous energy-efficient tunnel kiln (65 percent) and the older batch periodic kiln (35 percent). Estimates indicate that the tunnel kiln consumes 2.4×10^6 Btu/tons,⁷ while the periodic kiln consumes from two to five times as much. In most cases, the periodic kiln is used for small-scale production.

Since plant-specific data are not available on the number and production associated with each type of kiln, an average weighted energy consumption factor of 3.5×10^6 Btu/ton was selected.⁸ This factor was then applied to plant production to obtain estimates of energy consumption.

Natural gas is the predominate fuel fired in the kilns, although some newer kilns are designed to fire two or more types of fuel. For the purpose of this study, however, it has been assumed that all kilns are firing natural gas.^{6,9}

EMISSION ESTIMATES

Emission Factors

The emission factors for SO_x , NO_x , and HC are shown below (in pounds per ton):

	SO_x^{10}	NO_x^{11}	HC^{11}
Tunnel kilns	1.44×10^{-3}	0.15	0.02
Periodic kilns	1.44×10^{-3}	0.42	0.04
Weighted average	1.44×10^{-3}	0.225	0.027

The SO_x emission factor is a default value, since no published data were available on SO_x emissions from natural gas-fired brick kilns.¹⁰ The kiln emission factors were weighted based on the amount of U.S. production attributable to each kiln (tunnel kilns - 65 percent, periodic kilns - 35 percent).¹

Plant Emissions

The range in annual emissions for 134 plants analyzed (in tons/yr) are shown below:

	Low	High
NO _x	4	100
SO _x	negligible	
HC	1	11

Tables A.17-1 and A.17-2 summarize plant production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county, respectively.

TABLE A.17-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 134 BRICK/STRUCTURAL CLAY TILE PLANTS^x, LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	DALLAS	HENRY BRICK CO	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
AL	ELMORE	JENKINS BRICK	136.6	0.00	0.00	0.48	0.00	0.00	0.48	17	0	2
AL	JEFFERSON	BICKERSTAFF CL	59.4	0.00	0.00	0.21	0.00	0.00	0.21	7	0	1
AL	JEFFERSON	BIRMINGHAM CLAY	80.2	0.00	0.00	0.28	0.00	0.00	0.28	10	0	1
AL	JEFFERSON	WATKINS BRICK	80.2	0.00	0.00	0.28	0.00	0.00	0.28	10	0	1
AL	MADISON	GENERAL SHALE	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
AL	MONTGOMERY	JENKINS BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
AL	RUSSELL	BICKERSTAFF CL	451.4	0.00	0.00	1.58	0.00	0.00	1.58	55	0	6
AL	TALLAPOOSA	HILLABEE BRICK	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
Total - AL			1,315.7	0.00	0.00	4.60	0.00	0.00	4.60	161	1	18
CT	MIDDLESEX	MICHAEL KANE	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
GA	BIBB	BURNS BRICK CO	166.3	0.00	0.00	0.58	0.00	0.00	0.58	20	0	2
GA	BIBB	CHEROKEE BRICK	323.7	0.00	0.00	1.13	0.00	0.00	1.13	40	0	4
GA	COBB	BICKERSTAFF CL	68.3	0.00	0.00	0.24	0.00	0.00	0.24	8	0	1
GA	RICHMOND	GEORGIA CAROL	187.1	0.00	0.00	0.65	0.00	0.00	0.65	23	0	3
GA	RICHMOND	HERRY COMPANIES	311.8	0.00	0.00	1.09	0.00	0.00	1.09	38	0	4
Total - GA			1,057.3	0.00	0.00	3.70	0.00	0.00	3.70	129	1	14
IL	COOK	AMERICAN BRICK	210.9	0.00	0.00	0.74	0.00	0.00	0.74	26	0	3
IL	LA SALLE	STREATOR BRICK	202.0	0.00	0.00	0.71	0.00	0.00	0.71	25	0	3
IL	MADISON	RICHARDS BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
IL	PEORIA	PEORIA BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
Total - IL			576.2	0.00	0.00	2.02	0.00	0.00	2.02	70	0	8
IN	JACKSON	MEDORA BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
IN	LAKE	AMERICAN BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
IN	MORGAN	GENERAL SHALE	136.6	0.00	0.00	0.48	0.00	0.00	0.48	17	0	2
IN	VERMILION	COLONIAL BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
Total - IN			828.6	0.00	0.00	2.90	0.00	0.00	2.90	101	1	11
KY	BOYD	CLINE BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
KY	CHRISTIAN	DALTON BROS	32.7	0.00	0.00	0.11	0.00	0.00	0.11	4	0	0
KY	DAVIESS	OWENSBORO BRICK	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
KY	POWELL	HP STIPPLE BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
KY	WHITLEY	CORBIN BRICK	44.6	0.00	0.00	0.16	0.00	0.00	0.16	5	0	1
Total - KY			403.9	0.00	0.00	1.41	0.00	0.00	1.41	49	0	5
NE	ANDROSCOGGIN	MORIN BRICK CO	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2

(Continued)

TABLE A.17-1 (Continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
ME	CUMBERLAND	LA CHANCE BROS	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
Total - ME			163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
MD	BALTIMORE	BALTIMORE BRICK	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
MD	FREDERICK	BALTIMORE BRICK	62.4	0.00	0.00	0.22	0.00	0.00	0.22	8	0	1
MD	KENT	CHESTERTOWN BR	53.5	0.00	0.00	0.19	0.00	0.00	0.19	7	0	1
MD	PRINCE GEORGE	MARYLAND CLAY	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
MD	WASHINGTON	VICTOR CUSHWA	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
Total - MD			433.6	0.00	0.00	1.52	0.00	0.00	1.52	53	0	6
MA	PLYMOUTH	STILES & HART	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
MS	FORREST	MATTIESBURG BR	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
MS	HINDS	TRI STATE BRICK	210.9	0.00	0.00	0.74	0.00	0.00	0.74	26	0	3
MS	JONES	LAUREL BRICK	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
MS	LINCOLN	BROOKHAVEN	157.4	0.00	0.00	0.55	0.00	0.00	0.55	19	0	2
MS	LOWNDES	COLUMBUS BRICK	68.3	0.00	0.00	0.24	0.00	0.00	0.24	8	0	1
MS	MARSHALL	CLAY PRODUCTS	71.3	0.00	0.00	0.25	0.00	0.00	0.25	9	0	1
MS	MARSHALL	HOLLY SPRINGS	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
MS	MARSHALL	SOUTHERN BRICK	92.1	0.00	0.00	0.32	0.00	0.00	0.32	11	0	1
MS	MOXIBEE	DELTA SHUQUALAK	86.1	0.00	0.00	0.30	0.00	0.00	0.30	11	0	1
MS	MOXIBEE	DELTA-MACON	294.0	0.00	0.00	1.03	0.00	0.00	1.03	36	0	4
MS	SUNFLOWER	DELTA BRICK	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
MS	WINSTON	LOUISVILLE BR	225.7	0.00	0.00	0.79	0.00	0.00	0.79	28	0	3
Total - MS			1,594.9	0.00	0.00	5.58	0.00	0.00	5.58	195	1	22
NH	STRAFFORD	KANE SONIC BR	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NJ	SOMERSET	NJ SHALE BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NY	ALBANY	POWELL&MINNOCK	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
NY	BROOME	BINGHAMPTON BR	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NY	MASSAU	MASSAU BRICK	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
Total - NY			359.4	0.00	0.00	1.26	0.00	0.00	1.26	44	0	5
NC	ALAMANCE	HANFORD BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	CHATHAM	CHATHAM BRICK	121.8	0.00	0.00	0.43	0.00	0.00	0.43	15	0	2
NC	CLEVELAND	BENNETT BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	DAVIDSON	CUNNINGHAM BR	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	DURHAM	TRIANGLE BRICK	196.0	0.00	0.00	0.69	0.00	0.00	0.69	24	0	3
NC	GUILFORD	BOREN CLAY PR	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2

(Continued)

TABLE A.17-1 (Continued)

			Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	HENDERSON	MOLAND-DRYSDALE	282.2	0.00	0.00	0.99	0.00	0.00	0.99	34	0	4
NC	IREDELL	STATESVILLE BR	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	LEE	LEE BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	LEE	SANFORD BRICK	409.9	0.00	0.00	1.43	0.00	0.00	1.43	50	0	6
NC	MECKLENBURG	KENDRICK BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	NASH	NASH BRICK	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	ROCKINGHAM	PINE HALL BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
NC	ROCKINGHAM	WEBSTER BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	ROWAN	ISENHOUR BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
NC	ROWAN	OLD CAROLINA	53.5	0.00	0.00	0.19	0.00	0.00	0.19	7	0	1
NC	ROWAN	TAYLOR CLAY	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
NC	SAMPSON	BOREN CLAY PR	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	STANLY	STANLY SHALE	121.8	0.00	0.00	0.43	0.00	0.00	0.43	15	0	2
NC	UNION	KENDRICK BRICK	228.7	0.00	0.00	0.80	0.00	0.00	0.80	28	0	3
NC	WAKE	CHEROKEE BRICK	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
Total - NC			3,373.9	0.00	0.00	11.81	0.00	0.00	11.81	412	2	46
OH	ATHENS	GENERAL CLAY	83.2	0.00	0.00	0.29	0.00	0.00	0.29	10	0	1
OH	DELAWARE	GALENA SHALE	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
OH	FRANKLIN	CLAYCRAFT CO	193.1	0.00	0.00	0.68	0.00	0.00	0.68	24	0	3
OH	FRANKLIN	GENERAL CLAY	246.5	0.00	0.00	0.86	0.00	0.00	0.86	30	0	3
OH	HOCKING	GENERAL CLAY	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
OH	JEFFERSON	FRED J DANDO CO	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
OH	MEDINA	GENL WADSWORTH	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
OH	RICHLAND	RICHLAND BRICK	178.2	0.00	0.00	0.62	0.00	0.00	0.62	22	0	2
OH	STARK	BELDEN BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
OH	TUSCARAWAS	BELDEN BRICK	187.1	0.00	0.00	0.65	0.00	0.00	0.65	23	0	3
OH	TUSCARAWAS	BELDEN BRICK	196.0	0.00	0.00	0.69	0.00	0.00	0.69	24	0	3
OH	TUSCARAWAS	EVANS CLAY PROD	204.9	0.00	0.00	0.72	0.00	0.00	0.72	25	0	3
OH	TUSCARAWAS	GENL CLAY PROD	68.3	0.00	0.00	0.24	0.00	0.00	0.24	8	0	1
OH	TUSCARAWAS	STONE CREEK BR	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
OH	TUSCARAWAS	STRASBURG BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
OH	WYANDOT	CLAYCRAFT CO	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
Total - OH			2,165.1	0.00	0.00	7.58	0.00	0.00	7.58	265	2	29
PA	ALLEGHENY	ALLEGHENY BRICK	89.1	0.00	0.00	0.31	0.00	0.00	0.31	11	0	1
PA	ALLEGHENY	MILLIKEN BRICK	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
PA	ARMSTRONG	CONTINENTAL CL	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
PA	BEAVER	DARLINGTON BR	202.0	0.00	0.00	0.71	0.00	0.00	0.71	25	0	3
PA	BEAVER	MILLIKEN BRICK	80.2	0.00	0.00	0.28	0.00	0.00	0.28	10	0	1
PA	BERKS	GLEN GERY CORP	172.3	0.00	0.00	0.60	0.00	0.00	0.60	21	0	2
PA	BERKS	GLEN GERY CORP	216.8	0.00	0.00	0.76	0.00	0.00	0.76	27	0	3
PA	BUCKS	QUAKERTOWN BR	83.2	0.00	0.00	0.29	0.00	0.00	0.29	10	0	1

(Continued)

TABLE A.17-1 (Continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	CHESTER	MCADY VITR	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
PA	JEFFERSON	HANLEY CO	816.8	0.00	0.00	2.86	0.00	0.00	2.86	100	1	11
PA	LUZERNE	HAZLETON BRICK	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
PA	MCKEAN	HANLEY CO	487.1	0.00	0.00	1.70	0.00	0.00	1.70	60	0	7
PA	NORTHUMBERLA	GLEN GERY CORP	172.3	0.00	0.00	0.60	0.00	0.00	0.60	21	0	2
PA	NORTHUMBERLA	WATSONTOWN BR	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
PA	YORK	GLEN GERY CORP	193.1	0.00	0.00	0.68	0.00	0.00	0.68	24	0	3
Total - PA			3,109.6	0.00	0.00	10.88	0.00	0.00	10.88	380	2	42
SC	CHEROKEE	BOREN CLAY PROD	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
SC	CHEROKEE	BROAD RIVER BR	62.4	0.00	0.00	0.22	0.00	0.00	0.22	8	0	1
SC	CHESTERFIELD	PALMETTO BRICK	118.8	0.00	0.00	0.42	0.00	0.00	0.42	15	0	2
SC	DORCHESTER	DORCHESTER BR	59.4	0.00	0.00	0.21	0.00	0.00	0.21	7	0	1
SC	DORCHESTER	SALISBURY BRICK	130.7	0.00	0.00	0.46	0.00	0.00	0.46	16	0	2
SC	GREENWOOD	SOUTHERN BRICK	237.6	0.00	0.00	0.83	0.00	0.00	0.83	29	0	3
SC	MORRY	MACCANN CLAY	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
SC	LEXINGTON	GUIGNARD BRICK	77.2	0.00	0.00	0.27	0.00	0.00	0.27	9	0	1
SC	MARION	PEE DEE CERAMIC	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
SC	RICHLAND	CAROLINA CERAM	89.1	0.00	0.00	0.31	0.00	0.00	0.31	11	0	1
SC	RICHLAND	RICHTEX CORP	341.6	0.00	0.00	1.20	0.00	0.00	1.20	42	0	5
SC	SURTER	RICHTEX CORP	89.1	0.00	0.00	0.31	0.00	0.00	0.31	11	0	1
Total - SC			1,541.4	0.00	0.00	5.40	0.00	0.00	5.40	188	1	21
TN	DAVIDSON	HERBERT NATRLS	457.4	0.00	0.00	1.60	0.00	0.00	1.60	56	0	6
TN	HAMILTON	GENL SHALE PROD	71.3	0.00	0.00	0.25	0.00	0.00	0.25	9	0	1
TN	HENRY	LAIRD BRICK CO	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
TN	KNOX	GENL SHALE PROD	142.6	0.00	0.00	0.50	0.00	0.00	0.50	17	0	2
TN	SULLIVAN	GENL SHALE PROD	148.5	0.00	0.00	0.52	0.00	0.00	0.52	18	0	2
TN	WASHINGTON	GENL SHALE PROD	101.0	0.00	0.00	0.35	0.00	0.00	0.35	12	0	1
TN	WEAKLEY	GLEASON CLAY	41.6	0.00	0.00	0.15	0.00	0.00	0.15	5	0	1
Total - TN			1,009.8	0.00	0.00	3.53	0.00	0.00	3.53	123	1	14
VA	AMHERST	LOCHER BRICK	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
VA	BRUNSWICK	BRICK & TILE	130.7	0.00	0.00	0.46	0.00	0.00	0.46	16	0	2
VA	HENRICO	REDFORD BRICK	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
VA	MANSEMOND	WEBSTER BRICK	104.0	0.00	0.00	0.36	0.00	0.00	0.36	13	0	1
VA	ORANGE	WEBSTER BRICK	246.5	0.00	0.00	0.86	0.00	0.00	0.86	30	0	3
VA	ROANOKE	OLD VIRGINIA BR	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
VA	ROANOKE	WEBSTER BRICK	210.9	0.00	0.00	0.74	0.00	0.00	0.74	26	0	3
VA	ROCKBRIDGE	GENL SHALE PROD	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
VA	SNYTH	GENL SHALE PROD	234.6	0.00	0.00	0.82	0.00	0.00	0.82	29	0	3
Total - VA			1,292.0	0.00	0.00	4.52	0.00	0.00	4.52	158	1	17

(Continued)

TABLE A.17-1 (Continued)

			Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
WV	BERKELEY	CONTINENTAL CL	130.7	0.00	0.00	0.46	0.00	0.00	0.46	16	0	2
Total Study Area			19,682.2	0.00	0.00	68.89	0.00	0.00	68.89	2,406	14	266

TABLE A.17-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 134 BRICK/STRUCTURAL CLAY TILE PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	DALLAS	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
AL	ELMORE	All	136.6	0.00	0.00	0.48	0.00	0.00	0.48	17	0	2
AL	JEFFERSON	All	219.8	0.00	0.00	0.77	0.00	0.00	0.77	27	0	3
AL	MADISON	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
AL	MONTGOMERY	All	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
AL	RUSSELL	All	451.4	0.00	0.00	1.58	0.00	0.00	1.58	55	0	6
AL	TALLAPOOSA	All	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
Total - AL			1,315.7	0.00	0.00	4.60	0.00	0.00	4.60	161	1	18
CT	MIDDLESEX	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
GA	BIBB	All	490.1	0.00	0.00	1.72	0.00	0.00	1.72	60	0	7
GA	COBB	All	68.3	0.00	0.00	0.24	0.00	0.00	0.24	8	0	1
GA	RICHMOND	All	499.0	0.00	0.00	1.75	0.00	0.00	1.75	61	0	7
Total - GA			1,057.3	0.00	0.00	3.70	0.00	0.00	3.70	129	1	14
IL	COOK	All	210.9	0.00	0.00	0.74	0.00	0.00	0.74	26	0	3
IL	LA SALLE	All	202.0	0.00	0.00	0.71	0.00	0.00	0.71	25	0	3
IL	MADISON	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
IL	PEORIA	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
Total - IL			576.2	0.00	0.00	2.02	0.00	0.00	2.02	70	0	8
IN	JACKSON	All	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
IN	LAKE	All	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
IN	MORGAN	All	136.6	0.00	0.00	0.48	0.00	0.00	0.48	17	0	2
IN	VERMILION	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
Total - IN			828.6	0.00	0.00	2.90	0.00	0.00	2.90	101	1	11
KY	BOYD	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
KY	CHRISTIAN	All	32.7	0.00	0.00	0.11	0.00	0.00	0.11	4	0	0
KY	DAVIESS	All	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
KY	POWELL	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
KY	WHITLEY	All	44.6	0.00	0.00	0.16	0.00	0.00	0.16	5	0	1
Total - KY			403.9	0.00	0.00	1.41	0.00	0.00	1.41	49	0	5
ME	ANDROSCOGGIN	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
ME	CUMBERLAND	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
Total - ME			163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
MD	BALTIMORE	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1

(Continued)

TABLE A.17-2 (Continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MD	FREDERICK	All	62.4	0.00	0.00	0.22	0.00	0.00	0.22	8	0	1
MD	KENT	All	53.5	0.00	0.00	0.19	0.00	0.00	0.19	7	0	1
MD	PRINCE GEORGE	All	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
MD	WASHINGTON	All	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
Total - MD			433.6	0.00	0.00	1.52	0.00	0.00	1.52	53	0	6
MA	PLYMOUTH	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
MS	FORREST	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
MS	HINDS	All	210.9	0.00	0.00	0.74	0.00	0.00	0.74	26	0	3
MS	JONES	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
MS	LINCOLN	All	157.4	0.00	0.00	0.55	0.00	0.00	0.55	19	0	2
MS	LOWNDES	All	68.3	0.00	0.00	0.24	0.00	0.00	0.24	8	0	1
MS	MARSHALL	All	308.9	0.00	0.00	1.08	0.00	0.00	1.08	38	0	4
MS	MOXIBEE	All	380.2	0.00	0.00	1.33	0.00	0.00	1.33	46	0	5
MS	SUNFLOWER	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
MS	WINSTON	All	225.7	0.00	0.00	0.79	0.00	0.00	0.79	28	0	3
Total - MS			1,594.9	0.00	0.00	5.58	0.00	0.00	5.58	195	1	22
NH	STRAFFORD	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NJ	SOMERSET	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NY	ALBANY	All	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
NY	BROOME	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NY	NASSAU	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
Total - NY			359.4	0.00	0.00	1.26	0.00	0.00	1.26	44	0	5
NC	ALAMANCE	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	CHATHAM	All	121.8	0.00	0.00	0.43	0.00	0.00	0.43	15	0	2
NC	CLEVELAND	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	DAVIDSON	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	DURHAM	All	196.0	0.00	0.00	0.69	0.00	0.00	0.69	24	0	3
NC	GUILFORD	All	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
NC	HENDERSON	All	282.2	0.00	0.00	0.99	0.00	0.00	0.99	34	0	4
NC	IREDELL	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	LEE	All	525.7	0.00	0.00	1.84	0.00	0.00	1.84	64	0	7
NC	NECKLENBURG	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
NC	NASH	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
NC	ROCKINGHAM	All	335.6	0.00	0.00	1.17	0.00	0.00	1.17	41	0	5
NC	ROWAN	All	504.9	0.00	0.00	1.77	0.00	0.00	1.77	62	0	7
NC	SAMPSON	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1

(Continued)

TABLE A.17-2 (Continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	STANLY	All	121.8	0.00	0.00	0.43	0.00	0.00	0.43	15	0	2
NC	UNION	All	228.7	0.00	0.00	0.00	0.00	0.00	0.00	28	0	3
NC	WAKE	All	288.1	0.00	0.00	1.01	0.00	0.00	1.01	35	0	4
Total - NC			3,373.9	0.00	0.00	11.81	0.00	0.00	11.81	412	2	46
OH	ATHENS	All	83.2	0.00	0.00	0.29	0.00	0.00	0.29	10	0	1
OH	DELAWARE	All	163.4	0.00	0.00	0.57	0.00	0.00	0.57	20	0	2
OH	FRANKLIN	All	439.6	0.00	0.00	1.54	0.00	0.00	1.54	54	0	6
OH	HOCKING	All	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
OH	JEFFERSON	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
OH	MEDINA	All	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
OH	RICHLAND	All	178.2	0.00	0.00	0.62	0.00	0.00	0.62	22	0	2
OH	STARK	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
OH	TUSCARAWAS	All	819.7	0.00	0.00	2.87	0.00	0.00	2.87	100	1	11
OH	WYANDOT	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
Total - OH			2,165.1	0.00	0.00	7.58	0.00	0.00	7.58	265	2	29
PA	ALLEGHENY	All	252.5	0.00	0.00	0.88	0.00	0.00	0.88	31	0	3
PA	ARMSTRONG	All	74.3	0.00	0.00	0.26	0.00	0.00	0.26	9	0	1
PA	BEAVER	All	282.2	0.00	0.00	0.99	0.00	0.00	0.99	34	0	4
PA	BERKS	All	389.1	0.00	0.00	1.36	0.00	0.00	1.36	48	0	5
PA	BUCKS	All	83.2	0.00	0.00	0.29	0.00	0.00	0.29	10	0	1
PA	CHESTER	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
PA	JEFFERSON	All	816.8	0.00	0.00	2.86	0.00	0.00	2.86	100	1	11
PA	LUZERNE	All	98.0	0.00	0.00	0.34	0.00	0.00	0.34	12	0	1
PA	MCKEAN	All	487.1	0.00	0.00	1.70	0.00	0.00	1.70	60	0	7
PA	NORTHUMBERLAND	All	335.6	0.00	0.00	1.17	0.00	0.00	1.17	41	0	5
PA	YORK	All	193.1	0.00	0.00	0.68	0.00	0.00	0.68	24	0	3
Total - PA			3,109.6	0.00	0.00	10.88	0.00	0.00	10.88	380	2	42
SC	CHEROKEE	All	225.7	0.00	0.00	0.79	0.00	0.00	0.79	28	0	3
SC	CHESTERFIELD	All	118.8	0.00	0.00	0.42	0.00	0.00	0.42	15	0	2
SC	DORCHESTER	All	190.1	0.00	0.00	0.67	0.00	0.00	0.67	23	0	3
SC	GREENWOOD	All	237.6	0.00	0.00	0.83	0.00	0.00	0.83	29	0	3
SC	HORRY	All	115.8	0.00	0.00	0.41	0.00	0.00	0.41	14	0	2
SC	LEXINGTON	All	77.2	0.00	0.00	0.27	0.00	0.00	0.27	9	0	1
SC	MARION	All	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
SC	RICHLAND	All	430.7	0.00	0.00	1.51	0.00	0.00	1.51	53	0	6
SC	SUMTER	All	89.1	0.00	0.00	0.31	0.00	0.00	0.31	11	0	1
Total - SC			1,541.4	0.00	0.00	5.40	0.00	0.00	5.40	188	1	21
TN	DAVIDSON	All	457.4	0.00	0.00	1.60	0.00	0.00	1.60	56	0	6

(Continued)

TABLE A.17-2 (Continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
TN	HAMILTON	All	71.3	0.00	0.00	0.25	0.00	0.00	0.25	9	0	1
TN	HENRY	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
TN	KNOX	All	142.6	0.00	0.00	0.50	0.00	0.00	0.50	17	0	2
TN	SULLIVAN	All	148.5	0.00	0.00	0.52	0.00	0.00	0.52	18	0	2
TN	WASHINGTON	All	101.0	0.00	0.00	0.35	0.00	0.00	0.35	12	0	1
TN	WEAKEY	All	41.6	0.00	0.00	0.15	0.00	0.00	0.15	5	0	1
Total - TN			1,009.8	0.00	0.00	3.53	0.00	0.00	3.53	123	1	14
VA	AMHERST	All	47.5	0.00	0.00	0.17	0.00	0.00	0.17	6	0	1
VA	BRUNSWICK	All	130.7	0.00	0.00	0.46	0.00	0.00	0.46	16	0	2
VA	HENRICO	All	145.5	0.00	0.00	0.51	0.00	0.00	0.51	18	0	2
VA	MANASSAND	All	104.0	0.00	0.00	0.36	0.00	0.00	0.36	13	0	1
VA	ORANGE	All	246.5	0.00	0.00	0.86	0.00	0.00	0.86	30	0	3
VA	ROANOKE	All	326.7	0.00	0.00	1.14	0.00	0.00	1.14	40	0	4
VA	ROCKBRIDGE	All	56.4	0.00	0.00	0.20	0.00	0.00	0.20	7	0	1
VA	SNYTH	All	234.6	0.00	0.00	0.82	0.00	0.00	0.82	29	0	3
Total - VA			1,292.0	0.00	0.00	4.52	0.00	0.00	4.52	158	1	17
WV	BERKELEY	All	130.7	0.00	0.00	0.46	0.00	0.00	0.46	16	0	2
Total Study Area			19,682.2	0.00	0.00	68.89	0.00	0.00	68.89	2,406	14	266

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INDUSTRY: CLAY PRODUCTS

PLANT/FACILITY: LIGHTWEIGHT AGGREGATE

PLANT POPULATION

In 1981, there were 35 lightweight aggregate plants in the U.S., with 16 being located east of the Mississippi.¹ However, only 8 out of 16 plants met the established energy consumption criteria of 100×10^9 Btu/year. Capacity data were not available for the 8 plants analyzed. Hence, production was estimated from shipments data, which indicated that the total estimated 1981 production of the eight plants was approximately 2.0×10^6 tons, compared to a national total of about 3.65×10^6 tons.¹ The range in estimated 1981 plant production was 77,000 to 383,000 tons and the smallest plant had an estimated 1981 direct-fired energy consumption of 200×10^9 Btu.

COMBUSTION PROCESSES

Lightweight aggregates encompass a variety of raw materials used to provide bulk in concrete. The only major direct-fired process in this industry is the rotary kiln utilized in the manufacture of expanded clay, shale, and slate.² Coal is the predominant fuel utilized in this industry; accounting for approximately 95 percent of the total fuel consumed.^{2,3} Some kilns, however, are designed to fire coal, natural gas, fuel oil or a combination thereof.^{2,3}

PRODUCTION AND FUEL CONSUMPTION

Production

Actual plant capacity could only be obtained for one (Norlite Corporation) of the sixteen plants studied. This plant's reported 1981 annual capacity was 300,000 tons.⁴ Production for this plant was then estimated by multiplying the capacity times a 50 percent utilization factor, estimated by industry experts to be the level at which plants were operating in 1981.⁵

Production for the other 7 plants analyzed was estimated by apportioning the total U.S. production using the EIS report on shipments.⁶ Contained in this report are estimates of the shipments in millions of dollars for each plant having greater than 20 or more employees. EIS reported that 95 percent of production is by plants having greater than 20 employees⁷ and lists fourteen of the total 35 plants located in the U.S as being in that category.* Total production for these 14 plants (7 of which being located east of the Mississippi) was estimated by multiplying the sum of the total 1981 U.S. production of 3.65×10^6 tons¹ (minus 150,000 tons/year for the Norlite plant) by 0.95, yielding 3.32×10^6 tons.

Apportioning this 3.32×10^6 tons/year production among the seven plants located east of the Mississippi, was accomplished using the shipments in dollars provided in EIS. Total sales for the 14 plants were reported to be 21.7×10^6 dollars. Assuming

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* Norlite from its capacity appears to have more than 20 employees but for unexplained reasons is not in the list of 14 shown by the EIS data.

that each plant's shipments in dollars are directly equatable with production, each plant's share or percentage of the 21.7×10^6 dollars was calculated and applied to the 3.32×10^6 tons/year production figure to estimate plant specific production. The estimated 1981 plant production for these 7 plants located east of the Mississippi ranged from 77,000 to 383,000 tons.

The remaining 20 U.S. plants (excluding the Norlite plant, which was also not listed in the EIS report) were assumed to have less than 20 employees. Since shipment data were not available, an average plant size was calculated for these 20 plants (8 of which being located east of the Mississippi) by first multiplying the sum of the total U.S. 1981 production of 3.65×10^6 tons (minus 150,000 tons/year for the Norlite plant) by 0.05, yielding 0.18×10^6 tons/year. This figure was then divided by the 20 plants not listed in the EIS report to obtain an average production figure of approximately (9,000) tons/year. Based on this estimated average production figure, however, all of these plants were excluded from further consideration on the assumption that if the average plant in the group had energy consumption of 24×10^9 Btu/yr that all in the group would be under 100×10^9 Btu/yr. Therefore, a total of only eight plants with an estimated 1981 production of 2.0×10^6 tons, and a plant range of 77,000 to 383,000 tons were analyzed.

Energy Consumption - Fuel Type

Generally, the lightweight aggregate kiln consumes approximately 2.6×10^6 Btu/ton of aggregate produced.³ Therefore,

total 1981 energy consumption for the 8 plants was estimated at 5.2×10^{12} Btu with a plant range of 200×10^9 to $1,000 \times 10^9$ Btu. Coal was assumed to be the only fuel consumed.^{2,3}

EMISSION ESTIMATES

Emission Factors

Based on similarities in equipment and fuel usage, the NO_x and SO_x emission factors were derived from those factors provided in the literature for coal fired cement kilns. The specific emission factors as obtained from the U.S. EPA's AP-42 publication are: 2.6 and 6.8 (S) lb/ton cement for NO_x and SO_x respectively.⁸ The (S) in the SO_x factor represents the sulfur content of the coal in weight percent.

To account for the differences in energy consumption between the two industries, the factors were then adjusted by multiplying them times the ratio of the lightweight aggregate energy consumption rate to the cement energy consumption rate, i.e., 2.6×10^6 Btu/ton of aggregate and 5.5×10^6 Btu/ton of cement.⁹ The emission factors so converted are: 1.2 and 3.2 (S) lb/ton of aggregate for NO_x and SO_x respectively.

An industrial combustion default emission factor for overfeed stokers was assumed for HC because no other process specific factor was available from published literature. The HC emission default factor as obtained from the U.S. EPA's AP-42 publication is 0.1 lb/ton of coal fired.⁸ Utilizing the energy consumption factor of 2.6×10^6 Btu/ton and a heating value of 25×10^6 Btu/ton for bituminous coal,¹⁰ the emission factor converts to 1.04×10^{-2} lb/ton of aggregate for HC.

Plant Emissions

The range in total annual emissions (in tons/year) for the eight plants analyzed, is shown below:

	Low	High
NO _x	46	230
SO _x	173	1,526
HC	<1	2

Tables A.18-1 and A.18-2 summarize the plants estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions, respectively.

TABLE A.18-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 8 LIGHTWEIGHT AGGREGATE PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

*****												
St	County	Facility	Prod 1980 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	VULCAN MATERIAL	306.0	0.80	0.00	0.00	0.00	0.00	0.80	184	778	2
AL	SUNTER	TOMBIGBEE LTWT	383.0	1.00	0.00	0.00	0.00	0.00	1.00	230	974	2
Total - AL			689.0	1.79	0.00	0.00	0.00	0.00	1.79	413	1,753	4
GA	POLK	GALITE CORP	352.0	0.92	0.00	0.00	0.00	0.00	0.92	211	924	2
IN	MORGAN	HYDRAULIC PRESS	230.0	0.60	0.00	0.00	0.00	0.00	0.60	138	964	1
PA	FREDERICK	LEHIGH PORTLAND	77.0	0.20	0.00	0.00	0.00	0.00	0.20	46	202	0
NY	ALBANY	MORLITE CORP	150.0	0.39	0.00	0.00	0.00	0.00	0.39	90	442	1
OH	CUYAHOGA	HYDRAULIC PRESS	383.0	1.00	0.00	0.00	0.00	0.00	1.00	230	1,526	2
VA	AMHERST	AMLITE CORP	123.0	0.32	0.00	0.00	0.00	0.00	0.32	74	173	1
Total Study Area			2,004.0	5.21	0.00	0.00	0.00	0.00	5.21	1,282	5,903	10

TABLE A.18-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 8 LIGHTWEIGHT AGGREGATE PLANTS^x, LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	MC
AL	JEFFERSON	All	306.0	0.80	0.00	0.00	0.00	0.00	0.80	184	778	2
AL	SUMTER	All	383.0	1.00	0.00	0.00	0.00	0.00	1.00	230	974	2
Total - AL			689.0	1.79	0.00	0.00	0.00	0.00	1.79	413	1,753	4
GA	POLK	All	352.0	0.92	0.00	0.00	0.00	0.00	0.92	211	924	2
IN	MORGAN	All	230.0	0.60	0.00	0.00	0.00	0.00	0.60	138	964	1
MD	FREDERICK	All	77.0	0.20	0.00	0.00	0.00	0.00	0.20	46	202	0
NY	ALBANY	All	150.0	0.39	0.00	0.00	0.00	0.00	0.39	90	442	1
OH	CUYAHOGA	All	383.0	1.00	0.00	0.00	0.00	0.00	1.00	230	1,526	2
VA	AMHERST	All	123.0	0.32	0.00	0.00	0.00	0.00	0.32	74	173	1
Total Study Area			2,004.0	5.21	0.00	0.00	0.00	0.00	5.21	1,202	5,983	10

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INDUSTRY: CEMENT

PLANT/FACILITY: CEMENT PLANTS

PLANT POPULATION

In 1981, the U.S. Cement Industry operated 144 plants, 64 of which were located east of the Mississippi River. Capacity for these plants ranged from 71×10^3 to $2,346 \times 10^3$ tons/yr of product. Total estimated 1981 production of the 64 plants analyzed, was 30.7×10^6 tons compared to a national total of 66.6×10^6 tons. The smallest plant analyzed had a production estimate of 47.2×10^3 tons and direct-fired energy consumption of 260×10^9 Btu.

COMBUSTION PROCESSES

The only major direct-fired process in the cement industry is the kiln, which converts the raw material feed of limestone and silica, (with alumina and ferric oxide as fluxing agents), to clinker via a chemical reaction during calcination. Pulverizing the clinker and mixing with gypsum yields portland cement. About 95 percent of the plants utilize coal, as their primary fuel.

PRODUCTION AND FUEL CONSUMPTION

Production

Actual plant production was unavailable. Plant specific capacity data was obtained through the Portland Cement Association.¹ Regional capacity factors obtained from the Bureau of

Mines, were used to estimate production.² These capacity factors are presented in Table A.19-1.

Total estimated 1981 production for the 64 plants evaluated was 30.7×10^6 tons, with a plant range of 47.2×10^3 to $1,757.2 \times 10^3$ tons.

Energy Consumption - Fuel Type

Estimates indicate the cement kiln consumes approximately 5.5×10^6 Btu/ton.³ Total energy consumption for the 64 plants was estimated to be $168,860 \times 10^9$ Btu/yr with a plant range of 260×10^9 to $9,660 \times 10^9$ Btu/yr. Sixty of the 64 plants evaluated use coal as their primary fuel; three plants use natural gas and the remaining plant uses residual oil.

EMISSION ESTIMATES

Emission Factors

Emission factors are based on a combination of test data and default factors from the literature.^{4,5} Hydrocarbon default emission factors for coal, gas, and oil are 0.022, 0.0376, and 0.111 lb/ton cement, respectively.^{4,5} The NO_x emission factor for coal is 2.6 lb/ton.⁴ Oil and gas NO_x emissions are estimated using the equations derived from Mills et al.⁶

SO_x emission factors vary depending on the type of fuel and the percent sulfur in the fuel. The SO_x emission factor attributable to natural gas is 2.26×10^{-3} lb/ton.⁵ The formulae for estimating SO_x emissions (in lb/ton of product) from oil and coal are as follows.⁴

TABLE A.19-1. REGIONALIZED PERCENT UTILIZATION OF
CLINKER CAPACITY FOR STUDY AREA STATES²

District	Percent Utilization of Capacity
New York and Maine	84.1
Pennsylvania, eastern	66.5
Pennsylvania, western	66.3
Maryland and West Virginia	73.8
Ohio	66.8
Michigan	74.9
Indiana	51.1
Illinois	57.0
Tennessee	71.6
Kentucky, North Carolina and Virginia	81.9
South Carolina	77.9
Florida	81.7
Georgia	88.6
Alabama	59.1
Mississippi	82.1
Wisconsin	67.7

- ° Oil: 4.2 (S)
- ° Coal: 6.8 (S)

where S = the percent sulfur in fuel

An average percent sulfur in fuel has been obtained for each state and applied to the above formulae.^{7,8}

Plant Emissions

The range in emissions for the 64 plants analyzed, in tons/yr are shown below:

	Low	High
NO _x	48	2,284
SO _x	Negligible	7,829
HC	2	19

Production, energy consumption by fuel, and NO_x, SO_x and HC emissions for the 64 plants evaluated, are summarized by plant and county in Tables A.19-2 and A.19-3 respectively.

TABLE A.19-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x AND HC EMISSIONS FOR 64 CEMENT PLANTS LOCATED
EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	MC
AL	JEFFERSON	LEHIGH PORTLAND	329.8	1.81	0.00	0.00	0.00	0.00	1.81	429	1,783	4
AL	NARENGO	CITADEL CEMENT	443.3	2.44	0.00	0.00	0.00	0.00	2.44	576	2,396	5
AL	MOBILE	IDEAL BASIC IND	827.4	4.55	0.00	0.00	0.00	0.00	4.55	1,076	4,473	9
AL	ST CLAIR	NATL CEMENT CO	475.2	2.61	0.00	0.00	0.00	0.00	2.61	618	2,569	5
AL	SHELBY	MARTIN MARIETTA	384.2	2.11	0.00	0.00	0.00	0.00	2.11	499	2,077	4
Total - AL			2,459.7	13.53	0.00	0.00	0.00	0.00	13.53	3,198	13,297	27
FL	DADE	LONE STAR IND	991.8	2.73	0.00	2.73	0.00	0.00	5.46	999	3,676	15
FL	DADE	GENL PORTLAND	387.3	2.13	0.00	0.00	0.00	0.00	2.13	503	2,870	4
FL	DADE	RINKER PORTLAND	429.7	2.36	0.00	0.00	0.00	0.00	2.36	559	3,185	5
FL	HERNANDO	MOORE MCCORMACK	457.5	2.52	0.00	0.00	0.00	0.00	2.52	595	3,391	5
FL	HILLSBOROUGH	GENL PORTLAND	805.6	4.43	0.00	0.00	0.00	0.00	4.43	1,047	5,971	9
Total - FL			3,071.9	14.17	0.00	2.73	0.00	0.00	16.90	3,703	19,094	38
GA	FULTON	MARTIN MARIETTA	531.6	2.92	0.00	0.00	0.00	0.00	2.92	691	2,964	6
GA	HOUSTON	MEDUSA CEMENT	662.7	3.65	0.00	0.00	0.00	0.00	3.65	862	3,695	7
Total - GA			1,194.3	6.57	0.00	0.00	0.00	0.00	6.57	1,553	6,660	13
IL	LA SALLE	ILLINOIS CEMENT	244.0	1.34	0.00	0.00	0.00	0.00	1.34	317	1,526	3
IL	LA SALLE	MARQUETTE CO	255.9	1.41	0.00	0.00	0.00	0.00	1.41	333	1,601	3
IL	LEE	LONE STAR IND	325.5	1.79	0.00	0.00	0.00	0.00	1.79	423	2,036	4
IL	MASSAC	MISSOURI PORTLD	694.3	3.82	0.00	0.00	0.00	0.00	3.82	903	4,343	8
Total - IL			1,519.6	8.36	0.00	0.00	0.00	0.00	8.36	1,976	9,507	17
IN	CASS	LOUISVILLE CMT	251.4	1.38	0.00	0.00	0.00	0.00	1.38	327	2,240	3
IN	CLARK	LOUISVILLE CMT	539.6	2.97	0.00	0.00	0.00	0.00	2.97	702	4,807	6
IN	FOUNTAIN	LONE STAR IND	384.3	2.11	0.00	0.00	0.00	0.00	2.11	500	3,423	4
IN	LAWRENCE	LEHIGH PORTLAND	388.4	2.14	0.00	0.00	0.00	0.00	2.14	505	3,460	4
Total - IN			1,563.7	8.60	0.00	0.00	0.00	0.00	8.60	2,033	13,929	17
KY	JEFFERSON	MOORE MCCORMACK	522.5	2.87	0.00	0.00	0.00	0.00	2.87	679	4,459	6
ME	KNOX	MARTIN MARIETTA	380.1	2.09	0.00	0.00	0.00	0.00	2.09	494	2,611	4
MD	CARROLL	LEHIGH PORTLAND	687.8	3.78	0.00	0.00	0.00	0.00	3.78	894	3,835	8
MD	FREDERICK	ALPHA PORTLAND	287.8	1.58	0.00	0.00	0.00	0.00	1.58	374	1,605	3
MD	WASHINGTON	MARQUETTE CO	331.4	1.82	0.00	0.00	0.00	0.00	1.82	431	1,848	4
Total - MD			1,307.0	7.19	0.00	0.00	0.00	0.00	7.19	1,699	7,288	14
MI	ALPENA	NATL GYPSUM CO	1,757.2	9.66	0.00	0.00	0.00	0.00	9.66	2,284	7,767	19

(continued)

TABLE A.19-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MI	CHARLEVOIX	MEDUSA CEMENT	1,033.6	5.68	0.00	0.00	0.00	0.00	5.68	1,344	4,569	11
MI	MONROE	DUNDEE CEMENT	687.6	3.78	0.00	0.00	0.00	0.00	3.78	894	3,039	8
MI	WAYNE	GIFFORD-HILL	534.0	2.94	0.00	0.00	0.00	0.00	2.94	694	2,360	6
Total - MI			4,012.4	22.07	0.00	0.00	0.00	0.00	22.07	5,216	17,735	44
MS	LOWNDES	TEXAS IND	376.8	2.07	0.00	0.00	0.00	0.00	2.07	490	2,101	4
NY	ALBANY	ATLANTIC CEMENT	1,251.4	6.88	0.00	0.00	0.00	0.00	6.88	1,627	7,829	14
NY	CHAUTAUQUA	MOORE MCCORMACK	391.1	0.00	0.00	2.15	0.00	0.00	2.15	267	0	7
NY	GREENE	LEHIGH PORTLAND	364.2	2.00	0.00	0.00	0.00	0.00	2.00	473	2,278	4
NY	GREENE	MARQUETTE CO	473.5	2.60	0.00	0.00	0.00	0.00	2.60	616	2,962	5
NY	GREENE	ALPHA PORTLAND	437.3	2.41	0.00	0.00	0.00	0.00	2.41	569	2,736	5
Total - NY			2,917.4	13.90	0.00	2.15	0.00	0.00	16.05	3,551	15,805	35
NC	NEW HAMOVER	IDEAL BASIC IND	416.9	2.29	0.00	0.00	0.00	0.00	2.29	542	1,361	5
OH	GREENE	SW PORTLAND CMT	462.9	2.55	0.00	0.00	0.00	0.00	2.55	602	3,919	5
OH	LAWRENCE	MARQUETTE CO	170.3	0.94	0.00	0.00	0.00	0.00	0.94	221	1,442	2
OH	LUCAS	SME CEMENT INC	174.3	0.96	0.00	0.00	0.00	0.00	0.96	227	1,476	2
OH	MUSKINGUM	COLUMBIA CEMENT	434.2	2.39	0.00	0.00	0.00	0.00	2.39	564	3,676	5
OH	PAULDING	GENL PORTLAND	307.3	1.69	0.00	0.00	0.00	0.00	1.69	399	2,601	3
OH	STARK	SME CEMENT INC	138.9	0.76	0.00	0.00	0.00	0.00	0.76	181	1,176	2
Total - OH			1,688.0	9.28	0.00	0.00	0.00	0.00	9.28	2,194	14,291	19
PA	ALLEGHENY	MARQUETTE CO	245.3	1.35	0.00	0.00	0.00	0.00	1.35	319	1,760	3
PA	BERKS	NATL GYPSUM CO	553.3	3.04	0.00	0.00	0.00	0.00	3.04	719	3,969	6
PA	BUTLER	PENN-WEST CMT	197.6	1.09	0.00	0.00	0.00	0.00	1.09	257	1,417	2
PA	LAWRENCE	LOUISVILLE CMT	356.7	1.96	0.00	0.00	0.00	0.00	1.96	464	2,559	4
PA	LAWRENCE	MEDUSA CEMENT	472.7	2.60	0.00	0.00	0.00	0.00	2.60	615	3,391	5
PA	LEHIGH	GENL PORTLAND	507.4	2.79	0.00	0.00	0.00	0.00	2.79	660	3,640	6
PA	NORTHAMPTON	KEYSTONE PORTLD	386.4	2.13	0.00	0.00	0.00	0.00	2.13	502	2,772	4
PA	NORTHAMPTON	COPLAY CEMENT	655.7	3.61	0.00	0.00	0.00	0.00	3.61	852	4,704	7
PA	NORTHAMPTON	LONE STAR IND	437.6	2.41	0.00	0.00	0.00	0.00	2.41	569	3,139	5
PA	NORTHAMPTON	LEHIGH PORTLAND	47.2	0.00	0.26	0.00	0.00	0.00	0.26	50	140	3
PA	NORTHAMPTON	MARTIN MARIETTA	268.7	1.48	0.00	0.00	0.00	0.00	1.48	349	1,927	3
PA	NORTHAMPTON	MERCULES CMT	465.5	2.56	0.00	0.00	0.00	0.00	2.56	605	3,339	5
PA	YORK	MEDUSA CEMENT	87.8	0.00	0.00	0.48	0.00	0.00	0.48	48	0	2
Total - PA			4,681.8	25.01	0.26	0.48	0.00	0.00	25.75	4,009	32,758	54
SC	DORCHESTER	GIANT PORTLAND	753.3	0.00	0.00	4.14	0.00	0.00	4.14	583	1	14
SC	DORCHESTER	GIFFORD-HILL	429.2	2.36	0.00	0.00	0.00	0.00	2.36	558	2,058	5

(continued)

TABLE A.19-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
SC	ORANGEBURG	DUNDEE CEMENT	822.6	4.52	0.00	0.00	0.00	0.00	4.52	1,069	3,944	9
Total - SC			2,005.1	6.89	0.00	4.14	0.00	0.00	11.03	2,210	6,002	28
TN	HAMILTON	GENL PORTLAND	316.5	1.74	0.00	0.00	0.00	0.00	1.74	411	2,432	3
TN	KNOX	IDEAL BASIC IND	318.6	1.75	0.00	0.00	0.00	0.00	1.75	414	2,448	4
TN	MARION	MOORE MCCORMACK	171.8	0.95	0.00	0.00	0.00	0.00	0.95	223	1,320	2
TN	SULLIVAN	MOORE MCCORMACK	215.5	1.19	0.00	0.00	0.00	0.00	1.19	280	1,656	2
Total - TN			1,022.4	5.62	0.00	0.00	0.00	0.00	5.62	1,329	7,856	11
VA	ROANOKE	LONE STAR IND	900.9	4.95	0.00	0.00	0.00	0.00	4.95	1,171	2,695	10
WV	BERKELEY	MARTIN MARIETTA	662.0	3.64	0.00	0.00	0.00	0.00	3.64	861	4,029	7
Total Study Area			30,702.7	159.10	0.26	9.50	0.00	0.00	168.86	38,909	181,479	353

TABLE A.19-3. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR 64 CEMENT PLANTS LOCATED
EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/year			
			1000 Tons	Coal	Oil	Nat. Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	All	329.8	1.81	0.00	0.00	0.00	0.00	1.81	429	1,783	4
AL	MARENGO	All	443.3	2.44	0.00	0.00	0.00	0.00	2.44	576	2,396	5
AL	MOBILE	All	827.4	4.55	0.00	0.00	0.00	0.00	4.55	1,076	4,473	9
AL	ST CLAIR	All	475.2	2.61	0.00	0.00	0.00	0.00	2.61	618	2,569	5
AL	SHELBY	All	384.2	2.11	0.00	0.00	0.00	0.00	2.11	499	2,077	4
Total - AL			2,459.7	13.53	0.00	0.00	0.00	0.00	13.53	3,198	13,297	27
FL	DADE	All	1,808.8	7.22	0.00	2.73	0.00	0.00	9.95	2,061	9,732	24
FL	HERNANDO	All	457.5	2.52	0.00	0.00	0.00	0.00	2.52	595	3,391	5
FL	HILLSBOROUGH	All	805.6	4.43	0.00	0.00	0.00	0.00	4.43	1,047	5,971	9
Total - FL			3,071.9	14.17	0.00	2.73	0.00	0.00	16.90	3,703	19,094	38
GA	FULTON	All	531.6	2.92	0.00	0.00	0.00	0.00	2.92	691	2,964	6
GA	HOUSTON	All	662.7	3.65	0.00	0.00	0.00	0.00	3.65	862	3,695	7
Total - GA			1,194.3	6.57	0.00	0.00	0.00	0.00	6.57	1,553	6,660	13
IL	LA SALLE	All	499.9	2.75	0.00	0.00	0.00	0.00	2.75	650	3,127	5
IL	LEE	All	325.5	1.79	0.00	0.00	0.00	0.00	1.79	423	2,036	4
IL	MASSAC	All	694.3	3.82	0.00	0.00	0.00	0.00	3.82	903	4,343	8
Total - IL			1,519.6	8.36	0.00	0.00	0.00	0.00	8.36	1,976	9,507	17
IN	CASS	All	251.4	1.38	0.00	0.00	0.00	0.00	1.38	327	2,240	3
IN	CLARK	All	539.6	2.97	0.00	0.00	0.00	0.00	2.97	702	4,807	6
IN	FOUNTAIN	All	384.3	2.11	0.00	0.00	0.00	0.00	2.11	500	3,423	4
IN	LAWRENCE	All	388.4	2.14	0.00	0.00	0.00	0.00	2.14	505	3,460	4
Total - IN			1,563.7	8.60	0.00	0.00	0.00	0.00	8.60	2,033	13,929	17
KY	JEFFERSON	All	522.5	2.87	0.00	0.00	0.00	0.00	2.87	679	4,459	6
ME	KNOX	All	380.1	2.09	0.00	0.00	0.00	0.00	2.09	494	2,611	4
MD	CARROLL	All	687.8	3.78	0.00	0.00	0.00	0.00	3.78	894	3,835	8
MD	FREDERICK	All	287.8	1.58	0.00	0.00	0.00	0.00	1.58	374	1,605	3
MD	WASHINGTON	All	331.4	1.82	0.00	0.00	0.00	0.00	1.82	431	1,848	4
Total - MD			1,307.0	7.19	0.00	0.00	0.00	0.00	7.19	1,699	7,288	14
MI	ALPENA	All	1,757.2	9.66	0.00	0.00	0.00	0.00	9.66	2,284	7,767	19
MI	CHARLEVOIX	All	1,033.6	5.68	0.00	0.00	0.00	0.00	5.68	1,344	4,569	11
MI	MONROE	All	687.6	3.78	0.00	0.00	0.00	0.00	3.78	894	3,039	8

(continued)

TABLE A.19-3 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MI	WAYNE	All	534.0	2.94	0.00	0.00	0.00	0.00	2.94	694	2,360	6
Total - MI			4,012.4	22.07	0.00	0.00	0.00	0.00	22.07	5,216	17,735	44
MS	LOWNDES	All	376.8	2.07	0.00	0.00	0.00	0.00	2.07	490	2,101	4
NY	ALBANY	All	1,251.4	6.88	0.00	0.00	0.00	0.00	6.88	1,627	7,829	14
NY	CHAUTAUQUA	All	391.1	0.00	0.00	2.15	0.00	0.00	2.15	267	0	7
NY	BRENEE	All	1,275.0	7.01	0.00	0.00	0.00	0.00	7.01	1,657	7,976	14
Total - NY			2,917.4	13.90	0.00	2.15	0.00	0.00	16.05	3,551	15,805	35
NC	NEW HANDOVER	All	416.9	2.29	0.00	0.00	0.00	0.00	2.29	542	1,361	5
OH	GREENE	All	462.9	2.55	0.00	0.00	0.00	0.00	2.55	602	3,919	5
OH	LAWRENCE	All	170.3	0.94	0.00	0.00	0.00	0.00	0.94	221	1,442	2
OH	LUCAS	All	174.3	0.96	0.00	0.00	0.00	0.00	0.96	227	1,476	2
OH	MUSKINGUM	All	434.2	2.39	0.00	0.00	0.00	0.00	2.39	564	3,676	5
OH	PAULDING	All	307.3	1.69	0.00	0.00	0.00	0.00	1.69	399	2,601	3
OH	STARKE	All	138.9	0.76	0.00	0.00	0.00	0.00	0.76	181	1,176	2
Total - OH			1,688.0	9.28	0.00	0.00	0.00	0.00	9.28	2,194	14,291	19
PA	ALLEGHENY	All	245.3	1.35	0.00	0.00	0.00	0.00	1.35	319	1,760	3
PA	BERKS	All	553.3	3.04	0.00	0.00	0.00	0.00	3.04	719	3,969	6
PA	BUTLER	All	197.6	1.09	0.00	0.00	0.00	0.00	1.09	257	1,417	2
PA	LAWRENCE	All	829.4	4.56	0.00	0.00	0.00	0.00	4.56	1,078	5,950	9
PA	LEHIGH	All	507.4	2.79	0.00	0.00	0.00	0.00	2.79	660	3,640	6
PA	NORTHAMPTON	All	2,261.0	12.18	0.26	0.00	0.00	0.00	12.44	2,928	16,021	27
PA	YORK	All	87.8	0.00	0.00	0.48	0.00	0.00	0.48	48	0	2
Total - PA			4,681.8	25.01	0.26	0.48	0.00	0.00	25.75	6,009	32,758	54
SC	DORCHESTER	All	1,182.5	2.36	0.00	4.14	0.00	0.00	6.50	1,141	2,059	19
SC	ORANGEBURG	All	822.6	4.52	0.00	0.00	0.00	0.00	4.52	1,069	3,944	9
Total - SC			2,005.1	6.89	0.00	4.14	0.00	0.00	11.03	2,210	6,002	28
TN	HAMILTON	All	316.5	1.74	0.00	0.00	0.00	0.00	1.74	411	2,432	3
TN	KNOX	All	318.6	1.75	0.00	0.00	0.00	0.00	1.75	414	2,448	4
TN	MARION	All	171.8	0.95	0.00	0.00	0.00	0.00	0.95	223	1,320	2
TN	SULLIVAN	All	215.5	1.19	0.00	0.00	0.00	0.00	1.19	280	1,656	2
Total - TN			1,022.4	5.62	0.00	0.00	0.00	0.00	5.62	1,329	7,856	11
VA	ROANOKE	All	900.9	4.95	0.00	0.00	0.00	0.00	4.95	1,171	2,695	10

(continued)

TABLE A.19-3 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Eissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
WV	BERKELEY	All	662.0	3.64	0.00	0.00	0.00	0.00	3.64	861	4,029	7
Total Study Area			30,702.7	159.10	0.26	9.50	0.00	0.00	168.86	38,909	181,479	353

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INDUSTRY: GLASS

PLANT/FACILITY: CONTAINER GLASS PLANTS

PLANT POPULATION

In 1980, approximately 109 container glass plants operated in the U.S., 75 of which were located east of the Mississippi River.¹ All of these plants met the energy consumption criteria of 100×10^9 Btu/yr.

Capacity data were not available for the 75 plants analyzed. Hence, production was estimated from shipments data which indicated that total 1980 production for the 75 plants was approximately 10.1×10^6 tons, compared to a national production of 12.9×10^6 tons. The range in plant production was 12,900 to 615,300 tons, and the smallest plant had an estimated direct-fired energy consumption of 100×10^9 Btu.

COMBUSTION PROCESSES

The major direct-fired processes in this industry are melting, forming, and post-forming. The melting furnace is the largest consumer of direct-fired energy. Natural gas is the primary fuel utilized.

PRODUCTION AND FUEL CONSUMPTION

Production

An industry expert estimated 1980 U.S. production at 12.9×10^6 tons.² Total U.S. production was apportioned to each

plant based on its share of the U.S. market.¹ This apportioning method assumes that production can be directly correlated with shipments.

The EIS shipments report provides an estimate of each plant's sales and share of the market along with a listing of plants manufacturing and handling container glass. All plants were cross-referenced with Spinosa et al., 1979² to eliminate those plants that sell but do not manufacture container glass. A new share of the market based on shipments for the 75 plants analyzed was then developed and used in apportioning production.

Energy Consumption - Fuel Type

Industry experts estimate the total 1980 fuel consumption for container glass plants at 127.4×10^{12} Btu.² Direct-fired sources account for 96.4×10^{12} Btu/year or 7.4×10^6 Btu/ton.^{2,4} Total estimated 1980 energy consumption for the 75 plants analyzed was 74.6×10^{12} Btu, with a plant range of 100×10^9 to $4,550 \times 10^9$ Btu.

A breakdown of total plant energy consumption indicates that natural gas accounts for 95 percent of all fuels consumed at container glass plants in 1980.⁵ Natural gas was thus assumed for purposes of estimating emissions to be the only fuel utilized.

EMISSION ESTIMATES

The emission factors for NO_x and HC are taken from EPA's AP-42, and are 6.2 and 0.2 lb/ton respectively.⁶ The SO_x factor of 3.03×10^{-3} lb/ton, is a default value from EPA's

AP-40, that accounts only for fuel combustion only, not for SO_x emissions attributable to other materials.⁷

Plant Emissions

The range in annual emissions (in tons/yr) for the 75 plants analyzed, is shown below:

	Low	High
NO _x	40	1,908
SO _x	0	1
HC	1	62

Tables A.20-1 and A.20-2 summarize production, energy consumption by fuel, and NO_x, SO_x, and HC emissions for the 75 plants analyzed, by plant and county respectively.

TABLE A.20-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 75 CONTAINER GLASS PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other	Total	NO _x	SO _x	HC
AL	MONTGOMERY	BROCKWAY GLASS	192.2	0.00	0.00	1.42	0.00	0.00	1.42	595	0	19
CT	WINDHAM	GLASS CONTAINER	178.0	0.00	0.00	1.32	0.00	0.00	1.32	552	0	18
FL	DUVAL	ANCHOR HOCKING	98.0	0.00	0.00	0.73	0.00	0.00	0.73	304	0	10
FL	HILLSBOROUGH	THATCHER GLASS	92.9	0.00	0.00	0.69	0.00	0.00	0.69	288	0	9
FL	MANATEE	INDUSTRIAL GL	68.4	0.00	0.00	0.51	0.00	0.00	0.51	212	0	7
FL	POLA	OWENS ILLINOIS	64.5	0.00	0.00	0.48	0.00	0.00	0.48	200	0	6
Total - FL			323.8	0.00	0.00	2.40	0.00	0.00	2.40	1,094	0	32
GA	CLAYTON	GLASS CONTAINER	72.2	0.00	0.00	0.53	0.00	0.00	0.53	224	0	7
GA	FULTON	OWENS ILLINOIS	289.0	0.00	0.00	2.14	0.00	0.00	2.14	896	0	29
GA	HOUSTON	MIDLAND GLASS	74.8	0.00	0.00	0.55	0.00	0.00	0.55	232	0	7
Total - GA			436.0	0.00	0.00	3.23	0.00	0.00	3.23	1,352	1	44
IL	COOK	BALL GLASS CONT	113.5	0.00	0.00	0.84	0.00	0.00	0.84	352	0	11
IL	LAKE	ANCHOR HOCKING	81.3	0.00	0.00	0.60	0.00	0.00	0.60	252	0	8
IL	LA SALLE	OWENS ILLINOIS	421.8	0.00	0.00	3.12	0.00	0.00	3.12	1,308	1	42
IL	LA SALLE	THATCHER GLASS	157.4	0.00	0.00	1.16	0.00	0.00	1.16	488	0	16
IL	LOGAN	PIERCE GLASS	63.2	0.00	0.00	0.47	0.00	0.00	0.47	196	0	6
IL	MADISON	OWENS ILLINOIS	615.3	0.00	0.00	4.55	0.00	0.00	4.55	1,908	1	62
IL	MONTGOMERY	HILLSBORO GLASS	41.3	0.00	0.00	0.31	0.00	0.00	0.31	128	0	4
IL	WILL	KERR GLASS MFG	103.2	0.00	0.00	0.76	0.00	0.00	0.76	320	0	10
IL	WILL	NATIONAL BOTTLE	32.2	0.00	0.00	0.24	0.00	0.00	0.24	100	0	3
Total - IL			1,629.3	0.00	0.00	12.06	0.00	0.00	12.06	5,051	2	163
IN	DEARBORN	THATCHER GLASS	104.5	0.00	0.00	0.77	0.00	0.00	0.77	324	0	10
IN	GRANT	FOSTER FORBES	239.9	0.00	0.00	1.78	0.00	0.00	1.78	744	0	24
IN	GRANT	GLASS CONTAINER	67.1	0.00	0.00	0.50	0.00	0.00	0.50	208	0	7
IN	GRANT	OWENS ILLINOIS	205.1	0.00	0.00	1.52	0.00	0.00	1.52	636	0	21
IN	JAY	KERR GLASS	274.8	0.00	0.00	2.03	0.00	0.00	2.03	852	0	27
IN	MADISON	BROCKWAY GLASS	103.2	0.00	0.00	0.76	0.00	0.00	0.76	320	0	10
IN	MARION	GLASS CONTAINER	143.2	0.00	0.00	1.06	0.00	0.00	1.06	444	0	14
IN	RANDOLPH	ANCHOR HOCKING	179.3	0.00	0.00	1.33	0.00	0.00	1.33	556	0	18
IN	VIGO	MIDLAND GLASS	131.6	0.00	0.00	0.97	0.00	0.00	0.97	408	0	13
Total - IN			1,448.7	0.00	0.00	10.72	0.00	0.00	10.72	4,491	2	145
MD	BALTIMORE IN	CARR-LOWREY GL	98.0	0.00	0.00	0.73	0.00	0.00	0.73	304	0	10
MD	BALTIMORE IN	MARYLAND GLASS	110.9	0.00	0.00	0.82	0.00	0.00	0.82	344	0	11
Total - MD			209.0	0.00	0.00	1.55	0.00	0.00	1.55	648	0	21

(continued)

TABLE A.20-1 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MA	WORCESTER	FOSTER FORBES	107.1	0.00	0.00	0.79	0.00	0.00	0.79	332	0	11
MI	EATON	OWENS ILLINOIS	165.1	0.00	0.00	1.22	0.00	0.00	1.22	512	0	17
MS	DE SOTO	CHATTANOOGA GL	37.4	0.00	0.00	0.28	0.00	0.00	0.28	116	0	4
MS	HARRISON	CHATTANOOGA GL	41.3	0.00	0.00	0.31	0.00	0.00	0.31	128	0	4
MS	HINDS	GLASS CONTAINER	58.0	0.00	0.00	0.43	0.00	0.00	0.43	180	0	6
Total - MS			136.7	0.00	0.00	1.01	0.00	0.00	1.01	424	0	14
NJ	BERGEN	BALL GLASS CONT	100.6	0.00	0.00	0.74	0.00	0.00	0.74	312	0	10
NJ	BERGEN	METROFAX CONT	23.2	0.00	0.00	0.17	0.00	0.00	0.17	72	0	2
NJ	CUMBERLAND	KERR GLASS CO	295.4	0.00	0.00	2.19	0.00	0.00	2.19	916	0	30
NJ	CUMBERLAND	LEONE INDUSTR	24.5	0.00	0.00	0.18	0.00	0.00	0.18	76	0	2
NJ	CUMBERLAND	OWENS ILLINOIS	341.9	0.00	0.00	2.53	0.00	0.00	2.53	1,060	1	34
NJ	HUDSON	BALL GLASS CONT	100.6	0.00	0.00	0.74	0.00	0.00	0.74	312	0	10
NJ	HUDSON	MASDEN INDUST	16.8	0.00	0.00	0.12	0.00	0.00	0.12	52	0	2
NJ	HUDSON	OWENS ILLINOIS	205.1	0.00	0.00	1.52	0.00	0.00	1.52	636	0	21
NJ	MIDDLESEX	BALL GLASS CONT	68.4	0.00	0.00	0.51	0.00	0.00	0.51	212	0	7
NJ	MONMOUTH	BROCKWAY GLASS	167.7	0.00	0.00	1.24	0.00	0.00	1.24	520	0	17
NJ	MONMOUTH	MIDLAND GLASS	229.6	0.00	0.00	1.70	0.00	0.00	1.70	712	0	23
NJ	MORRIS	THATCHER GLASS	154.8	0.00	0.00	1.15	0.00	0.00	1.15	480	0	15
NJ	SALEM	ANCHOR HOOKING	130.3	0.00	0.00	0.96	0.00	0.00	0.96	404	0	13
Total - NJ			1,859.9	0.00	0.00	13.76	0.00	0.00	13.76	5,763	3	186
NY	CHEMUNGE	THATCHER GLASS	210.3	0.00	0.00	1.56	0.00	0.00	1.56	652	0	21
NY	MONROE	LEONE INDUSTR	27.1	0.00	0.00	0.20	0.00	0.00	0.20	84	0	3
NY	MONROE	OWENS ILLINOIS	160.0	0.00	0.00	1.18	0.00	0.00	1.18	496	0	16
NY	ROCKLAND	GLENSHAW GLASS	73.5	0.00	0.00	0.54	0.00	0.00	0.54	228	0	7
Total - NY			470.9	0.00	0.00	3.48	0.00	0.00	3.48	1,460	1	47
NC	FORSYTH	OWENS ILLINOIS	86.4	0.00	0.00	0.64	0.00	0.00	0.64	268	0	9
NC	VANCE	LAURENS GLASS	120.0	0.00	0.00	0.89	0.00	0.00	0.89	372	0	12
NC	WILSON	KERR GLASS MFG	34.8	0.00	0.00	0.26	0.00	0.00	0.26	108	0	3
Total - NC			241.2	0.00	0.00	1.79	0.00	0.00	1.79	748	0	24
OH	KNOX	CHATTANOOGA GL	116.1	0.00	0.00	0.86	0.00	0.00	0.86	360	0	12
PA	ALLEGHENY	GLENSHAW GLASS	162.5	0.00	0.00	1.20	0.00	0.00	1.20	504	0	16
PA	ARMSTRONG	GLASS CONTAINER	55.5	0.00	0.00	0.41	0.00	0.00	0.41	172	0	6
PA	CLARION	GLASS CONTAINER	76.1	0.00	0.00	0.56	0.00	0.00	0.56	236	0	8
PA	CLARION	OWENS ILLINOIS	189.6	0.00	0.00	1.40	0.00	0.00	1.40	588	0	19

(continued)

TABLE A.20-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	FAYETTE	ANCHOR HOOKING	185.8	0.00	0.00	1.37	0.00	0.00	1.37	576	0	19
PA	FOREST	GLASS CONTAINER	60.6	0.00	0.00	0.45	0.00	0.00	0.45	188	0	6
PA	JEFFERSON	BROCKWAY GLASS	143.2	0.00	0.00	1.06	0.00	0.00	1.06	444	0	14
PA	MONTGOMERY	DIAMOND GLASS	73.5	0.00	0.00	0.54	0.00	0.00	0.54	228	0	7
PA	VENANGO	FOSTER FORBES	103.2	0.00	0.00	0.76	0.00	0.00	0.76	320	0	10
PA	WASHINGTON	BALL GLASS CONT	59.3	0.00	0.00	0.44	0.00	0.00	0.44	184	0	6
PA	WASHINGTON	BROCKWAY GLASS	38.7	0.00	0.00	0.29	0.00	0.00	0.29	120	0	4
Total - PA			1,148.1	0.00	0.00	8.50	0.00	0.00	8.50	3,559	2	115
SC	LAURENS	LAURENS GLASS	108.4	0.00	0.00	0.80	0.00	0.00	0.80	336	0	11
TN	HAMILTON	CHATTANOOGA GL	189.6	0.00	0.00	1.40	0.00	0.00	1.40	586	0	19
VA	JAMES CITY	OWENS ILLINOIS	56.8	0.00	0.00	0.42	0.00	0.00	0.42	176	0	6
VA	PITTSYLVANIA	BROCKWAY GLASS	12.9	0.00	0.00	0.10	0.00	0.00	0.10	40	0	1
Total - VA			69.7	0.00	0.00	0.52	0.00	0.00	0.52	216	0	7
WV	CABELL	KERR GLASS MFG	67.1	0.00	0.00	0.50	0.00	0.00	0.50	209	0	7
WV	CABELL	OWENS ILLINOIS	379.3	0.00	0.00	2.81	0.00	0.00	2.81	1,176	1	38
WV	MINERAL	CHATTANOOGA GL	67.1	0.00	0.00	0.50	0.00	0.00	0.50	209	0	7
WV	WOOD	NATIONAL BOTTLE	406.3	0.00	0.00	3.01	0.00	0.00	3.01	1,260	1	41
Total - WV			919.8	0.00	0.00	6.81	0.00	0.00	6.81	2,851	1	92
WI	RACINE	FOSTER FORBES	132.9	0.00	0.00	0.98	0.00	0.00	0.98	412	0	13
Total Study Area			10,081.4	0.00	0.00	74.60	0.00	0.00	74.60	31,252	15	1,008

TABLE A.20-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 75 CONTAINER GLASS
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MONTGOMERY	All	192.2	0.00	0.00	1.42	0.00	0.00	1.42	596	0	19
CT	WINDHAM	All	178.0	0.00	0.00	1.32	0.00	0.00	1.32	552	0	18
FL	DUVAL	All	98.0	0.00	0.00	0.73	0.00	0.00	0.73	304	0	10
FL	HILLSBOROUGH	All	92.9	0.00	0.00	0.69	0.00	0.00	0.69	288	0	9
FL	MANATEE	All	60.4	0.00	0.00	0.51	0.00	0.00	0.51	212	0	7
FL	POLK	All	64.5	0.00	0.00	0.48	0.00	0.00	0.48	200	0	6
Total - FL			323.8	0.00	0.00	2.40	0.00	0.00	2.40	1,004	0	32
GA	CLAYTON	All	72.2	0.00	0.00	0.53	0.00	0.00	0.53	224	0	7
GA	FULTON	All	289.0	0.00	0.00	2.14	0.00	0.00	2.14	891	0	29
GA	HOUSTON	All	74.8	0.00	0.00	0.55	0.00	0.00	0.55	232	0	7
Total - GA			436.0	0.00	0.00	3.23	0.00	0.00	3.23	1,352	1	44
IL	COOK	All	113.5	0.00	0.00	0.84	0.00	0.00	0.84	352	0	11
IL	LAKE	All	81.3	0.00	0.00	0.60	0.00	0.00	0.60	252	0	8
IL	LA SALLE	All	579.2	0.00	0.00	4.29	0.00	0.00	4.29	1,796	1	58
IL	LOSA	All	63.2	0.00	0.00	0.47	0.00	0.00	0.47	196	0	6
IL	MADISON	All	615.3	0.00	0.00	4.35	0.00	0.00	4.35	1,908	1	62
IL	MONTGOMERY	All	41.3	0.00	0.00	0.31	0.00	0.00	0.31	128	0	4
IL	WILL	All	135.5	0.00	0.00	1.00	0.00	0.00	1.00	420	0	14
Total - IL			1,629.3	0.00	0.00	12.06	0.00	0.00	12.06	5,051	2	163
IN	DEARBORN	All	104.5	0.00	0.00	0.77	0.00	0.00	0.77	324	0	10
IN	GRANT	All	512.1	0.00	0.00	3.79	0.00	0.00	3.79	1,568	1	51
IN	JAY	All	274.8	0.00	0.00	2.03	0.00	0.00	2.03	852	0	27
IN	MADISON	All	103.2	0.00	0.00	0.76	0.00	0.00	0.76	320	0	10
IN	MARION	All	143.2	0.00	0.00	1.06	0.00	0.00	1.06	444	0	14
IN	RANDOLPH	All	179.5	0.00	0.00	1.33	0.00	0.00	1.33	556	0	18
IN	VIGO	All	131.6	0.00	0.00	0.97	0.00	0.00	0.97	408	0	13
Total - IN			1,448.7	0.00	0.00	10.72	0.00	0.00	10.72	4,491	2	145
MD	BALTIMORE IN	All	209.0	0.00	0.00	1.55	0.00	0.00	1.55	648	0	21
MA	WORCESTER	All	107.1	0.00	0.00	0.79	0.00	0.00	0.79	332	0	11
MI	EATON	All	165.1	0.00	0.00	1.22	0.00	0.00	1.22	512	0	17
MS	DE SOTO	All	37.4	0.00	0.00	0.28	0.00	0.00	0.28	116	0	4
MS	HARRISON	All	41.3	0.00	0.00	0.31	0.00	0.00	0.31	128	0	4

(continued)

TABLE A.20-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MS	HINDS	All	58.0	0.00	0.00	0.43	0.00	0.00	0.43	180	0	6
Total - MS			136.7	0.00	0.00	1.01	0.00	0.00	1.01	424	0	14
NJ	BERGEN	All	123.8	0.00	0.00	0.92	0.00	0.00	0.92	384	0	12
NJ	CUMBERLAND	All	661.8	0.00	0.00	4.90	0.00	0.00	4.90	2,051	1	66
NJ	HUDSON	All	322.5	0.00	0.00	2.39	0.00	0.00	2.39	1,090	0	32
NJ	MIDDLESEX	All	68.4	0.00	0.00	0.51	0.00	0.00	0.51	212	0	7
NJ	MONMOUTH	All	397.3	0.00	0.00	2.94	0.00	0.00	2.94	1,232	1	40
NJ	MORRIS	All	154.8	0.00	0.00	1.15	0.00	0.00	1.15	480	0	15
NJ	SALEM	All	130.3	0.00	0.00	0.96	0.00	0.00	0.96	404	0	13
Total - NJ			1,858.9	0.00	0.00	13.76	0.00	0.00	13.76	5,763	3	186
NY	CHEMUNG	All	210.3	0.00	0.00	1.56	0.00	0.00	1.56	652	0	21
NY	MONROE	All	187.0	0.00	0.00	1.38	0.00	0.00	1.38	580	0	19
NY	ROCKLAND	All	73.5	0.00	0.00	0.54	0.00	0.00	0.54	228	0	7
Total - NY			470.8	0.00	0.00	3.48	0.00	0.00	3.48	1,460	1	47
NC	FORSYTH	All	86.4	0.00	0.00	0.64	0.00	0.00	0.64	268	0	9
NC	VANCE	All	120.0	0.00	0.00	0.89	0.00	0.00	0.89	372	0	12
NC	WILSON	All	34.8	0.00	0.00	0.26	0.00	0.00	0.26	108	0	3
Total - NC			241.2	0.00	0.00	1.79	0.00	0.00	1.79	748	0	24
OH	KNOX	All	116.1	0.00	0.00	0.86	0.00	0.00	0.86	360	0	12
PA	ALLEGHENY	All	162.5	0.00	0.00	1.20	0.00	0.00	1.20	564	0	16
PA	ARMSTRONG	All	55.5	0.00	0.00	0.41	0.00	0.00	0.41	172	0	6
PA	CLARION	All	265.7	0.00	0.00	1.97	0.00	0.00	1.97	824	0	27
PA	FAYETTE	All	185.8	0.00	0.00	1.37	0.00	0.00	1.37	576	0	19
PA	FOREST	All	60.6	0.00	0.00	0.45	0.00	0.00	0.45	188	0	6
PA	JEFFERSON	All	143.2	0.00	0.00	1.06	0.00	0.00	1.06	444	0	14
PA	MONTGOMERY	All	73.5	0.00	0.00	0.54	0.00	0.00	0.54	228	0	7
PA	VENANGO	All	103.2	0.00	0.00	0.76	0.00	0.00	0.76	320	0	10
PA	WASHINGTON	All	98.0	0.00	0.00	0.73	0.00	0.00	0.73	304	0	10
Total - PA			1,148.1	0.00	0.00	8.50	0.00	0.00	8.50	3,559	2	115
SC	LAURENS	All	108.4	0.00	0.00	0.80	0.00	0.00	0.80	336	0	11
TN	HAMILTON	All	189.6	0.00	0.00	1.40	0.00	0.00	1.40	588	0	19
VA	JAMES CITY	All	56.8	0.00	0.00	0.42	0.00	0.00	0.42	176	0	6

(continued)

TABLE A.20-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
VA	PITTSYLVANIA	All	12.9	0.00	0.00	0.10	0.00	0.00	0.10	40	0	1
Total - VA			69.7	0.00	0.00	0.52	0.00	0.00	0.52	216	0	7
WV	CABELL	All	446.3	0.00	0.00	3.30	0.00	0.00	3.30	1,384	1	45
WV	MINERAL	All	67.1	0.00	0.00	0.50	0.00	0.00	0.50	208	0	7
WV	WOOD	All	406.3	0.00	0.00	3.01	0.00	0.00	3.01	1,260	1	41
Total - WV			919.8	0.00	0.00	6.81	0.00	0.00	6.81	2,851	1	92
WI	RACINE	All	132.9	0.00	0.00	0.98	0.00	0.00	0.98	412	0	13
Total Study Area			10,081.4	0.00	0.00	74.60	0.00	0.00	74.60	31,252	15	1,008

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4. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. Prepared for Bureau of Mines, June 1975.
5. U.S. Department of Commerce, Bureau of the Census. 1980 Annual Survey of Manufacturers. Fuels and Electric Energy Consumed. Industry Groups and Industries. M80(AS)-4.1, August 1982.
6. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). AP-42. Research Triangle Park, North Carolina, 1977.
7. U.S. Environmental Protection Agency. Air Pollution Engineering Manual. 2nd edition AP-40, Research Triangle Park, North Carolina. 1973.

INDUSTRY: GLASS

PLANT/FACILITY: FLAT GLASS PLANTS

PLANT POPULATION

In 1980, approximately 28 flat glass plants operated in the U.S., 21 of which were located east of the Mississippi River. Capacity data were not available for the 21 plants analyzed. Hence, production was estimated from shipments data which indicated that total 1980 production for the 21 plants was 2.3×10^6 tons compared to a national production of 2.78×10^6 tons. The range in plant production was 16,700 to 500,100 tons, and the smallest plant had an estimated direct-fired energy consumption of 290×10^9 Btu.

COMBUSTION PROCESSES

In flat glass plants direct-fired energy is consumed during melting, forming, and post-forming. The melting furnace accounts for approximately 90 percent of each plant's total direct-fired energy.¹ Natural gas is the primary fuel utilized.

PRODUCTION AND FUEL CONSUMPTION

Production

An estimated 1980 production for the U.S. was calculated by taking 1976 production data and updating it to 1980. The 1976 estimate of 2.91×10^6 tons was obtained using data from

Reference 2. Flat glass shipments data from 1976 and 1980 were then examined and shown to have declined 4.3 percent between 1976 and 1980.³ It was assumed that production declined in proportion to shipments and the resulting 1980 production was estimated to be 2.78×10^6 tons.

Total U.S. production was apportioned to each plant based on its share of the U.S. market.⁴ In utilizing this apportioning method, it was assumed that production can be directly correlated with shipments. The EIS Shipments report estimates each plant's sales and share of the market along with a complete listing of plants manufacturing or handling flat glass. This report was cross-referenced with Spinosa et al., 1979 to eliminate those plants selling, but not producing, glass.⁵ Only 21 plants were found to produce glass and a new share of the market was calculated for these plants using the EIS data.

Total estimated 1980 production for the 21 plants evaluated was 2.3×10^6 tons, with a plant range of 16,700 to 500,100 tons.

Energy Consumption - Fuel Type

Available estimates indicate that this industry used 21×10^6 Btu/ton of direct-fired energy for all processes.¹ The direct-fired (melting, forming, and post-forming) processing segments of the flat glass industry account for about 82 percent of this total. Therefore, the unit energy consumption for direct-fired processes is estimated to be 17.4×10^6 Btu/ton.¹ Natural gas, accounting for 90 percent of total flat glass

industry fuel use in 1980,⁶ was assumed, for purposes of estimating emissions, to be the only fuel utilized in this industry.

Total estimated 1980 energy consumption for the 21 plants evaluated was 40.4×10^{12} Btu, with a plant range of 0.29×10^{12} to 8.7×10^{12} Btu.

EMISSION ESTIMATES

Emission Factors

The emissions factors for NO_x and HC are taken from EPA's AP-42 and are 8.0 and 0.1 lb/ton respectively.⁷ The SO_x factor of 7.13×10^{-3} is a default value from EPA's AP-40, that accounts only for fuel combustion, not for SO_x emissions attributable to other materials.⁸ The default emission factor was converted from lb/ 10^6 Btu to lb/ton of product using the heating value of natural gas (1,024 Btu/ft³)⁹ and the energy consumption value of 17.4×10^6 Btu/ton of flat glass.

Plant Emissions

The range in annual emissions (in tons/yr) for the 21 plants evaluated, is shown below:

	Low	High
NO_x	67	2,000
SO_x	<1	2
HC	1	25

Tables A.21-1 and A.21-2 summarize production, energy consumption by fuel, and NO_x , SO_x , and HC emissions for the 21 plants analyzed, by plant and county respectively.

TABLE A.21-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 21 FLAT GLASS PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MADISON	PPG INDUSTRIES	52.8	0.00	0.00	0.92	0.00	0.00	0.92	211	0	3
IL	LA SALLE	L-O-F GLASS	243.0	0.00	0.00	4.23	0.00	0.00	4.23	972	1	12
IL	LOGAN	PPG CO	43.4	0.00	0.00	0.75	0.00	0.00	0.75	173	0	2
IL	MACON	PPG CO	43.4	0.00	0.00	0.75	0.00	0.00	0.75	173	0	2
Total - IL			329.7	0.00	0.00	5.74	0.00	0.00	5.74	1,319	1	16
MD	ALLEGANY	PPG INDUSTRIES	33.6	0.00	0.00	0.59	0.00	0.00	0.59	135	0	2
MI	MONROE	GUARDIAN IND	104.8	0.00	0.00	1.82	0.00	0.00	1.82	419	0	5
NC	BURLINGTON	AFG INDUSTRIES	122.6	0.00	0.00	2.13	0.00	0.00	2.13	490	0	6
NC	SAMPSON	L-O-F THERMO	25.0	0.00	0.00	0.44	0.00	0.00	0.44	100	0	1
NC	SCOTLAND	L-O-F CO	107.3	0.00	0.00	1.87	0.00	0.00	1.87	429	0	5
Total - NC			132.3	0.00	0.00	2.30	0.00	0.00	2.30	529	0	7
OH	CRAWFORD	PPG INDUSTRIES	62.5	0.00	0.00	1.09	0.00	0.00	1.09	250	0	3
OH	LUCAS	L-O-F CO	79.5	0.00	0.00	1.38	0.00	0.00	1.38	318	0	4
OH	WOOD	L-O-F CO	357.2	0.00	0.00	6.22	0.00	0.00	6.22	1,429	1	18
Total - OH			499.3	0.00	0.00	8.69	0.00	0.00	8.69	1,997	2	25
PA	ALLEGHENY	PPG INDUSTRIES	81.7	0.00	0.00	1.42	0.00	0.00	1.42	327	0	4
PA	ARMSTRONG	PPG CO	115.4	0.00	0.00	2.01	0.00	0.00	2.01	461	0	6
PA	BLAIR	PPG INDUSTRIES	52.8	0.00	0.00	0.92	0.00	0.00	0.92	211	0	3
PA	CRAWFORD	PPG INDUSTRIES	62.5	0.00	0.00	1.09	0.00	0.00	1.09	250	0	3
PA	CUMBERLAND	PPG CO	99.8	0.00	0.00	1.74	0.00	0.00	1.74	399	0	5
PA	WESTMORELAND	PPG CO	43.1	0.00	0.00	0.75	0.00	0.00	0.75	172	0	2
Total - PA			455.4	0.00	0.00	7.92	0.00	0.00	7.92	1,821	2	23
TN	DAVIDSON	FORD MOTOR CO	500.1	0.00	0.00	8.70	0.00	0.00	8.70	2,000	2	25
TN	SULLIVAN	AFG INDUSTRIES	16.7	0.00	0.00	0.29	0.00	0.00	0.29	67	0	1
Total - TN			516.8	0.00	0.00	8.99	0.00	0.00	8.99	2,067	2	26
WV	HARRISON	FOURCO GLASS CO	72.6	0.00	0.00	1.26	0.00	0.00	1.26	290	0	4
Total Study Area			2,319.9	0.00	0.00	40.37	0.00	0.00	40.37	9,280	8	116

TABLE A.21-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 21 FLAT GLASS PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	MADISON	All	52.8	0.00	0.00	0.92	0.00	0.00	0.92	211	0	3
IL	LA SALLE	All	243.0	0.00	0.00	4.23	0.00	0.00	4.23	972	1	12
IL	LUBAN	All	43.4	0.00	0.00	0.75	0.00	0.00	0.75	173	0	2
IL	MACON	All	43.4	0.00	0.00	0.75	0.00	0.00	0.75	173	0	2
Total - IL			329.7	0.00	0.00	5.74	0.00	0.00	5.74	1,319	1	16
MD	ALLEGANY	All	33.6	0.00	0.00	0.59	0.00	0.00	0.59	135	0	2
MI	MONROE	All	104.8	0.00	0.00	1.82	0.00	0.00	1.82	419	0	5
NJ	BURLINGTON	All	122.6	0.00	0.00	2.13	0.00	0.00	2.13	490	0	6
NC	SAMPSON	All	25.0	0.00	0.00	0.44	0.00	0.00	0.44	100	0	1
NC	SCOTLAND	All	107.3	0.00	0.00	1.87	0.00	0.00	1.87	429	0	5
Total - NC			132.3	0.00	0.00	2.30	0.00	0.00	2.30	529	0	7
OH	CRAWFORD	All	62.5	0.00	0.00	1.09	0.00	0.00	1.09	250	0	3
OH	LUCAS	All	79.5	0.00	0.00	1.38	0.00	0.00	1.38	318	0	4
OH	WOOL	All	357.2	0.00	0.00	6.22	0.00	0.00	6.22	1,429	1	18
Total - OH			499.3	0.00	0.00	8.69	0.00	0.00	8.69	1,997	2	25
PA	ALLEGHENY	All	81.7	0.00	0.00	1.42	0.00	0.00	1.42	327	0	4
PA	ARMSTRONG	All	115.4	0.00	0.00	2.01	0.00	0.00	2.01	461	0	6
PA	BLAIR	All	52.8	0.00	0.00	0.92	0.00	0.00	0.92	211	0	3
PA	CRAWFORD	All	62.5	0.00	0.00	1.09	0.00	0.00	1.09	250	0	3
PA	CUMBERLAND	All	99.8	0.00	0.00	1.74	0.00	0.00	1.74	395	0	5
PA	WESTMORELAND	All	43.1	0.00	0.00	0.75	0.00	0.00	0.75	172	0	2
Total - PA			455.4	0.00	0.00	7.92	0.00	0.00	7.92	1,821	2	23
TN	DAVIDSON	All	500.1	0.00	0.00	8.70	0.00	0.00	8.70	2,000	2	25
TN	SULLIVAN	All	16.7	0.00	0.00	0.29	0.00	0.00	0.29	67	0	1
Total - TN			516.8	0.00	0.00	8.99	0.00	0.00	8.99	2,067	2	26
WV	HARRISON	All	72.6	0.00	0.00	1.26	0.00	0.00	1.26	290	0	4
Total Study Area			2,319.9	0.00	0.00	40.37	0.00	0.00	40.37	9,280	8	116

REFERENCES

1. Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. PB 245759. June 1975.
2. U.S. Environmental Protection Agency. Glass Manufacturing Plants. Draft Environmental Impact Statement. Background Information: Proposed Standards of Performance. EPA-450/3-70-005A. June 1979.
3. U.S. Department of Commerce. 1982 U.S. Industrial Outlook. Bureau of Industrial Economics, Washington, D.C. 1982.
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6. U.S. Department of Commerce. Bureau of the Census. 1980 Annual Survey of Manufacturers - Fuels and Electric Energy Consumed. Industry Groups and Industries M80(AS)-4.1. August, 1982.
7. U.S. Environmental Protection Agency. Compilation of the Air Pollutant Emission Factors. 3rd edition (including Supplements 1 through 13, Final). AP-42. Research Triangle Park, North Carolina, 1977.
8. U.S. Environmental Protection Agency. Air Pollution Engineering Manual, 2nd edition. AP-40. Research Triangle Park, North Carolina, 1973.
9. U.S. Department of Energy. State Energy Data Report. July 1982. DOE/EIA-0214(80). Average Industrial Consumption in U.S. 1980.

INDUSTRY: GLASS

PLANT/FACILITY: PRESSED AND BLOWN GLASS PLANTS

PLANT POPULATION

In 1980, approximately 83 pressed and blown plants operated in the U.S., 74 of which were located east of the Mississippi River. Only 64 of these plants, however, met the energy consumption criteria of 100×10^9 Btu/yr. The other 10 plants were excluded from further consideration.

Capacity data were not available for the 64 plants analyzed. Hence, production was estimated from shipments data which indicated that total 1980 production for the 64 plants was 1.6×10^6 tons compared to a national production of 2.11×10^6 tons. The range in plant production was 3,400 to 138,000 tons, and the smallest plant had an estimated direct-fired energy consumption of 110×10^9 Btu.

COMBUSTION PROCESSES

Direct-fired energy in this industry is consumed during melting, forming, and post-forming. The melting furnace accounts for approximately 60 percent of total direct-fired energy.¹ Natural gas is the primary fuel utilized.

PRODUCTION AND FUEL CONSUMPTION

Production

1980 production for the U.S. was calculated by updating reported 1976 production of 1.95×10^6 tons.² Pressed and blown glass shipments data from 1977 and 1980 were reported to have increased 8.1 percent between 1976 and 1980.³ It was assumed that production increased in proportion to shipments, and the resulting 1980 production estimate was 2.11×10^6 tons.

Total U.S. production was then apportioned to each plant based on its share of the market using the EIS Shipments report.⁴ In utilizing this apportioning method, it was assumed that production can be directly correlated with shipments. The EIS Shipments report provides data on plant sales and share of the market along with a complete listing of facilities manufacturing or selling pressed and blown glass.⁴ This facility listing was cross-referenced with Spinosa et al., 1979⁵ to eliminate those plants selling but not manufacturing pressed and blown glass. The share of the market for each of the 64 plants manufacturing pressed and blown glass was then determined based on EIS data.⁴

Using this approach the total estimated 1980 production for the 64 plants analyzed was calculated to be 1.6×10^6 tons, with a range of plant output from 3,400 to 138,000 tons.

Energy Consumption - Fuel Type

Unit energy consumption for all direct-fired processes is approximately 33.3×10^6 Btu/ton.⁶ Natural gas is the preferred and primary fuel for the melting furnace, accounting for 95

percent of the total fuel consumed in this industry in 1980.⁷

It was thus assumed for purposes of emission estimates that all plants fired natural gas.

Total estimated 1980 energy consumption for the 64 plants analyzed was $52,790 \times 10^9$ Btu, with a plant range of 110×10^9 to $4,600 \times 10^9$ Btu.

EMISSION ESTIMATES

Emission Factors

The emission factors for NO_x and HC are taken from EPA's AP-42 and are 8.5 and 0.3 lb/ton respectively.⁸ The SO_x factor of 1.37×10^{-2} lb/ton, is a default value from EPA's AP-40 that accounts for only fuel combustion, not for SO_x emissions attributable to other materials.⁹

Plant Emissions

The range in annual emissions (in tons/yr) for the 64 plants analyzed, is shown below:

	Low	High
NO_x	14	586
SO_x	0	1
HC	1	21

Tables A.22-1 and A.22-2 summarize production, energy consumption by fuel, and NO_x , SO_x , and HC emissions for the 64 plants analyzed, by plant and county respectively.

TABLE A.22-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 64 PRESSED AND BLOWN GLASS PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
IL	COOK	OWENS ILLINOIS	24.3	0.00	0.00	0.81	0.00	0.00	0.81	103	0	4
IN	JAY	INDIANA GLASS	28.1	0.00	0.00	0.93	0.00	0.00	0.93	119	0	4
IN	KOSCIUSKO	OWENS ILLINOIS	14.6	0.00	0.00	0.48	0.00	0.00	0.48	62	0	2
IN	WELLS	CORNING GLASS	39.2	0.00	0.00	1.31	0.00	0.00	1.31	167	0	6
Total - IN			81.9	0.00	0.00	2.73	0.00	0.00	2.73	348	1	12
KY	BOYLE	CORNING GLASS	39.2	0.00	0.00	1.31	0.00	0.00	1.31	167	0	6
KY	MERCER	CORNING GLASS	33.5	0.00	0.00	1.12	0.00	0.00	1.12	143	0	5
KY	PULASKI	GENERAL ELEC	8.4	0.00	0.00	0.28	0.00	0.00	0.28	36	0	1
Total - KY			81.2	0.00	0.00	2.71	0.00	0.00	2.71	345	1	12
MS	HINDS	CATAPHOTE DIV	5.5	0.00	0.00	0.18	0.00	0.00	0.18	23	0	1
MS	HINDS	GENERAL ELEC	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
Total - MS			8.9	0.00	0.00	0.30	0.00	0.00	0.30	38	0	1
NJ	CUMBERLAND	OWENS ILLINOIS	96.6	0.00	0.00	3.22	0.00	0.00	3.22	411	1	14
NJ	CUMBERLAND	O-1 SCHOTT PROC	9.1	0.00	0.00	0.30	0.00	0.00	0.30	39	0	1
Total - NJ			105.7	0.00	0.00	3.52	0.00	0.00	3.52	449	1	16
NY	CHEMUNG	CORNING GLASS	3.8	0.00	0.00	0.13	0.00	0.00	0.13	16	0	1
NY	KINGS	SUPER GLASS	9.5	0.00	0.00	0.32	0.00	0.00	0.32	40	0	1
NY	MONROE	BAUSCH & LOMB	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1
NY	ORANGE	GILLINDER BROS	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
NY	ST LAWRENCE	CORNING GLASS	15.6	0.00	0.00	0.52	0.00	0.00	0.52	66	0	2
NY	STEUBEN	CORNING GLASS	105.1	0.00	0.00	3.50	0.00	0.00	3.50	447	1	16
Total - NY			144.3	0.00	0.00	4.81	0.00	0.00	4.81	613	1	22
OH	BELMONT	IMPERIAL GLASS	13.7	0.00	0.00	0.46	0.00	0.00	0.46	58	0	2
OH	BELMONT	RODEFER GLEASON	5.5	0.00	0.00	0.18	0.00	0.00	0.18	23	0	1
OH	CUYAHOGA	GENERAL ELEC	18.1	0.00	0.00	0.60	0.00	0.00	0.60	77	0	3
OH	DARKE	CORNING GLASS	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
OH	FAIRFIELD	ANCHOR HOCKING	138.0	0.00	0.00	4.60	0.00	0.00	4.60	586	1	21
OH	FAIRFIELD	LANCASTER GLASS	31.9	0.00	0.00	1.06	0.00	0.00	1.06	135	0	5
OH	FRANKLIN	OWENS ILLINOIS	34.0	0.00	0.00	1.13	0.00	0.00	1.13	144	0	5
OH	GUERNSEY	CAMBRIDGE GLASS	4.2	0.00	0.00	0.14	0.00	0.00	0.14	18	0	1
OH	HOCKING	GENERAL ELEC	7.8	0.00	0.00	0.26	0.00	0.00	0.26	33	0	1
OH	LUCAS	OWENS ILLINOIS	106.1	0.00	0.00	3.53	0.00	0.00	3.53	451	1	16
OH	MUSKINGUM	BROCKWAY GLASS	58.2	0.00	0.00	1.94	0.00	0.00	1.94	248	0	9
OH	PICKAWAY	RCA CORP	24.9	0.00	0.00	0.83	0.00	0.00	0.83	106	0	4

(continued)

TABLE A.22-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
OH	TRUMBULL	GENERAL ELEC	17.3	0.00	0.00	0.58	0.00	0.00	0.58	74	0	3
Total - OH			506.8	0.00	0.00	16.88	0.00	0.00	16.88	2,154	3	76
PA	ALLEGHENY	GENERAL ELEC	5.3	0.00	0.00	0.18	0.00	0.00	0.18	22	0	1
PA	ALLEGHENY	KOPP GLASS INC	5.7	0.00	0.00	0.19	0.00	0.00	0.19	24	0	1
PA	BEAVER	PHOENIX GLASS	17.3	0.00	0.00	0.58	0.00	0.00	0.58	74	0	3
PA	CENTRE	CORNING GLASS	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
PA	FAYETTE	MOUZE GLASS	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1
PA	FRANKLIN	CORNING GLASS	38.2	0.00	0.00	1.27	0.00	0.00	1.27	162	0	6
PA	LUZERNE	OWENS ILLINOIS	14.1	0.00	0.00	0.47	0.00	0.00	0.47	60	0	2
PA	LUZERNE	SCHOTT OPTICAL	17.3	0.00	0.00	0.58	0.00	0.00	0.58	74	0	3
PA	MCKEAN	HOUSTON ELECTR	8.0	0.00	0.00	0.27	0.00	0.00	0.27	34	0	1
PA	MCKEAN	PITTS CORNING	6.5	0.00	0.00	0.22	0.00	0.00	0.22	28	0	1
PA	MCKEAN	PITTS CORNING	13.5	0.00	0.00	0.45	0.00	0.00	0.45	57	0	2
PA	TIOGA	GTE SYLVANIA	13.5	0.00	0.00	0.45	0.00	0.00	0.45	57	0	2
PA	WASHINGTON	CORNING GLASS	94.5	0.00	0.00	3.15	0.00	0.00	3.15	402	1	14
PA	WESTMORELAND	L E SMITH GLASS	13.1	0.00	0.00	0.44	0.00	0.00	0.44	56	0	2
PA	WESTMORELAND	LENDX CRYSTAL	10.3	0.00	0.00	0.34	0.00	0.00	0.34	44	0	2
PA	WESTMORELAND	WESTMORELAND GL	8.0	0.00	0.00	0.27	0.00	0.00	0.27	34	0	1
Total - PA			319.5	0.00	0.00	10.64	0.00	0.00	10.64	1,358	2	48
RI	PROVIDENCE	CORNING GLASS	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
VA	PITTSYLVANIA	CORNING GLASS	54.9	0.00	0.00	1.83	0.00	0.00	1.83	233	0	8
WV	BROOKE	CRESCENT GLASS	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
WV	CABELL	BLEND GLASS CO	5.3	0.00	0.00	0.18	0.00	0.00	0.18	22	0	1
WV	HARRISON	ANCHOR MOCKING	34.0	0.00	0.00	1.13	0.00	0.00	1.13	144	0	5
WV	HARRISON	HARVEY IND	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
WV	LEWIS	LOUIE GLASS CO	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1
WV	LEWIS	MASON GLASSWARE	6.8	0.00	0.00	0.22	0.00	0.00	0.22	29	0	1
WV	LEWIS	WV GLASS SPEC	15.6	0.00	0.00	0.52	0.00	0.00	0.52	66	0	2
WV	MARSHALL	FOSTORIA GLASS	16.7	0.00	0.00	0.56	0.00	0.00	0.56	71	0	3
WV	MONONGALIA	BEAUMONT CO	5.5	0.00	0.00	0.18	0.00	0.00	0.18	23	0	1
WV	MONONGALIA	DAVIS LYNCH GL	7.4	0.00	0.00	0.25	0.00	0.00	0.25	31	0	1
WV	RITCHIE	MID ATLANTIC GL	4.0	0.00	0.00	0.13	0.00	0.00	0.13	17	0	1
WV	WAYNE	PILGRAM GLASS	3.8	0.00	0.00	0.13	0.00	0.00	0.13	16	0	1
WV	WETZEL	CORNING GLASS	30.6	0.00	0.00	1.02	0.00	0.00	1.02	130	0	5
WV	WETZEL	VIKING GLASS	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1
WV	WOOD	BROCKWAY GLASS	19.2	0.00	0.00	0.64	0.00	0.00	0.64	82	0	3
WV	WOOD	CORNING GLASS	41.4	0.00	0.00	1.38	0.00	0.00	1.38	176	0	6
Total - WV			210.8	0.00	0.00	7.02	0.00	0.00	7.02	896	1	32

(continued)

TABLE A.22-1 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
Total Study Area			1,585.2	0.00	0.00	52.79	0.00	0.00	52.79	6,737	11	238

TABLE A.22-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 64 PRESSED AND BLOWN GLASS
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
IL	COOK	All	24.3	0.00	0.00	0.81	0.00	0.00	0.81	103	0	4
IN	JAY	All	28.1	0.00	0.00	0.93	0.00	0.00	0.93	119	0	4
IN	KOSCIUSKO	All	14.6	0.00	0.00	0.48	0.00	0.00	0.48	62	0	2
IN	WELLS	All	39.2	0.00	0.00	1.31	0.00	0.00	1.31	167	0	6
Total - IN			81.9	0.00	0.00	2.73	0.00	0.00	2.73	348	1	12
KY	BOYLE	All	39.2	0.00	0.00	1.31	0.00	0.00	1.31	167	0	6
KY	MERCER	All	33.5	0.00	0.00	1.12	0.00	0.00	1.12	143	0	5
KY	PULASKI	All	8.4	0.00	0.00	0.28	0.00	0.00	0.28	36	0	1
Total - KY			81.2	0.00	0.00	2.71	0.00	0.00	2.71	345	1	12
MS	HINDS	All	8.9	0.00	0.00	0.30	0.00	0.00	0.30	38	0	1
NJ	CUMBERLAND	All	105.7	0.00	0.00	3.52	0.00	0.00	3.52	449	1	16
NY	CHEMUNG	All	3.8	0.00	0.00	0.13	0.00	0.00	0.13	16	0	1
NY	KINGS	All	9.5	0.00	0.00	0.32	0.00	0.00	0.32	40	0	1
NY	MONROE	All	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1
NY	ORANGE	All	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
NY	ST LAWRENCE	All	15.6	0.00	0.00	0.52	0.00	0.00	0.52	66	0	2
NY	STEUBEN	All	105.1	0.00	0.00	3.50	0.00	0.00	3.50	447	1	16
Total - NY			144.3	0.00	0.00	4.81	0.00	0.00	4.81	613	1	22
OH	BELMONT	All	19.2	0.00	0.00	0.64	0.00	0.00	0.64	82	0	3
OH	CUYAHOGA	All	18.1	0.00	0.00	0.60	0.00	0.00	0.60	77	0	3
OH	DARKE	All	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
OH	FAIRFIELD	All	169.9	0.00	0.00	5.66	0.00	0.00	5.66	722	1	25
OH	FRANKLIN	All	34.0	0.00	0.00	1.13	0.00	0.00	1.13	144	0	5
OH	GUERNSEY	All	4.2	0.00	0.00	0.14	0.00	0.00	0.14	18	0	1
OH	HOCKING	All	7.8	0.00	0.00	0.26	0.00	0.00	0.26	33	0	1
OH	LUCAS	All	106.1	0.00	0.00	3.53	0.00	0.00	3.53	451	1	16
OH	MUSKINGUM	All	58.2	0.00	0.00	1.94	0.00	0.00	1.94	248	0	9
OH	PICKAWAY	All	24.9	0.00	0.00	0.83	0.00	0.00	0.83	106	0	4
OH	TRUMBULL	All	17.3	0.00	0.00	0.58	0.00	0.00	0.58	74	0	3
Total - OH			506.8	0.00	0.00	16.88	0.00	0.00	16.88	2,154	3	76
PA	ALLEGHENY	All	11.0	0.00	0.00	0.37	0.00	0.00	0.37	47	0	2
PA	BEAVER	All	17.3	0.00	0.00	0.58	0.00	0.00	0.58	74	0	3
PA	CENTRE	All	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
PA	FAYETTE	All	7.0	0.00	0.00	0.23	0.00	0.00	0.23	30	0	1

(continued)

TABLE A.22-2 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	FRANKLIN	All	38.2	0.00	0.00	1.27	0.00	0.00	1.27	162	0	6
PA	LUZERNE	All	31.4	0.00	0.00	1.05	0.00	0.00	1.05	134	0	5
PA	MCKEAN	All	28.1	0.00	0.00	0.93	0.00	0.00	0.93	119	0	4
PA	TIOGA	All	13.5	0.00	0.00	0.45	0.00	0.00	0.45	57	0	2
PA	WASHINGTON	All	94.5	0.00	0.00	3.15	0.00	0.00	3.15	402	1	14
PA	WESTMORELAND	All	31.4	0.00	0.00	1.05	0.00	0.00	1.05	134	0	5
Total - PA			319.5	0.00	0.00	10.64	0.00	0.00	10.64	1,358	2	48
RI	PROVIDENCE	All	47.1	0.00	0.00	1.57	0.00	0.00	1.57	200	0	7
VA	PITTSYLVANIA	All	54.9	0.00	0.00	1.83	0.00	0.00	1.83	233	0	8
WV	BROOKE	All	3.4	0.00	0.00	0.11	0.00	0.00	0.11	14	0	1
WV	CABELL	All	5.3	0.00	0.00	0.18	0.00	0.00	0.18	22	0	1
WV	HARRISON	All	37.3	0.00	0.00	1.24	0.00	0.00	1.24	159	0	6
WV	LEWIS	All	29.3	0.00	0.00	0.98	0.00	0.00	0.98	125	0	4
WV	MARSHALL	All	16.7	0.00	0.00	0.56	0.00	0.00	0.56	71	0	3
WV	MOMONGALIA	All	12.9	0.00	0.00	0.43	0.00	0.00	0.43	55	0	2
WV	RITCHIE	All	4.0	0.00	0.00	0.13	0.00	0.00	0.13	17	0	1
WV	WAYNE	All	3.8	0.00	0.00	0.13	0.00	0.00	0.13	16	0	1
WV	METZEL	All	37.6	0.00	0.00	1.25	0.00	0.00	1.25	160	0	6
WV	WOOD	All	60.6	0.00	0.00	2.02	0.00	0.00	2.02	257	0	9
Total - WV			210.8	0.00	0.00	7.02	0.00	0.00	7.02	896	1	32
Total Study Area			1,585.2	0.00	0.00	52.79	0.00	0.00	52.79	6,737	11	238

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2. U.S. Environmental Protection Agency. Glass Manufacturing Plants. Draft Environmental Impact Statement. Background Information: Proposed Standards of Performance. EPA-450/3-79-005A. June 1979.
3. U.S. Department of Commerce. 1982 and 1983. U.S. Industrial Outlook. Bureau of Industrial Economics, Washington, D.C. 1982.
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6. Battelle Columbus Laboratories. Industrial Energy Study of the Glass Industry. Prepared for the Federal Energy Administration, December 1974.
7. U.S. Department of Commerce. Bureau of the Census. 1980 Annual Survey of Manufacturers. Fuels and Electric Energy Consumed. Industry Groups and Industries Pressed and Blown Glass M80(AS)4-1. August 1982.
8. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. 3rd Edition (including Supplements 1 through 13, Final). AP-42. Research Triangle Park, North Carolina, 1977.
9. U.S. Environmental Protection Agency. Air Pollution Engineering Manual. 2nd edition. AP-40. Research Triangle Park, North Carolina, 1973.

INDUSTRY: MINERAL WOOL

PLANT/FACILITY: SLAG WOOL PLANTS

PLANT POPULATION

The term "mineral wool" is used to describe any fibrous glassy substance made from minerals or mineral products. Mineral wool is defined here, for convenience, to include only that made primarily from natural rock or metallurgical slag. Thus, fibrous glass wool, although considered "mineral wool", is addressed separately under the fiberglass wool industry (Appendix A-24).

In 1980, there were approximately 26 mineral wool plants in the U.S., with 16 being located east of the Mississippi.¹ However, only 8 out of the 16 plants met the established energy consumption criteria of 100×10^9 Btu/year. Therefore, the remaining 8 plants were excluded from further consideration. Capacity data were not available for the 8 plants evaluated. Hence, production was estimated from shipments data, which indicated that the total estimated production of the 8 plants in 1980 was 0.66×10^6 tons, compared with a national total of about 0.81×10^6 tons. The range in production was 47,300 to 181,200 tons, and the smallest plant had an estimated 1980 direct-fired energy consumption of 140×10^9 Btu.

COMBUSTION PROCESSES

The only significant direct-fired process in the manufacture of mineral wool is the melting of the natural rock or metallurgical slag in a cupola.¹ The molten minerals are then fiberized on a spinning rotor using a high velocity stream of air or steam to assist in fiber attenuation and collected on a wire mesh conveyor. The cupola furnaces are direct-fired with coke.¹

PRODUCTION AND FUEL CONSUMPTION

Production

Because specific production or capacity data were not available in the literature, production was estimated on the basis of the annual consumption of coke for the entire industry. The annual cupola charge for the industry in 1980 was identified at 1.35×10^6 tons.¹ A 60 percent input volume reduction was specified as output from the furnace to final product.¹ Therefore, total mineral wool production in 1980 for the U.S. was estimated to be 0.81×10^6 tons.

Apportioning the total U.S. production to the plants located east of the Mississippi was accomplished using the EIS report on shipments.² This report provides estimates of each company's shipments in millions of dollars. Total sales of the 16 plants located east of the Mississippi, were approximately 151.3×10^6 dollars.² Assuming that each plant's shipments in dollars is directly equatable with production, each plant's share or percentage of the 151.3 million dollars was calculated and applied to the total U.S. production to estimate plant specific production. Since shipment data were not provided by EIS for three of

the plants, an average plant production of 31,150 tons/year was assumed. This was estimated by dividing the total 1980 production of 0.81×10^6 tons by the 26 total U.S. plants. Before calculating the other 23 plants' production using EIS shipment data, the U.S. production was adjusted downward by the average production of three plants or 93,450 tons/year.

As mentioned previously, the total 1980 production of the 8 plants whose energy consumption was equal to or greater than 100×10^9 Btu was estimated to be 0.66×10^6 tons with a plant range of 47,300 to 181,200 tons.

Energy Consumption - Fuel Type

Energy consumption was estimated by multiplying the 101,400 tons of purchased coke³ used by the industry by an average heating value of 24×10^6 Btu/ton for coke.⁴ In this way, the total energy consumed by this industry in 1980 was estimated to be approximately 2.43×10^{12} Btu. Dividing this estimated energy consumption by the total 1980 U.S. mineral wool production of 0.81×10^6 tons, the energy consumption factor of 3.0×10^6 Btu/ton was obtained.

Total 1980 energy consumption for the 8 plants evaluated is estimated at $1,970 \times 10^9$ Btu with a plant range of 140×10^9 to 540×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Nitrogen oxide and SO_x emissions from cupola furnaces have been identified as 1.6 and 17.43 lb/ton of material charged,

respectively.^{1,5} Utilizing the 60 percent reduction figure, which represents 1 ton of charge per 0.6 ton of product, the emission factors converted to lb/ton of product are 2.67 and 29.1 for NO_x and SO_x, respectively. Hydrocarbon emissions were assumed to be negligible.⁶

Plant Emissions

The range in total annual emissions (in tons/year) for the eight plants is shown below:

	Low	High
NO _x	63	242
SO _x	688	2,636
HC	Negligible	

Tables A.23-1 and A.23-2 summarize the 8 plants' estimated production, energy consumption by fuel, and NO_x, SO_x and HC emissions by plant and county, respectively.

TABLE A.23-1. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x, SO_x, AND HC EMISSIONS FOR 8 SLAG WOOL PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	ROCKWOOL MFG CO	65.2	0.00	0.00	0.00	0.20	0.00	0.20	87	949	0
IN	HUNTINGTON	GUARDIAN IND	50.9	0.00	0.00	0.00	0.15	0.00	0.15	68	741	0
IN	MADISON	ROCKWOOL IND	83.8	0.00	0.00	0.00	0.25	0.00	0.25	112	1,219	0
IN	WABASH	CELOTEX	90.3	0.00	0.00	0.00	0.27	0.00	0.27	121	1,314	0
IN	WABASH	U.S. GYPSUM CO	181.2	0.00	0.00	0.00	0.54	0.00	0.54	242	2,636	0
Total - IN			406.2	0.00	0.00	0.00	1.22	0.00	1.22	542	5,910	0
NJ	SUSSEX	U.S. MINERAL PR	86.7	0.00	0.00	0.00	0.26	0.00	0.26	116	1,261	0
OH	STARK	FORTY EIGHT INS	47.3	0.00	0.00	0.00	0.14	0.00	0.14	63	688	0
PA	LUZERNE	CELOTEX	50.1	0.00	0.00	0.00	0.15	0.00	0.15	67	729	0
Total Study Area			655.5	0.00	0.00	0.00	1.97	0.00	1.97	875	9,538	0

TABLE A.23-2. SUMMARY OF 1981 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 8 SLAG WOOL PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	All	65.2	0.00	0.00	0.00	0.20	0.00	0.20	87	949	0
IN	HUNTINGTON	All	50.9	0.00	0.00	0.00	0.15	0.00	0.15	68	741	0
IN	MADISON	All	83.8	0.00	0.00	0.00	0.25	0.00	0.25	112	1,219	0
IN	WABASH	All	271.5	0.00	0.00	0.00	0.81	0.00	0.81	362	3,950	0
Total - IN			406.2	0.00	0.00	0.00	1.22	0.00	1.22	542	5,910	0
NJ	SUSSEX	All	86.7	0.00	0.00	0.00	0.26	0.00	0.26	116	1,261	0
OH	STARK	All	47.3	0.00	0.00	0.00	0.14	0.00	0.14	63	688	0
PA	LUZERNE	All	50.1	0.00	0.00	0.00	0.15	0.00	0.15	67	729	0
Total Study Area			655.5	0.00	0.00	0.00	1.97	0.00	1.97	875	9,538	0

REFERENCES

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INDUSTRY: FIBERGLASS WOOL

PLANT/FACILITY: FIBERGLASS WOOL PLANTS

PLANT POPULATION

In 1980, there were approximately 27 fiberglass wool plants in the U.S., with 17 being located east of the Mississippi.^{1,2,3} However, 2 of the 17 were excluded from further consideration; one plant utilized an electric furnace and the other was below the established energy consumption criteria of 100×10^9 Btu. Capacity data were not available for the 15 plants evaluated. Hence, production was estimated from shipments data that indicated the total 1980 production of the 15 plants to be 697,800 tons, compared to a national total of about 1.19×10^6 tons. The range in 1980 plant production was 18,200 to 178,400 tons, with the smallest plant having an estimated direct-fired energy consumption of 100×10^9 Btu.

COMBUSTION PROCESSES

The only significant direct-fired process in the manufacture of fiberglass wool is the melting of the glassy raw materials by the use of regenerative or recuperative furnaces.² Presently, there are only 2 operational regenerative furnaces left in the U.S., and these will soon be phased out of production.⁴ Based on these facts, the 15 plants were all assumed to have recuperative type furnaces. Melting temperatures in recuperative furnaces

are in the range of 870° to 1090°C (1600° to 2000°F).⁵ The furnaces are designed to burn either natural gas or fuel oil.⁴

PRODUCTION AND FUEL CONSUMPTION

Production

The total U.S. production of fiberglass wool in 1976 was reported to be 0.986×10^6 tons.² The 1976 production was updated to 1980 using estimated shipments for the mineral wool industry for years 1976 (892×10^6 dollars) and 1980 (1075×10^6 dollars) obtained from the U.S. Department of Commerce's Industrial Outlook publications.^{6,7} Therefore, by multiplying the 1976 production rate by the ratio of 1980 to 1976 shipments, the 1980 U.S. production of fiberglass wool was estimated to be 1.19×10^6 tons.

Apportioning the U.S. production to an industrial plant was accomplished by using the EIS report on shipments.³ Contained in this report are estimates of the shipments in millions of dollars for each plant. Assuming that shipments in dollars for each plant is directly equatable with production, plant-specific production was estimated by multiplying each company's market share of total U.S. shipments of fiberglass wool times the total U.S. production.

Since shipment data were not available in EIS for four of the plants, three located east of the Mississippi, an average production of 44,100 tons/year was assumed. The average production was estimated by dividing the total 1980 U.S. production of 1.19×10^6 tons by the total number of plants (27) located in the

U.S. In estimating the plant production for the other 23 plants, the estimated U.S. production was first adjusted downward by the sum of the average productions assumed for the four plants.

Total 1980 production of the 15 plants above the 100×10^9 Btu/yr cutoff, was estimated to be approximately 697,800 tons, with a plant range of 18,200 to 178,400 tons.

Energy Consumption - Fuel Type

Information obtained from a leading manufacturer of fiberglass furnaces, indicated that an average recuperative furnace consumes approximately 5.5×10^6 Btu/ton.⁴ Although the furnaces are designed to fire either natural gas or fuel oil, U.S. companies are presently burning strictly natural gas in their furnaces.⁴ Therefore, the total 1980 energy consumption for the 15 plants was estimated to be 3.84×10^{12} Btu, with a plant range of 100×10^9 to 980×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Nitrogen oxide emissions from recuperative furnaces have been identified as 5.0 lb/ton of product.²

Industrial combustion source default emission factors from the U.S. EPA's AP-40 publication⁸ were used for SO_x and HC for recuperative furnaces. The SO_x and HC emission factors are: 0.42 and $7.0 \text{ lb}/10^6 \text{ ft}^3$ natural gas, respectively.⁸ The emission factors converted to lb/ton for a recuperative furnace based on its energy consumption of 5.5×10^6 Btu/ton and a

heating value of 1024 Btu/ft³ for natural gas⁹ are: 2.26 x 10⁻³ and 3.76 x 10⁻² for SO_x and HC, respectively.

Plant Emissions

The range in total annual emissions (in tons/year) for the 15 plants is shown below:

	Low	High
NO _x	46	446
SO _x	negligible	
HC	<1	3

Tables A.24-1 and A.24-2 summarize the plants estimated production, energy consumption by fuel, and NO_x, SO_x, and HC emissions by plant and county respectively.

TABLE A.24-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x AND HC EMISSIONS FOR 15 FIBERGLASS WOOL PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SO _x	HC
GA	BARROW	JOHNS-MANVILLE	20.3	0.00	0.00	0.11	0.00	0.00	0.11	51	0	0
GA	CLARKE	CERTAIN-TEED	26.4	0.00	0.00	0.15	0.00	0.00	0.15	66	0	0
GA	FULTON	OWENS-CORNING	31.4	0.00	0.00	0.17	0.00	0.00	0.17	79	0	1
Total - GA			78.1	0.00	0.00	0.43	0.00	0.00	0.43	195	0	1
IL	LAKE	JOHNS-MANVILLE	44.1	0.00	0.00	0.24	0.00	0.00	0.24	110	0	1
IN	SHELBY	KNAUF FIBERGL	47.6	0.00	0.00	0.26	0.00	0.00	0.26	119	0	1
IN	WAYNE	JOHNS-MANVILLE	39.5	0.00	0.00	0.22	0.00	0.00	0.22	99	0	1
Total - IN			87.1	0.00	0.00	0.48	0.00	0.00	0.48	218	0	2
NJ	CAMDEN	CERTAIN-TEED	32.4	0.00	0.00	0.18	0.00	0.00	0.18	81	0	1
NJ	CAMDEN	OWENS-CORNING	84.1	0.00	0.00	0.46	0.00	0.00	0.46	210	0	2
Total - NJ			116.5	0.00	0.00	0.64	0.00	0.00	0.64	291	0	2
NY	ALBANY	OWENS-CORNING	36.5	0.00	0.00	0.20	0.00	0.00	0.20	91	0	1
OH	DEFIANCE	JOHNS-MANVILLE	20.3	0.00	0.00	0.11	0.00	0.00	0.11	51	0	0
OH	DEFIANCE	JOHNS-MANVILLE	18.2	0.00	0.00	0.10	0.00	0.00	0.10	46	0	0
OH	DEFIANCE	JOHNS-MANVILLE	44.1	0.00	0.00	0.24	0.00	0.00	0.24	110	0	1
OH	LICKING	OWENS-CORNING	178.4	0.00	0.00	0.98	0.00	0.00	0.98	446	0	3
Total - OH			261.0	0.00	0.00	1.44	0.00	0.00	1.44	653	0	5
PA	LUZERNE	CERTAIN-TEED	44.1	0.00	0.00	0.24	0.00	0.00	0.24	110	0	1
WV	WOOD	JOHNS-MANVILLE	30.4	0.00	0.00	0.17	0.00	0.00	0.17	76	0	1
Total Study Area			697.8	0.00	0.00	3.84	0.00	0.00	3.84	1,745	1	13

TABLE A.24-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x , SO_x AND HC EMISSIONS BY COUNTY, FOR 15 FIBERGLASS WOOL PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
GA	BARROW	All	20.3	0.00	0.00	0.11	0.00	0.00	0.11	51	0	0
GA	CLARKE	All	26.4	0.00	0.00	0.15	0.00	0.00	0.15	66	0	0
GA	FULTON	All	31.4	0.00	0.00	0.17	0.00	0.00	0.17	79	0	1
Total - GA			78.1	0.00	0.00	0.43	0.00	0.00	0.43	195	0	1
IL	LAKE	All	44.1	0.00	0.00	0.24	0.00	0.00	0.24	110	0	1
IN	SHELBY	All	47.6	0.00	0.00	0.26	0.00	0.00	0.26	119	0	1
IN	WAYNE	All	39.5	0.00	0.00	0.22	0.00	0.00	0.22	99	0	1
Total - IN			87.1	0.00	0.00	0.48	0.00	0.00	0.48	218	0	2
NJ	CAMDEN	All	116.5	0.00	0.00	0.64	0.00	0.00	0.64	291	0	2
NY	ALBANY	All	36.5	0.00	0.00	0.20	0.00	0.00	0.20	91	0	1
OH	DEFIANCE	All	82.6	0.00	0.00	0.45	0.00	0.00	0.45	207	0	2
OH	LICKING	All	178.4	0.00	0.00	0.98	0.00	0.00	0.98	446	0	3
Total - OH			261.0	0.00	0.00	1.44	0.00	0.00	1.44	653	0	5
PA	LUZERNE	All	44.1	0.00	0.00	0.24	0.00	0.00	0.24	110	0	1
WV	WOOD	All	30.4	0.00	0.00	0.17	0.00	0.00	0.17	76	0	1
Total Study Area			697.8	0.00	0.00	3.84	0.00	0.00	3.84	1,745	1	13

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9. State Energy Data Report, U.S. DOE. July 1982. DOE/EIA-0214(80). Average Industrial Consumption in U.S. 1980.

INDUSTRY: IRON AND STEEL

PLANT/FACILITY: INTEGRATED PLANTS

PLANT POPULATION

Forty-one integrated iron and steel plants (out of 46 nationally) are located east of the Mississippi and were included in this analysis. These plants have an average raw steel capacity range of 700 to 28,900 tons per day and a total estimated 1980 production of 99.3×10^6 tons, compared to a national total of 111.8×10^6 tons. The smallest plant analyzed had an estimated 1980 production of 113,000 tons of raw steel and consumed 490×10^9 Btu in direct-fired energy consumption.

A number of the plants in this analysis are composed of several works located in close proximity to one another. These plants are summarized in Table A.25-1, and were considered to be a single facility.

COMBUSTION PROCESSES

Direct-fired fuel is utilized in the following integrated iron and steel processes, (the type of fuel will vary from plant to plant according to the type of fuel available at any given time).

- ° Sinter plants - a combination of natural gas process gas and/or oil is burned to sinter mixtures of lime, ore fines, and coke to produce blast furnace feed.

TABLE A.25-1. INTEGRATED STEEL MILLS IN THE EASTERN UNITED STATES
HAVING SEVERAL WORKS IN CLOSE PROXIMITY

Company	City	County	State
Armco Steel Corporation ^a	Middletown	Butler	OH
Interlake Incorporated ^b	South Chicago and Chicago	Cook	IL
McLouth Steel Corporation ^c	Trenton	Wayne	MI
National Steel Corporation ^d	River Rouge and Ecorse	Wayne	MI
National Steel Corporation ^e	Weirton	Hancock	WV
Republic Steel Corporation ^f	Warren and Niles and Youngstown	Trumbull and Mahoning	OH
Republic Steel Corporation ^g	Canton and Massillon	Stark	OH
United States Steel Corporation ^h	Homestead	Allegheny	PA
United States Steel Corporation ⁱ	Lorain	Lorain and Cuyahoga	OH
United States Steel Corporation ^j	Duquesne	Allegheny	PA
United States Steel Corporation ^k	Braddock	Allegheny	PA
Wheeling-Pittsburgh Steel ^l Corporation	Steubenville	Jefferson	OH

^a Armco Middletown includes the plant at Hamilton.

^b Interlake South Chicago also includes the works at Riverdale Station.

^c McLouth Steel includes the works at Trenton, Detroit, and Gibraltar.

^d National Steel includes the plants at both River Rouge and Ecorse.

^e National Steel includes the facilities at Steubenville.

^f Republic Steel Mahoning Valley District Works include both the Warren Works and the Youngstown Works.

^g Republic Steel Central Alloy District includes both the Canton Works and the Massillon Works.

^h U.S.S. Homestead includes Rankin, Saxonburg, and McKeesport.

ⁱ U.S.S. Lorain - Cuyahoga Works includes the Lorain Works and the Cleveland Works which has two locations within Cleveland.

^j U.S.S. National Duquesne Works also includes the McKeesport Plant.

^k U.S.S. Braddock Works includes the locations of Dravosburg, and Vandergrift.

^l Wheeling-Pittsburgh's Steubenville Plant includes the Coke Plant at Follansbee, West Virginia.

- ° Coke ovens - a combination of coke oven gas, blast furnace gas, and natural gas is burned to provide the heat needed to volatilize coal to produce coke.
- ° Blast furnace stoves - a combination of process gas and natural gas is fired to preheat the combustion air for the blast furnace, for reduction of ore to pig iron.
- ° Basic oxygen furnace - natural gas is burned to preheat ladles and runners (heat for metal refining is provided from exothermic reaction).
- ° Electric furnace - natural gas is burned to preheat ladles and runners (heat for metal refining is from electrical energy).
- ° Open hearth - natural gas, oil, and process fuel are burned to provide the heat required during metal refining.
- ° Soaking pits - natural gas, process gas, and/or oil is burned to heat steel ingots subsequent to rolling.
- ° Continuous casting - natural gas is burned in the tundish to ensure the metal remains molten prior to casting.
- ° Reheating furnace - natural gas, process gas, and/or fuel oil is burned to heat intermediate steel shapes.
- ° Annealing furnace - natural gas, process gas, and/or fuel oil is burned to anneal (soften) steel that has been cold-rolled.

These processes account for at least 90 percent of the total direct-fired energy consumption in integrated iron and steel plants. Vacuum degassers and heat treating furnaces also use direct-fired fuel but in amounts that were estimated to be below the 100×10^9 Btu/yr established for major point sources. Lime plants, another direct-fired combustion process sometimes located in integrated iron and steel plants, were evaluated separately within the lime industry population.

Table A.25-2 characterizes process capacity and types of fuel utilized in major combustion processes found in the 41 integrated iron and steel plants.

PRODUCTION AND FUEL CONSUMPTION

Production

The steps involved in calculating plant production were 1) locating the plants, 2) identification of processes, 3) determination of process capacities, and 4) determination of process capacity factors. Process capacities for individual plants were gathered from a number of sources.¹⁻¹⁴ For the most part, 1980 data were used. To complete the individual facility analyses it was necessary to deal with variations unique to individual facilities. This involved determination of the distribution of production between types of steel furnaces employed, distinguishing between plants using continuous casting and those with reheat furnaces, and identification of those employing fossil fuel-fired annealing furnaces.

Production was estimated for each process by applying a capacity factor to process capacity data. For blast furnaces, open-hearth furnaces, electric furnaces, and basic oxygen furnaces, capacity factors are based on national average U.S. production applied to the process capacity data as shown in Table A.25-3. For all the other direct-fired processes excluding coke ovens (i.e., sinter plant, soaking pits, continuous casting, reheat and annealing furnaces) it was assumed that the capacity factor was

TABLE A.25-2. CHARACTERIZATION OF PROCESS CAPACITY AND TYPES OF FUEL
UTILIZED IN INTEGRATED IRON AND STEEL PLANTS LOCATED
EAST OF THE MISSISSIPPI

Process	No. of plants ^a	Capacity range, 1000 tons/yr	Fuel(s) used
Sinter plant	22	500 - 6,000	Natural gas, process gas, and oil
Coke ovens	27	180 - 4,650	Natural gas, process gas, and oil
Blast furnaces	34	920 - 4,560	Natural gas, process gas, and oil
BOF	31	900 - 5,800	Natural gas
Electric furnaces	20	350 - 1,700	Natural gas
Open hearth	8	1,080 - 3,950	Natural gas, process gas, and oil
Soaking pits	40	70 - 7,550	Natural gas, process gas, and oil
Continuous casting	15	250 - 2,400	Natural gas
Reheating furnace	38	640 - 8,950	Natural gas, process gas, and oil
Annealing furnace	36	180 - 2,530	Natural gas, process gas, and oil

^a Number of plants containing the listed process.

TABLE A.25-3. 1980 PERCENT UTILIZATION OF CAPACITY FOR
STEELMAKING PROCESS IN THE IRON AND STEEL INDUSTRY

	1980 blast furnace	1979-1980 open hearth furnace	1980 electric furnace	1980 BOF	1980 total
U.S. capacities, ^a 10 ⁶ tpy	101.6	21.06	68.04 ^b	82.92	172.02
U.S. production, ^c 10 ⁶ tpy	68.7	13.05	31.16	67.62	111.83
Percent utilization	67.62	61.97	45.79	81.54	65.01

^a The Institute for Iron and Steel Studies. Steel Industry in Brief: Databook, U.S.A. 1979-80. Greenbrook, New Jersey.

^b Obtained by subtracting the open hearth and BOF raw steel capacity from the total raw steel capacity.

^c American Iron and Steel Institute. Annual Statistical Report. 1981. Washington, D.C.

65 percent (this is a weighted average of the steel furnaces shown in Table A.25-3).

Capacity factors for coke ovens were estimated using regionalized production and capacity data as shown in Table A.25-4.

Energy Consumption

Table A.25-5 presents the unit energy consumption factors for each direct-fired process¹⁵⁻¹⁸ using the Inland Steel Plant in East Chicago as an example. As illustrated in this table, the energy consumption factors were multiplied by process production to obtain energy consumption by process. Total estimated 1980 energy consumption for the 41 plants analyzed was 540.93×10^{12} Btu, with a range of 490×10^9 Btu/year at a plant containing only electric furnaces, soaking pits and annealing furnaces, to $42,520 \times 10^9$ Btu/year, at a plant containing all of the major steel processes that utilize direct-fired fuel.

Fuel Types

The mix of fuels used in individual processes at an integrated plant is highly variable, although natural gas is used almost exclusively in the basic oxygen furnace, electric furnace, and continuous caster. An approximate breakdown in fuels for each process is shown in Table A.25-6, and is based on separate national data categorized into 1) blast furnace area, 2) steel-making furnaces, 3) heating furnaces, and 4) other equipment¹⁷ when reported. All annealing furnaces were assumed to fire fossil fuels unless literature sources specifically indicated they were electric. Specific fuel use was available and utilized for selected processes at 25 plants.

TABLE A.25-4. 1980 REGIONALIZED PERCENT UTILIZATION OF COKE OVEN CAPACITY^{1,2}

State ^a	Production 10 ⁶ TPY	Capacity 10 ⁶ TPY	Percent Utilization
Alabama	3.41	4.69	72.71
Illinois	1.16	1.35	85.93
Indiana	8.03	13.74	50.44
Kentucky, Missouri, Tennessee, and Texas	1.53	2.35	65.02
Maryland and New York	4.12	6.05	68.10
Michigan and Wisconsin	3.05	3.89	78.41
Ohio	6.94	12.98	53.46
Pennsylvania	12.22	15.75	77.59
Virginia and West Virginia	3.07	4.37	70.20 ^b

^a Includes only those regions with states in the study area.

^b Capacity data was not available for the two closed plants in these states, so a national average was assumed to estimate capacity.

TABLE A.25-5. SUMMARY OF UNIT ENERGY CONSUMPTION FACTORS AND TOTAL ENERGY CONSUMPTION AT TYPICAL STEEL PLANTS IN THE STUDY AREA

Process	Unit energy consumption ^{a,b,c,d}	Annual capacity	Percent utilization ^e	Annual energy consumption, 10 ³ Btu/yr
Sinter plant	0.29 x 10 ⁶ Btu/ton sinter	1.20 x 10 ⁶ ton sinter/year ^f	0.65	226.2
Coke plant	3.10 x 10 ⁶ Btu/ton coke	4.09 x 10 ⁶ ton coke/year ^g	0.58	7,353.8
Blast Furnace stoves	1.90 x 10 ⁶ Btu/ton pig iron	8.10 x 10 ⁶ Ton pig iron/year ^f	0.67	10,311.3
BOF	0.20 x 10 ⁶ Btu/ton raw steel	6.70 x 10 ⁶ ton raw steel/year ^h	0.82	109.9
Electric furnace	0.10 x 10 ⁶ Btu/ton raw steel	0.50 x 10 ⁶ ton raw steel/year ^f	0.45	22.5
Open hearth	3.30 x 10 ⁶ Btu/ton raw steel	2.40 x 10 ⁶ ton raw steel/year ^f	0.62	4,910.4
Soaking pits	1.40 x 10 ⁶ Btu/ton ingot steel	5.69 x 10 ⁶ ton ingot steel/year ^{f,i}	0.65	5,177.9
Continuous casting-slab	0.10 x 10 ⁶ Btu/ton steel	1.80 x 10 ⁶ ton steel/year ^h	0.65	117.0
Reheat furnace	2.00 x 10 ⁶ Btu/ton steel	8.95 x 10 ⁶ ton steel/year ⁱ	0.65	11,635.0
Annealing furnace	0.90 x 10 ⁶ Btu/ton steel	2.85 x 10 ⁶ ton steel/year ^{h,i,j}	0.65	1,667.2

^a Vaughan, W. J. Residuals Management Model of Iron and Steel Industry: A Linear Programming Approach. Ph.D. Thesis. Georgetown University. 1975.

^b Battelle Columbus Laboratories. Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing. Prepared for the Bureau of Mines, September 1975.

^c American Iron and Steel Institute. 1980 Annual Statistical Report. Washington, D.C., 1981.

^d Koinis, F. J., et al. "Improved Thermal Efficiency in Reheat Furnaces Through Heat Transfer Analysis and Correlation," Iron and Steel Engineer. (59)(2):43-46. February, 1982.

^e Pietrucha, W. E., et al. Steel Industry in Brief: Databook, U.S.A. 1977. Institute for Iron and Steel Studies, Green Brook, New Jersey. 1977.

^f PEDCO Environmental, Inc. Development of Air Pollution Control Cost. Functions for the Integrated Iron and Steel Industry. EPA 68-01-4500, 1979.

^g PEDCO Environmental, Inc. Revised Technical Approach for a Coke Production Cost Model. EPA 68-02-3554, January, 1981.

^h 33 Metal Producing. World Steel Industry Data Handbook. Volume I. The United States. Published by McGraw-Hill Publications Company, New York. 1978.

ⁱ American Iron and Steel Institute. Directory of Iron and Steel Works of the U.S. and Canada. Washington D.C., 1980.

^j Utilized the following estimation methods when capacity data was not directly available:

- 75 percent of the cold reduction capacity, or if cold reduction capacity was not available,
- 52 percent of the primary (hot) rolling capacity x 75 percent.

TABLE A.25-6. ESTIMATED 1980 FUEL DIRECT-FIRED BREAKDOWN
FOR IRON AND STEEL PROCESSES
(percent)

	Oil	Natural gas	Other ^a
Sinter plant	5.4	41.4	53.2
Coke oven	5.4	41.4	53.2
Blast furnace	0	15.2	84.8
BOF	0	100	0
Electric furnace	0	100	0
Open hearth	36.0	37.8	26.2
Soaking pit	5.4	41.4	53.2
Continuous casting	0	100	0
Reheating furnace	5.0	70.5	24.5
Annealing furnace	5.0	70.5	24.5

^a Includes coke oven gas, blast furnace gas, tar, and pitch.

EMISSION ESTIMATES

Emission Factors

After determination of the amount and type of fuel used in each process, for all facilities, emission factors were accumulated from various sources.¹⁹⁻²⁶ These are tabulated in Table A.25-7.

Specific emission factors were not available for NO_x emissions from the basic oxygen process, continuous casting, or annealing furnaces. The NO_x emission factors for these processes were based on equations developed by mills, et al.,²⁵ for oil and gas emissions.

Plant Emissions

The emission ranges for all plants east of the Mississippi are shown below:

	Low	High
SO _x	41	14,279
NO _x	124	12,445
HC	7	1,152

Tables A.25-8 and A.25-9 summarize energy consumption and NO_x, SO_x, and HC emissions by plant and county, respectively for the 41 integrated iron and steel plants evaluated. Raw steel production is obtained by summing production from the basic oxygen furnace, electric furnace and open hearth furnace. The Shenango Steel plant located in Allegheny County, Pennsylvania is a merchant blast furnace plant (sells pig iron to other iron and steel facilities) and therefore does not produce raw steel.

TABLE A.25-7. IRON AND STEEL EMISSION FACTORS

	Uncontrolled		
	SO _x ^a	NO _x ^a	HC
Sintering (windbox), lb/ton sinter	1.8 ^a	1.6 ^b	0.24 ^a
By-product coking, lb/ton coke	6.18 ^{c,d,e,f}	1.89 ^g	0.094 ^{1,m}
Ironmaking (BF), lb/ton pig iron ^h	0.26 ^{j,k}	0.34 ^b	0.121 ^{1,m}
Steelmaking (UHM), lb/ton steel ⁿ (BOF), lb/ton steel ⁿ (EF), lb/ton steel ⁿ	1.4 ^b Neg. Neg.	4.5 ^b o 0.009 ^b	0.042 ^{1,m} 0.001 ^{1,m} Neg.
Continuous casting, lb/ton steel	Neg.	o	Neg.
Soaking pits, lbs/ton steel	0.083(s) ₁ ^{†,m} 0.126	0.8 ^b	0.042 ^{1,m}
Reheating furnaces, lb/ton steel	0.11(s) ₁ ^{†,m} 0.184	1.1 ^b	0.022 ^{1,m}
Annealing, lb/ton steel	0.050(s) ₁ ^{†,m} 0.083	o	0.009 ^{1,m}

^a PEDCo Environmental, Inc. Development of Air Pollution Control Cost Functions for the Integrated Iron and Steel Industry. EPA 68-01-4600. July 1979.

^b Acurex. Emission Characterization of Stationary NO_x Sources. EPA 68-02-2160. Research Triangle Park, NC. 1978.

^c Stack emissions comprise bulk and are based on: (1) sulfur content of coal charged to oven is 0.8 weight %; (2) about 33 weight % of total sulfur in the coal charged to oven is transferred to the coke oven gas; (3) about 40% of coke oven gas is burned during the underfiring operation, and the remainder is used in other parts of the steel operation, where the rest of the sulfur dioxide is discharged - about 6 lb/ton (3 kg/MT) of coal charged; and (4) gas used in underfiring has not been desulfurized. For those plants that desulfurize an emission factor of 1.24 lb/ton is applied.

^d EPA. Compilation of Air Pollutant Emission Factors. 3rd Ed. (including Supplements 1 through 13). AP-42 Research Triangle Park, NC.

^e Andonyev, S. and O. Filysyed. Dust and Fume Generation in the Iron and Steel Industry. Mir Publications, Moscow. 1977.

^f PEDCo Environmental, Inc. Cost Effectiveness Model for Pollution Control at Coking Facilities. EPA 600/2-79-185.

^g EPA Draft EIS Coke Oven Battery Stacks. Washington, D.C. 1980.

^h Blast furnace gas normally consumed for heating value and/or by-products and not exhausted.

ⁱ Blast furnace stoves.

^j Cast house fugitive emissions.

^k EPA. Blast Furnace Cast House Emission Control Technology Assessment. EPA-600/2-77-231. 1977.

^l Used a default weighted average emission factor based on ratio of fuels consumed in each process. Assumed emission rate of natural gas for BFG and COG and assumed emission rate of fuel oil for tar and pitch. The heating value of process fuels has been incorporated into emission factors.

^m U.S. EPA. Air Pollution Engineering Manual. 2nd Edition. Research Triangle Park, North Carolina, 1973.

ⁿ Ladle preheaters.

^o See attached Figure 1.

Neg = Negligible (emission factor results in less than 1 ton of emissions per year).

TABLE A.25-8. SUMMARY OF PRODUCTION, ENERGY CONSUMPTION AND NO_x, SO_x, AND HC EMISSIONS BY PLANT FOR 41 IRON AND STEEL PLANTS EAST OF THE MISSISSIPPI

			Raw Steel Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	ETOWAH	REPUBLIC STEEL	1,230	0.00	0.22	2.86	0.00	2.68	5.77	1,574	1,508	121
AL	JEFFERSON	US STEEL	2,870	0.00	0.49	6.63	0.00	7.47	14.59	4,839	6,988	464
Total - AL			4,100	0.00	0.71	9.49	0.00	10.15	20.35	6,412	8,495	585
IL	COOK	INTERLAKE	902	0.00	0.15	1.94	0.00	2.60	4.69	995	1,910	85
IL	COOK	REPUBLIC STEEL	1,416	0.00	0.34	4.05	0.00	3.59	7.98	2,295	2,171	157
IL	COOK	US STEEL	2,861	0.00	0.36	5.54	0.00	7.46	13.36	3,296	1,775	361
IL	MADISON	NATIONAL STEEL	2,050	0.00	0.19	5.94	0.00	3.76	9.89	2,817	3,282	224
Total - IL			7,229	0.00	1.04	17.48	0.00	17.40	35.92	9,403	9,139	827
IN	LAKE	INLAND STEEL	7,207	0.00	3.76	19.98	0.00	18.78	42.52	12,233	5,451	718
IN	LAKE	JONES&LAUGHLIN	4,177	0.00	6.24	7.26	0.00	8.87	22.37	8,224	5,804	436
IN	LAKE	US STEEL	6,560	0.00	1.35	19.39	0.00	21.52	42.27	12,445	14,279	1,152
IN	PORTER	BETHLEHEM STEEL	3,936	0.00	0.72	9.95	0.00	9.86	20.55	5,749	3,253	476
Total - IN			21,880	0.00	12.08	56.58	0.00	59.05	127.70	38,652	28,788	2,776
KY	BOYD	ARMCO	1,640	0.00	0.29	4.25	0.00	4.38	8.93	2,308	1,182	210
KY	CAMPBELL	NEWPORT STEEL	110	0.00	0.03	0.23	0.00	0.24	0.49	124	41	7
Total - KY			1,753	0.00	0.32	4.48	0.00	4.62	9.41	2,432	1,223	217
MD	BALTIMORE	BETHLEHEM STEEL	5,024	0.00	5.82	13.49	0.00	19.49	38.80	14,653	7,159	862
MI	WAYNE	FORD ROTOP	3,526	0.00	0.60	7.58	0.00	7.73	15.92	3,714	4,658	238
MI	WAYNE	MCCLOUTH STEEL	2,485	0.00	0.19	3.76	0.00	3.17	7.12	1,341	509	104
MI	WAYNE	NATIONAL STEEL	5,085	0.00	0.82	10.14	0.00	10.91	21.88	6,081	3,404	494
Total - MI			11,095	0.00	1.62	21.48	0.00	21.82	44.92	11,135	8,571	836
NY	ERIE	REPUBLIC STEEL	820	0.00	0.09	1.43	0.00	1.92	3.45	616	256	65
NY	ERIE	BETHLEHEM STEEL	4,100	0.00	0.80	10.31	0.00	11.71	22.82	5,891	3,051	479
Total - NY			4,920	0.00	0.89	11.74	0.00	13.63	26.27	6,506	3,307	544
OH	BUTLER	ARMCO	3,126	0.00	1.97	7.96	0.00	7.54	17.48	6,167	2,944	301
OH	CUYAHOGA	JONES&LAUGHLIN	2,955	0.00	0.31	4.88	0.00	4.36	9.55	1,999	729	138
OH	CUYAHOGA	REPUBLIC STEEL	3,766	0.00	1.45	7.84	0.00	6.33	15.62	4,897	4,483	183
OH	JEFFERSON	WHEELING PITT	2,378	0.00	0.67	7.49	0.00	8.66	16.81	4,306	1,975	308
OH	LORAIN	US STEEL	2,460	0.00	0.36	4.70	0.00	5.18	10.23	2,286	3,276	161
OH	RICHLAND	CYCLOPS	158	0.00	0.13	1.65	0.00	1.06	2.84	725	243	28
OH	STAP	REPUBLIC STEEL	693	0.00	0.20	2.37	0.00	1.38	3.95	1,075	603	36
OH	TRUMBELL	REPUBLIC STEEL	1,820	0.00	0.42	5.05	0.00	6.12	11.60	2,815	4,160	223
Total - OH			17,356	0.00	5.50	41.94	0.00	40.62	88.06	24,269	18,412	1,378

(Continued)

TABLE A.25-8 (Continued)

		Raw Steel	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year				
		Prod										
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	ALLEGHENY	JONES & LAUGHLIN	765	0.00	0.53	5.21	0.00	4.59	10.33	2,944	1,474	126
PA	ALLEGHENY	SHEMANGO	0	0.00	0.06	0.64	0.00	1.72	2.41	440	1,130	59
PA	ALLEGHENY	US STEEL BRAD	2,050	0.00	0.24	4.21	0.00	5.17	9.62	1,758	718	174
PA	ALLEGHENY	US STEEL DUG	2,221	0.00	0.23	3.91	0.00	6.12	10.26	1,776	758	210
PA	ALLEGHENY	US STEEL HDML	1,984	0.00	2.79	8.22	0.00	7.62	18.64	9,697	4,938	578
PA	BEAVER	CRUCIBLE STEEL	918	0.00	0.13	1.94	0.00	2.11	4.18	815	319	69
PA	BEAVER	JONES & LAUGHLIN	2,870	0.00	0.53	6.29	0.00	4.37	11.19	3,022	3,860	119
PA	BUCKS	US STEEL	2,555	0.00	3.37	11.55	0.00	9.47	24.39	10,447	4,793	478
PA	BUTLER	ARMCO	392	0.00	0.11	1.31	0.00	0.82	2.25	618	189	22
PA	CAMBERN	BETHLEHEM STEEL	1,210	0.00	1.06	3.94	0.00	4.71	9.72	3,578	1,740	221
PA	DAUPHIN	BETHLEHEM STEEL	311	0.00	0.09	1.28	0.00	0.47	1.85	452	155	11
PA	NEPCEP	SHARON STEEL	1,510	0.00	0.15	2.51	0.00	2.25	4.91	995	374	71
PA	NORTHAMPTON	BETHLEHEM STEEL	3,019	0.00	0.51	5.84	0.00	8.82	15.17	4,578	3,157	468
PA	WESTMORELAND	WHEELING PITT	1,312	0.00	0.13	1.59	0.00	3.04	4.76	1,227	1,854	144
Total - PA			21,115	0.00	9.96	58.45	0.00	61.29	129.69	42,347	25,410	2,750
WV	HAMCOCK	NATIONAL STEEL	4,756	0.00	0.79	9.29	0.00	9.70	19.79	6,178	5,680	524
Total Study Area			99,227	0.00	38.74	244.42	0.00	257.77	540.93	161,987	116,185	11,299

TABLE A.25-9. SUMMARY OF PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR 41 IRON AND STEEL PLANTS EAST OF THE MISSISSIPPI

St	County	Facility	Raw Steel	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			Prod 1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	ETOWAH	All	1,230	0.00	0.22	2.86	0.00	2.68	5.77	1,574	1,508	121
AL	JEFFERSON	All	2,870	0.00	0.49	6.63	0.00	7.47	14.59	4,839	6,988	464
Total - AL			4,100	0.00	0.71	9.49	0.00	10.15	20.35	6,412	8,495	585
IL	COOK	All	5,179	0.00	0.85	11.53	0.00	13.65	26.03	6,587	5,856	603
IL	MADISON	All	2,050	0.00	0.19	5.94	0.00	3.76	9.89	2,817	3,283	224
Total - IL			7,229	0.00	1.04	17.48	0.00	17.40	35.92	9,403	9,139	827
IN	LAKE	All	17,944	0.00	11.35	46.63	0.00	49.17	107.16	32,903	25,534	2,300
IN	PORTER	All	3,936	0.00	0.72	9.95	0.00	9.88	20.55	5,749	3,253	476
Total - IN			21,880	0.00	12.08	56.58	0.00	59.05	127.70	38,652	28,788	2,776
KY	BOYD	All	1,640	0.00	0.29	4.25	0.00	4.38	8.93	2,308	1,182	210
KY	CAMPBELL	All	113	0.00	0.03	0.23	0.00	0.24	0.49	124	41	7
Total - KY			1,753	0.00	0.32	4.48	0.00	4.62	9.41	2,432	1,223	217
MD	BALTIMORE	All	5,024	0.00	5.82	13.49	0.00	19.49	38.80	14,653	7,159	862
MI	WAYNE	All	11,095	0.00	1.62	21.48	0.00	21.82	44.92	11,135	8,571	836
Total - MI			11,095	0.00	1.62	21.48	0.00	21.82	44.92	11,135	8,571	836
NY	ERIE	All	4,920	0.00	0.89	11.74	0.00	13.63	26.27	6,506	3,307	544
Total - NY			4,920	0.00	0.89	11.74	0.00	13.63	26.27	6,506	3,307	544
OH	BUTLER	All	3,126	0.00	1.97	7.96	0.00	7.54	17.48	6,167	2,944	301
OH	CUYAHOGA	All	6,721	0.00	1.76	12.72	0.00	10.68	25.16	6,895	5,212	321
OH	JEFFERSON	All	2,378	0.00	0.67	7.49	0.00	8.66	16.81	4,306	1,975	308
OH	LORAIN	All	2,460	0.00	0.36	4.70	0.00	5.18	10.23	2,286	3,276	161
OH	RICHLAND	All	158	0.00	0.13	1.65	0.00	1.06	2.84	725	243	28
OH	STARV	All	693	0.00	0.20	2.37	0.00	1.38	3.95	1,075	603	36
OH	TRUMBELL	All	1,820	0.00	0.42	5.05	0.00	6.12	11.60	2,815	4,160	223
Total - OH			17,356	0.00	5.50	41.94	0.00	40.62	88.06	24,269	18,412	1,378
PA	ALLEGHENY	All	7,020	0.00	3.86	22.19	0.00	25.22	51.27	16,616	8,969	1,147
PA	BEAVER	All	3,788	0.00	0.67	8.23	0.00	6.48	15.37	3,837	4,179	188
PA	BUCKS	All	2,555	0.00	3.37	11.55	0.00	9.47	24.39	10,447	4,793	478
PA	BUTLER	All	392	0.00	0.11	1.31	0.00	0.82	2.25	618	189	22
PA	CAMBRIA	All	1,210	0.00	1.06	3.94	0.00	4.71	9.72	3,578	1,740	221

(Continued)

TABLE A.25-9 (Continued)

St	County	Facility	Raw Steel Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
PA	DAUPHIN	All	311	0.00	0.09	1.28	0.00	0.47	1.85	452	155	11
PA	MERCER	All	1,510	0.00	0.15	2.51	0.00	2.25	4.91	995	374	71
PA	NORTHAMPTON	All	3,019	0.00	0.51	5.84	0.00	8.82	15.17	4,578	3,157	468
PA	WESTMORELAND	All	1,312	0.00	0.13	1.59	0.00	3.04	4.76	1,227	1,854	144
Total - PA			21,115	0.00	9.96	58.45	0.00	61.29	129.69	42,347	25,410	2,750
WV	HANCOCK	All	4,756	0.00	0.79	9.29	0.00	9.70	19.79	6,178	5,680	524
Total Study Area			99,227	0.00	38.74	244.42	0.00	257.77	540.93	161,987	116,183	11,299

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INDUSTRY: IRON AND STEEL

PLANT/FACILITY: MINI AND MIDI PLANTS

PLANT POPULATION

Mini and midi plants manufacture raw steel. They are differentiated from integrated steel plants by their size and their raw material input. Generally, mini and midi plants are smaller than their integrated counterparts and start with scrap rather than ore. In 1980, approximately 100 mini and midi plants operated in the United States,^{1,2} 73 of which are located east of the Mississippi River. This industry is characterized by numerous small specialty oriented plants. Forty-seven plants did not meet the established energy criteria of 100×10^9 Btu/yr, and only 26 plants were evaluated.

The plants evaluated have an overall raw steel capacity range of 40,000 to 2.1×10^6 tons/yr. The total 1980 production of these 26 plants is estimated to be 5.9×10^6 tons of raw steel, compared to a national raw steel production total of 111.8×10^6 tons. The smallest plant evaluated had an estimated raw steel production of 41,000 tons, and direct-fired energy consumption of 110×10^9 Btu.

COMBUSTION PROCESSES

The direct-fired processes in mini and midi plants include:

1. Electric furnace - natural gas is burned to preheat ladles and runners (heat for metal refining is from electrical energy).

2. Open hearth - natural gas, process fuel, and/or oil is burned to provide the heat required during metal refining.
3. Soaking pits - natural gas, process gas, and/or oil is burned to heat steel ingots subsequent to rolling.
4. Reheating furnace - natural gas, process gas, and/or fuel oil is burned to heat intermediate steel shapes.
5. Annealing furnace - natural gas, process gas, and/or fuel oil is burned to anneal (soften) steel that has been cold rolled.

Most plants in the study area do not have all of these processes. Generally a plant incorporates two or three pieces of direct-fired equipment into its processing configuration.

Many specialty oriented plants process small quantities of metal. Since energy consumption and emissions from these small plants are relatively insignificant, and detailed capacity data for the smallest plants are often not available, a cutoff related to equipment capacity was developed to eliminate those plants that were below the minimum energy consumption criteria of 100×10^9 Btu/yr. Thus, in order to be included in the methodology a plant had to meet one of the following criteria:

- ° An open hearth capacity greater than or equal to 0.05×10^6 tons per year
- ° A repeat furnace capacity greater than or equal to 0.08×10^6 tons per year
- ° An electric furnace production greater than 0.10×10^6 tons/yr at plants reporting only having electric furnaces. This energy consumption cut-off value is approximately 50×10^9 Btu/yr, since electric furnaces have minimal direct-fired energy consumption.

Table A.26-1 summarizes process capacity and types of fuel utilized in major direct-fired process found in the 26 mini and midi plants evaluated.

TABLE A.26-1. CHARACTERIZATION OF PROCESS CAPACITY AND
TYPES OF FUEL UTILIZED IN MINI AND MIDI STEEL PLANTS
LOCATED EAST OF THE MISSISSIPPI

Process	No. of plants ^a	Capacity range, 1,000 tons/yr	Fuel(s) used
Electric furnace	37	40 - 2,100	Natural gas
Open hearth furnace	2	120 - 180	Natural gas and oil
Soaking pits	12	510 - 2,390	Natural gas and oil
Reheating furnace	38	70 - 5,250	Natural gas and oil
Annealing furnace	11	30 - 490	Natural gas and oil

PRODUCTION AND FUEL CONSUMPTION

Production

The methodology developed for the integrated iron and steel industry was applied where possible to mini and midi plants. Capacity data for the direct-fired processes were obtained from published literature^{1,2,3,4} with the exception of annealing furnace capacities, for which data were not available. In this case, an in-house industry expert was consulted who estimated that in general, 75 percent of cold rolled steel is annealed. Thus, when cold rolled steel production was available, it was multiplied by 0.75 to estimate annealing capacity. At plants where cold rolling capacity was not available, hot rolling capacity was used as a substitute. Here, it was assumed that 50 percent of the hot rolled steel was also cold rolled. The resulting cold-rolled capacity was then multiplied by 0.75 to obtain an annealing furnace capacity.

Production was calculated using the same capacity factors applied to the integrated steel industry (see Appendix A-25). Table A.26-2 summarizes these capacity factors.^{1,5} The electric arc and open hearth furnace capacity factors are furnace specific, while the other direct-fired processes are assumed to be operating at the national average total raw steel capacity factor of 65 percent.

TABLE A.26-2. 1980 PERCENT UTILIZATION OF CAPACITY FOR STEELMAKING PROCESS IN THE IRON AND STEEL INDUSTRY

	1979-1980 open hearth furnace	1980 electric furnace	1980 total raw steel
U.S. capacity ^a 10 ⁶ ton/yr	21.06	68.04 ^b	172.02
U.S. production ^c , 10 ⁶ ton/yr	13.05	31.16	111.83
Capacity utilization, percent	61.97	45.79	65.01

^a The Institute for Iron and Steel Studies. Steel Industry in Brief: Databook, U.S.A. 1979-80. Greenbrook, New Jersey.

^b Obtained by subtracting the open hearth and BOF raw steel capacity from the total raw steel capacity

^c American Iron and Steel Institute. Annual Statistical Report. 1981. Washington, D.C.

Total estimated 1980 production for the 26 plants analyzed was estimated to be 5.9×10^6 tons, with a plant range of 18,000 to 945,000 tons/yr.

Energy Consumption

Estimates of direct-fired unit energy consumption were as follows: 5,6,7,8,9

- ° Electric furnace (0.10×10^6 Btu/ton)
- ° Open hearth furnace (3.30×10^6 Btu/ton)
- ° Soaking pit (1.40×10^6 Btu/ton)
- ° Reheat furnace (2.00×10^6 Btu/ton)
- ° Annealing furnace (0.90×10^6 Btu/ton)

Total estimated 1980 energy consumption for the 26 plants evaluated was estimated to be $3,3570 \times 10^9$ Btu, with a plant range of 110×10^9 to $6,920 \times 10^9$ Btu.

Fuel Type

The ratio of fuels used within each plant has been estimated based on national averages.⁷ Unlike the integrated iron and steel industry, mini and midi plants do not produce or consume by-product fuels. The 1980 national fuel breakdown for mini and midi plants are derived from estimates for the entire iron and steel industry and are shown below:⁷

	Electric furnace	Open hearth furnace	Soaking pit	Reheating and annealing furnaces
Fuel Oil	0%	48.80%	11.49%	6.70%
Natural gas	100%	51.20%	88.51%	93.30%

EMISSION ESTIMATES

Emission Factors

Table A.26-3 presents emission factors selected for this industry. In most cases, the emission factors are the same as those used in the integrated iron and steel methodology. It should be noted that weighted average default emission factors are used in some cases to account for fuel combustion. Since these weighted average factors vary according to the ratio of fuels burned in each process, they are slightly different than the integrated iron and steel emission factors (which take into account the combustion of by-product fuels).

Plant Emissions

The range in annual emissions (in tons/yr), for the 26 plants evaluated, is shown below:

	Low	High
NO _x	26	1,881
SO _x	6	331
HC	<1	27

Production, energy consumption by fuel, and NO_x, SO_x, and HC emissions for the 26 plants are summarized by plant and county in tables A.26-4, and A.26-5 respectively.

TABLE A.26-3. MINI AND MIDI PLANT EMISSION FACTORS
(lb/ton)

	Uncontrolled		
	SO _x	NO _x	HC
Steelmaking (OHF), lb/ton steel (EF), lb/ton steel	1.4 ^a neg. ^{b,c}	4.5 ^b 0.009 ^a	0.044 ^{b,c} 0.001 ^{b,c}
Soaking pits, lbs/ton steel	1.77 x 10 ⁻¹ (s) + 0.001 ^{b,c}	0.8 ^a	0.011 ^{b,c}
Reheating furnaces, lb/ton steel	1.47 x 10 ⁻¹ (s) + 0.001 ^{b,c}	1.1 ^a	0.016 ^{b,c}
Annealing, lb/ton steel	0.066(s) ^{b,c}	d	0.007 ^{b,c}

^a Acurex. Emission Characterization of Stationary NO_x Sources. EPA 68-02-2160, Research Triangle Park, NC. 1978.

^b Used a default weighted average emission factor based on ratio of fuels consumed in each process.

^c U.S. EPA. Air Pollution Engineering Manual. 2nd Edition. AP-40, Research Triangle Park, North Carolina, 1973.

^d Derived from emission graphs in Mills et al, 1961.

neg = negligible.

TABLE A.26-4. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 26 MINI AND MIDI IRON AND STEEL PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Raw Steel	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			Prod 1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
CT	FAIRFIELD	CARPENTER TECH	77	0.00	0.06	0.51	0.00	0.00	0.57	153	46	2
CT	NEW HAVEN	YALE STEEL CO	63	0.00	0.01	0.18	0.00	0.00	0.19	30	9	1
Total - CT			140	0.00	0.07	0.68	0.00	0.00	0.75	203	56	3
DE	NEW CASTLE	PHOENIX STEEL	239	0.00	0.16	1.80	0.00	0.00	1.95	497	121	8
FL	DUVAL	FLORIDA STEEL	72	0.00	0.03	0.40	0.00	0.00	0.42	115	30	2
FL	HILLSBOROUGH	FLORIDA STEEL	54	0.00	0.02	0.35	0.00	0.00	0.37	100	26	1
FL	MARTIN	FLORIDA STEEL	54	0.00	0.01	0.20	0.00	0.00	0.21	57	15	1
Total - FL			180	0.00	0.07	0.94	0.00	0.00	1.01	273	70	4
GA	BARTOW	ATLANTIC STEEL	72	0.00	0.01	0.19	0.00	0.00	0.20	54	14	1
GA	FULTON	ATLANTIC STEEL	135	0.00	0.11	1.22	0.00	0.00	1.33	369	121	5
Total - GA			207	0.00	0.13	1.41	0.00	0.00	1.53	422	135	6
IL	COOK	BM STEEL	50	0.00	0.01	0.15	0.00	0.00	0.16	43	8	1
IL	COOK	CALIFORNIA STL	32	0.00	0.01	0.12	0.00	0.00	0.13	36	6	1
IL	COOK	CECO CORP	95	0.00	0.02	0.28	0.00	0.00	0.30	79	14	1
IL	COOK	KEYSTONE STEEL	0	0.00	0.01	0.13	0.00	0.00	0.14	39	7	1
IL	MADISON	LACLEDE STEEL	356	0.00	0.13	1.40	0.00	0.00	1.53	421	96	6
IL	PEORIA	KEYSTONE STEEL	270	0.00	0.07	0.60	0.00	0.00	0.67	186	54	3
IL	WHITESIDE	NORTHWESTERN	945	0.00	0.46	6.46	0.00	0.00	6.92	1,881	331	27
IL	MILL	PENN-DIXIE CORP	0	0.00	0.01	0.19	0.00	0.00	0.21	57	10	1
Total - IL			1,746	0.00	0.73	9.34	0.00	0.00	10.07	2,742	526	39
IN	ALLEN	JOSLYN ST STEEL	27	0.00	0.01	0.16	0.00	0.00	0.17	41	8	1
IN	HOWARD	PENN-DIXIE CORP	270	0.00	0.09	0.86	0.00	0.00	0.94	259	62	4
Total - IN			297	0.00	0.10	1.02	0.00	0.00	1.11	299	70	4
KY	DAVIESS	JESSOP STEEL	95	0.00	0.08	0.73	0.00	0.00	0.81	227	61	3
MD	BALTIMORE	EASTERN ST STL	41	0.00	0.01	0.11	0.00	0.00	0.11	26	6	0
MS	RANKIN	MISSISSIPPI STL	27	0.00	0.02	0.25	0.00	0.00	0.26	72	19	1
NJ	MIDDLESEX	NJ STEEL	113	0.00	0.02	0.29	0.00	0.00	0.31	83	16	1
NJ	MIDDLESEX	RARITAN RIV STL	270	0.00	0.05	0.75	0.00	0.00	0.81	216	41	3
Total - NJ			383	0.00	0.07	1.04	0.00	0.00	1.12	298	56	4
NY	ALBANY	ALTECH SPEC STL	27	0.00	0.02	0.30	0.00	0.00	0.32	81	16	1

(Continued)

TABLE A.26-4 (Continued)

St	County	Facility	Raw Steel	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			Prod 1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NY	CAYUGA	AUBURN STEEL	50	0.00	0.02	0.31	0.00	0.00	0.33	90	17	1
NY	NIAGARA	ROBLIN STEEL	0	0.00	0.01	0.17	0.00	0.00	0.19	45	10	1
Total - NY			77	0.00	0.06	0.78	0.00	0.00	0.83	215	43	3
NC	MECKLENBURG	FLORIDA STEEL	54	0.00	0.02	0.25	0.00	0.00	0.27	72	19	1
OH	STARK	TIMKEN CO	716	0.00	0.14	1.56	0.00	0.00	1.70	432	109	7
OH	TRUMBELL	COPPERWELD STL	356	0.00	0.16	1.62	0.00	0.00	1.77	488	121	7
Total - OH			1,071	0.00	0.30	3.18	0.00	0.00	3.47	921	230	13
PA	ALLEGHENY	ALLEGHENY LUDL	72	0.00	0.23	2.21	0.00	0.00	2.44	631	177	9
PA	ALLEGHENY	CYCLOPS CORP	77	0.00	0.01	0.16	0.00	0.00	0.17	41	9	1
PA	ALLEGHENY	NESTA MACHINE	152	0.00	0.18	0.19	0.00	0.00	0.37	251	78	2
PA	BEAVER	BABCOCK&WILCOX	198	0.00	0.19	1.74	0.00	0.00	1.93	515	151	7
PA	BERKS	CARPENTER TECH	27	0.00	0.01	0.16	0.00	0.00	0.17	41	9	1
PA	CHESTER	PHOENIX STEEL	74	0.00	0.12	0.13	0.00	0.00	0.25	167	52	2
PA	CHESTER	LUKENS STEEL	198	0.00	0.32	2.90	0.00	0.00	3.22	905	248	12
PA	MIFFLIN	STANDARD STEEL	162	0.00	0.01	0.19	0.00	0.00	0.20	51	9	1
PA	NORTHUMBERLA	CECO CORP	50	0.00	0.01	0.16	0.00	0.00	0.17	47	9	1
PA	WASHINGTON	JESSOP STEEL	18	0.00	0.01	0.20	0.00	0.00	0.21	55	11	1
Total - PA			1,028	0.00	1.10	8.04	0.00	0.00	9.14	2,704	753	37
SC	GEORGETOWN	KORF INDUSTRIES	176	0.00	0.06	0.87	0.00	0.00	0.93	251	65	4
WV	WAYNE	CONNORS STEEL	135	0.00	0.01	0.20	0.00	0.00	0.21	54	10	1
Total Study Area			5,892	0.00	2.97	30.61	0.00	0.00	33.57	9,276	2,239	131

TABLE A.26-5. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY FOR 26 MINI AND MIDI IRON AND STEEL^x PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Raw Steel	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			Prod 1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
CT	FAIRFIELD	All	77	0.00	0.06	0.51	0.00	0.00	0.57	153	46	2
CT	NEW HAVEN	All	63	0.00	0.01	0.18	0.00	0.00	0.19	50	9	1
Total - CT			140	0.00	0.07	0.68	0.00	0.00	0.75	203	56	3
DE	NEW CASTLE	All	239	0.00	0.16	1.80	0.00	0.00	1.95	497	121	8
FL	DUVAL	All	72	0.00	0.03	0.40	0.00	0.00	0.42	115	30	2
FL	HILLSBOROUGH	All	54	0.00	0.02	0.35	0.00	0.00	0.37	100	26	1
FL	MARTIN	All	54	0.00	0.01	0.20	0.00	0.00	0.21	57	15	1
Total - FL			180	0.00	0.07	0.94	0.00	0.00	1.01	273	70	4
GA	BARTOW	All	72	0.00	0.01	0.19	0.00	0.00	0.20	54	14	1
GA	FULTON	All	135	0.00	0.11	1.22	0.00	0.00	1.33	369	121	5
Total - GA			207	0.00	0.13	1.41	0.00	0.00	1.53	422	135	6
IL	COOK	All	176	0.00	0.05	0.68	0.00	0.00	0.73	197	35	3
IL	MADISON	All	356	0.00	0.13	1.40	0.00	0.00	1.53	421	96	6
IL	PEORIA	All	270	0.00	0.07	0.60	0.00	0.00	0.67	186	54	3
IL	WHITESIDE	All	945	0.00	0.46	6.46	0.00	0.00	6.92	1,881	331	27
IL	MILL	All	0	0.00	0.01	0.19	0.00	0.00	0.21	57	10	1
Total - IL			1,746	0.00	0.73	9.34	0.00	0.00	10.07	2,742	526	39
IN	ALLEN	All	27	0.00	0.01	0.16	0.00	0.00	0.17	41	8	1
IN	HOWARD	All	270	0.00	0.09	0.86	0.00	0.00	0.94	259	62	4
Total - IN			297	0.00	0.10	1.02	0.00	0.00	1.11	299	70	4
KY	DAVIESS	All	95	0.00	0.08	0.73	0.00	0.00	0.81	227	61	3
MD	BALTIMORE	All	41	0.00	0.01	0.11	0.00	0.00	0.11	26	6	0
MS	RANKIN	All	27	0.00	0.02	0.25	0.00	0.00	0.26	72	19	1
NJ	MIDDLESEX	All	383	0.00	0.07	1.04	0.00	0.00	1.12	298	56	4
Total - NJ			383	0.00	0.07	1.04	0.00	0.00	1.12	298	56	4
NY	ALBANY	All	27	0.00	0.02	0.30	0.00	0.00	0.32	81	16	1
NY	CAYUGA	All	50	0.00	0.02	0.31	0.00	0.00	0.33	90	17	1
NY	NIAGARA	All	0	0.00	0.01	0.17	0.00	0.00	0.19	45	10	1
Total - NY			77	0.00	0.06	0.78	0.00	0.00	0.83	215	43	3

(continued)

TABLE A.26-5 (Continued)

St	County	Facility	Raw Steel	Fuel Consumption, Trillion Btu/year					Emissions, Tons/Year			
			Prod 1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	MECKLENBURG	All	54	0.00	0.02	0.25	0.00	0.00	0.27	72	19	1
OH	STARK	All	716	0.00	0.14	1.56	0.00	0.00	1.70	432	109	7
OH	TRUMBELL	All	356	0.00	0.16	1.62	0.00	0.00	1.77	488	121	7
Total - OH			1,071	0.00	0.30	3.18	0.00	0.00	3.47	921	230	13
PA	ALLEGHENY	All	301	0.00	0.42	2.57	0.00	0.00	2.99	924	264	13
PA	BEAVER	All	198	0.00	0.19	1.74	0.00	0.00	1.93	515	151	7
PA	BERKS	All	27	0.00	0.01	0.16	0.00	0.00	0.17	41	9	1
PA	CHESTER	All	272	0.00	0.44	3.03	0.00	0.00	3.47	1,072	300	14
PA	MIFFLIN	All	162	0.00	0.01	0.19	0.00	0.00	0.20	51	9	1
PA	NORTHUMBERLA	All	50	0.00	0.01	0.16	0.00	0.00	0.17	47	9	1
PA	WASHINGTON	All	18	0.00	0.01	0.20	0.00	0.00	0.21	55	11	1
Total - PA			1,028	0.00	1.10	8.04	0.00	0.00	9.14	2,704	753	37
SC	GEORGETOWN	All	176	0.00	0.06	0.87	0.00	0.00	0.93	251	65	4
WV	WAYNE	All	135	0.00	0.01	0.20	0.00	0.00	0.21	54	10	1
Total Study Area			5,892	0.00	2.97	30.61	0.00	0.00	33.57	9,276	2,239	131

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INDUSTRY: IRON AND STEEL

FACILITY: COKE PLANTS

PLANT POPULATION

In 1980, the coke industry operated 60 plants, 17 classified as merchant, and 43 as furnace. Merchant plants are associated with chemical companies, gas utilities, or produce coke and coal chemicals sold in the open market. Furnace plants, often referred to as captive plants are owned by iron and steel companies. These companies produce blast furnace coke for their own use. Furnace plants that were located on the same site as an integrated iron and steel plant, were included in the integrated iron and steel methodology (see Appendix A-26). All other furnace plants (i.e., those not directly associated with an integrated iron and steel plant) were included in this methodology.

Of the 60 coke plants operating in 1980, 50 are located east of the Mississippi River. However, only 23 plants (15 merchant, and 8 furnace not on site at an integrated iron and steel plant), were evaluated.

The estimated daily 1980 capacities of the 23 plants evaluated ranged from 250 to 18,160 tons. Total 1980 production from these plants was estimated to be 12.2 million tons of coke, as compared to a national coke production of 46.1 million tons.² The smallest plant analyzed had an estimated 1980 production of

65,400 tons of coke and direct-fired energy consumption of 200×10^9 Btu.

Combustion Processes

Underfiring of the coke oven is the only significant direct fired process at coke plants. Coke oven gas is the primary fuel. It should be noted that although some of the coke plants evaluated also produce benzene, toluene, xylenes (BTX), and other by-product chemicals, this results in no additional direct-fired energy consumption.¹

PRODUCTION AND FUEL CONSUMPTION

Production

Plant capacities were obtained through published sources.¹ A regionalized percent utilization of capacity was used to estimate production,^{1,2} as presented in Table A.27-1. Total estimated production for the 23 plants was 12.2 million tons with a plant range of 65,400 to 5.1 million tons.

Energy Consumption - Fuel Type

Coke plants generally consume 3.10×10^6 Btu/ton of direct-fired energy (assuming a 0.7 ton coal/ton coke conversion factor).^{1,3} Since coal is consumed as a feedstock, it was not included in the energy consumption estimates. For the 23 plants evaluated, total estimated 1980 coke plant energy consumption totaled $37,870 \times 10^9$ Btu, with a plant range of 200 to $15,950 \times 10^9$ Btu. Coke oven gas is the primary fuel.

TABLE A.27-1. 1980 REGIONALIZED PERCENT UTILIZATION
OF COKE OVEN CAPACITY^{1,2}

State ^a	Production 10 ⁶ TPY	Capacity 10 ⁶ TPY	Percent utilization
Alabama	3.41	4.69	72.71
California, Colorado, and Utah	2.60	3.96	65.65
Illinois	1.16	1.35	85.93
Indiana	8.03	13.74	58.44
Kentucky, Missouri, Tennessee, and Texas	1.53	2.35	65.02
Maryland and New York	4.12	6.05	68.10
Michigan and Wisconsin	3.05	3.89	78.41
Ohio	6.94	12.98	53.46
Pennsylvania	12.22	15.75	77.59
Virginia and West Virginia	3.07	4.37 ^b	70.20 ^b

^a Includes only those regions with states in the study area.

^b Capacity data was not available for the two closed plants in these states, so a national average was assumed to estimate capacity.

EMISSION ESTIMATES

Emission Factors

Emissions have been calculated using the following emission factors: 4,5,6,7

- ° SO_x : 6.18 lb/ton coke (assumes 0.6 percent sulfur)
- ° NO_x : 1.89 lb/ton coke
- ° HC: 0.094 lb/ton coke

For plants desulfurizing their coke oven gas, an alternative SO_x emission factor of 1.24 lb/ton coke is used.

Plant Emissions

The range in total annual emissions (in tons/year) for the 23 plants analyzed, is shown below:

	Low	High
NO_x	62	4,862
SO_x	202	15,898
HC	3	242

Production, energy consumption by fuel, and NO_x , SO_x and HC emissions are summarized by plant and county in Tables A.27-2 and A.27-3, respectively.

TABLE A.27-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x,
AND HC EMISSIONS FOR 23 COKE PLANTS LOCATED EAST
OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	ALABAMA BYPROD	530.7	0.00	0.00	0.00	0.00	1.65	1.65	502	1,640	25
AL	JEFFERSON	KOPPERS CO	450.7	0.00	0.00	0.00	0.00	1.40	1.40	426	1,393	21
AL	JEFFERSON	REPUBLIC STEEL	254.4	0.00	0.00	0.00	0.00	0.79	0.79	240	786	12
AL	JEFFERSON	JIM WALTERS RES	399.9	0.00	0.00	0.00	0.00	1.24	1.24	378	1,236	19
AL	TUSCALOOSA	EMPIRE COKE CO	65.4	0.00	0.00	0.00	0.00	0.20	0.20	62	202	3
Total - AL			1,701.2	0.00	0.00	0.00	0.00	5.27	5.27	1,608	5,257	80
IN	MARION	CITIZENS GAS	309.5	0.00	0.00	0.00	0.00	0.96	0.96	292	956	15
IN	VIGO	INDIANA GAS	87.6	0.00	0.00	0.00	0.00	0.27	0.27	83	271	4
IN	WAYNE	DETROIT COKE	397.1	0.00	0.00	0.00	0.00	1.23	1.23	375	1,227	19
Total - IN			794.2	0.00	0.00	0.00	0.00	2.46	2.46	751	2,454	37
KY	BOYD	ALLIED CHEMICAL	689.0	0.00	0.00	0.00	0.00	2.14	2.14	651	2,129	32
NY	ERIE	DONNER-HANNA	633.3	0.00	0.00	0.00	0.00	1.96	1.96	598	399	30
NY	ERIE	TONAWANDA COKE	224.7	0.00	0.00	0.00	0.00	0.70	0.70	212	694	11
Total - NY			858.1	0.00	0.00	0.00	0.00	2.66	2.66	811	1,093	40
OH	LAKE	ERIE COKE&CHEM	85.6	0.00	0.00	0.00	0.00	0.27	0.27	81	265	4
OH	LAWRENCE	MCLOUTH STEEL	508.3	0.00	0.00	0.00	0.00	1.58	1.58	480	1,570	24
OH	LUCAS	KOPPERS CO	91.0	0.00	0.00	0.00	0.00	0.28	0.28	86	281	4
OH	MAHONING	JONES&LAUGHLIN	642.0	0.00	0.00	0.00	0.00	1.99	1.99	607	1,984	30
OH	SCIOTO	NEW BOSTON COKE	235.4	0.00	0.00	0.00	0.00	0.73	0.73	222	727	11
Total - OH			1,562.2	0.00	0.00	0.00	0.00	4.84	4.84	1,476	4,827	73
PA	ALLEGHENY	SHENANGO INC	434.6	0.00	0.00	0.00	0.00	1.35	1.35	411	274	20
PA	ALLEGHENY	US STEEL CORP	5,144.9	0.00	0.00	0.00	0.00	15.95	15.95	4,862	15,898	242
PA	ERIE	KOPPERS CO	178.5	0.00	0.00	0.00	0.00	0.55	0.55	169	532	8
PA	MONTGOMERY	ALABAMA BYPROD	341.4	0.00	0.00	0.00	0.00	1.06	1.06	323	215	16
PA	PHILADELPHIA	EASTERN GAS	248.3	0.00	0.00	0.00	0.00	0.77	0.77	235	767	12
Total - PA			6,347.7	0.00	0.00	0.00	0.00	19.68	19.68	5,999	17,705	298
TN	HAMILTON	CHATT COKE&CHEM	91.0	0.00	0.00	0.00	0.00	0.28	0.28	86	281	4
WI	MILWAUKEE	PICKANDS MATHER	172.5	0.00	0.00	0.00	0.00	0.53	0.53	163	533	8
Total Study Area			12,215.8	0.00	0.00	0.00	0.00	37.87	37.87	11,544	34,280	574

TABLE A.27-3. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x,
AND HC EMISSIONS BY COUNTY, FOR 23 COKE PLANTS LOCATED EAST
OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	JEFFERSON	All	1,635.7	0.00	0.00	0.00	0.00	5.07	5.07	1,546	5,054	77
AL	TUSCALOOSA	All	65.4	0.00	0.00	0.00	0.00	0.20	0.20	62	202	3
Total - AL			1,701.2	0.00	0.00	0.00	0.00	5.27	5.27	1,608	5,257	80
IN	MARION	All	309.5	0.00	0.00	0.00	0.00	0.96	0.96	292	956	15
IN	VIGO	All	87.6	0.00	0.00	0.00	0.00	0.27	0.27	83	271	4
IN	WAYNE	All	397.1	0.00	0.00	0.00	0.00	1.23	1.23	375	1,227	19
Total - IN			794.2	0.00	0.00	0.00	0.00	2.46	2.46	751	2,454	37
KY	BOYD	All	689.0	0.00	0.00	0.00	0.00	2.14	2.14	651	2,129	32
NY	ERIE	All	858.1	0.00	0.00	0.00	0.00	2.66	2.66	811	1,093	40
OH	LAKE	All	85.6	0.00	0.00	0.00	0.00	0.27	0.27	81	265	4
OH	LAWRENCE	All	508.3	0.00	0.00	0.00	0.00	1.58	1.58	480	1,570	24
OH	LUCAS	All	91.0	0.00	0.00	0.00	0.00	0.28	0.28	86	281	4
OH	MAHONING	All	642.0	0.00	0.00	0.00	0.00	1.99	1.99	607	1,984	30
OH	SCIOTO	All	235.4	0.00	0.00	0.00	0.00	0.73	0.73	222	727	11
Total - OH			1,562.2	0.00	0.00	0.00	0.00	4.84	4.84	1,476	4,827	73
PA	ALLEGHENY	All	5,579.4	0.00	0.00	0.00	0.00	17.30	17.30	5,273	16,171	262
PA	ERIE	All	178.5	0.00	0.00	0.00	0.00	0.55	0.55	169	552	8
PA	MONTGOMERY	All	341.4	0.00	0.00	0.00	0.00	1.06	1.06	323	215	16
PA	PHILADELPHIA	All	248.3	0.00	0.00	0.00	0.00	0.77	0.77	235	767	12
Total - PA			6,347.7	0.00	0.00	0.00	0.00	19.68	19.68	5,999	17,705	298
TN	HAMILTON	All	91.0	0.00	0.00	0.00	0.00	0.28	0.28	86	281	4
WI	MILWAUKEE	All	172.5	0.00	0.00	0.00	0.00	0.53	0.53	163	533	8
Total Study Area			12,215.8	0.00	0.00	0.00	0.00	37.87	37.87	11,544	34,280	574

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INDUSTRY: IRON AND STEEL

PLANT/FACILITY: IRON FOUNDRIES

PLANT POPULATION

Approximately 1,396 domestic iron foundries operated in 1980.¹ Total shipments of iron castings in 1980 were 12.2 million tons.¹ Forty-four percent of all iron foundries were small facilities having fewer than 50 employees. Since these small foundries generally consume less than 100×10^9 Btu/year, they were eliminated from further investigations.

When considering those foundries with 50 or more employees for 1980, only 99 out of 263 eastern foundries consumed more than 100×10^9 Btu. These 99 medium to large foundries ranged in capacity between 11.5 and 260.0 tons/hour and had total estimated 1980 production of 10.6×10^6 tons as compared with national shipments of 12.2×10^6 tons/yr. The smallest foundry investigated had an estimated 1980 production of 30,000 tons and consumed 100×10^9 Btu of direct-fired energy.

COMBUSTION PROCESSES

The cupola is the principal direct-fired melting furnace found in this industry. It accounts for approximately 70 percent of all foundry iron produced.¹ The remaining 30 percent of production is melted in electric arc, electric induction and

reverberatory furnaces. Although direct fired, the reverberatory furnaces are generally small (capacities less than 2 tons/hr) and have energy consumption of less than 100×10^9 Btu/year. In cupolas, heat from the combustion of coke is used to melt the iron.

PRODUCTION AND ENERGY CONSUMPTION

Production

The steps involved in estimating production were as follows:

- 1) Plant location was determined by obtaining a listing for those plants with 50 or more employees through Penton.²

- 2) This plant listing was cross referenced with Davis et al. which provided 1974 plant capacity data.³ It was assumed that capacity for plants existing in 1980, remained constant between 1974 and 1980. Some foundries ceased operation in this time frame while others opened. Corrections to the list were made from the Penton data. Capacity estimates for new facilities were made based on an average cupola capacity of 11.5 tons/hour and the number of cupolas at each facility, as described by Penton.^{1,3}

- 3) Average capacity factors were determined by using foundry size classifications based on foundry employment from Davis, et al.³ and an estimate of operating hours from NEDS. The two size categories were large (≥ 250 employees) and medium (50-249 employees). The number of operating hours for the two employment ranges were then estimated using NEDS data.⁴ This was done by taking the median value of the range of operating hours the large

and medium-size foundry categories. Based on these estimates, it was assumed that in 1980, medium foundries operate 2500 hours per year while large foundries operated 5150 hours per year. The 99 plants analyzed east of the Mississippi, had a total 1980 production estimate of 10.6×10^6 tons with a plant range of 30,000 to 803,400 tons.

Energy Consumption - Fuel Type

Unit energy requirements for the cupola are estimated at 3.38×10^6 Btu/ton.⁵ Coke is fired exclusively. For those plants evaluated, total 1980 energy consumption was estimated to be $35,660 \times 10^9$ Btu with a plant range of 100×10^9 to $2,720 \times 10^9$ Btu.

EMISSION ESTIMATES

Emission Factors

Emission factors were applied to each plant's production based on both test data and default estimates from the literature. The NO_x emission factor is 0.11 lb/ton.⁶ The SO_x emission factor is 1.25 (S) lb/ton, where S equals the percent sulfur in coke.⁷ It was assumed that all foundry coke had 0.6 percent sulfur.⁸ Hydrocarbon emissions were assumed to be negligible.⁷

Plant Emissions

The range in annual emissions (in tons/yr), for the 99 plants evaluated, is shown below:

	Low	High
NO _x	2	44
SO _x	11	301
HC	Negligible	

Data on production, energy consumption by fuel and NO_x, SO_x, and HC are summarized by plant and county in Tables A.28-1 and A.28-2 respectively.

TABLE A.28-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION AND NO_x, SO_x,
AND HC EMISIONS FOR 99 IRON FOUNDRIES LOCATED
EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	CALHOUN	MCWANE INC	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
AL	CALHOUN	US PIPE & FNDRY	139.1	0.00	0.00	0.00	0.47	0.00	0.47	8	52	0
AL	JEFFERSON	AMER CAST IRON	43.3	0.00	0.00	0.00	0.15	0.00	0.15	2	16	0
AL	JEFFERSON	JEFFERSON FNDRY	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
AL	JEFFERSON	MCWANE CAST IRN	123.6	0.00	0.00	0.00	0.42	0.00	0.42	7	46	0
AL	JEFFERSON	STOCKHAM VALVES	309.0	0.00	0.00	0.00	1.04	0.00	1.04	17	116	0
AL	JEFFERSON	US PIPE & FNDRY	803.4	0.00	0.00	0.00	2.72	0.00	2.72	44	301	0
AL	TALLADEGA	BROOKS FOUNDRY	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
AL	TALLADEGA	CORE INDUSTRIES	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
AL	TALLAPOOSA	ROBINSON FNDRY	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
AL	TALLAPOOSA	RUSSELL PIPE	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
AL	TUSCALOOSA	CENTRAL FNDRY	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
Total - AL			1,767.6	0.00	0.00	0.00	5.97	0.00	5.97	97	663	0
CT	FAIRFIELD	WHITE CONS IND	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IL	BOONE	MO LINE CORP	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	COOK	VULCAN MOLD CO	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	HENRY	GALVA FOUNDRY	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	ROCK ISLAND	FRANK FOUNDRIES	45.0	0.00	0.00	0.00	0.15	0.00	0.15	2	17	0
IL	VERMILION	GENERAL MOTORS	602.6	0.00	0.00	0.00	2.04	0.00	2.04	33	226	0
IL	WINNEBAGO	KELSEY-HAYES CO	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
Total - IL			774.6	0.00	0.00	0.00	2.62	0.00	2.62	43	290	0
IN	BARTHOLOMEW	TEXTRON INC	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	HAMILTON	TRW	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
IN	KOSCIUSKO	DALTON FOUNDRY	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
IN	LAKE	YOUNGSTOWN SHI	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	LA PORTE	TELEDYNE INC	55.6	0.00	0.00	0.00	0.19	0.00	0.19	3	21	0
IN	LA PORTE	MYLAIN INC	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	MARION	CHRYSLER CORP	160.7	0.00	0.00	0.00	0.54	0.00	0.54	9	60	0
IN	NOBLE	CHROMALLOY AMER	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	NOBLE	LANE FOUNDRY	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	WAYNE	DANA CORP	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
Total - IN			561.9	0.00	0.00	0.00	1.90	0.00	1.90	31	211	0
KY	HARRISON	EATON CORP	36.0	0.00	0.00	0.00	0.12	0.00	0.12	2	14	0
KY	JEFFERSON	AMER STANDARD	68.0	0.00	0.00	0.00	0.23	0.00	0.23	4	25	0
KY	JEFFERSON	INTL HARVESTER	154.5	0.00	0.00	0.00	0.52	0.00	0.52	8	58	0
Total - KY			258.5	0.00	0.00	0.00	0.87	0.00	0.87	14	97	0
MA	HAMPDEN	JOHN FOUNDRY	52.5	0.00	0.00	0.00	0.18	0.00	0.18	3	20	0

(continued)

TABLE A.28-1 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MI	BERRIEN	BENDIX CORP	106.6	0.00	0.00	0.00	0.36	0.00	0.36	6	40	0
MI	BRANCH	HARMON GROUP	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
MI	CALHOUN	BROOKS FOUNDRY	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
MI	CHARLEVOIX	E JORDAN IRON	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
MI	DICKINSON	GREDE FOUNDRIES	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
MI	KENT	MUSKEGON PISTON	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
MI	MACOMB	NEW HAVEN FNDRY	154.5	0.00	0.00	0.00	0.52	0.00	0.52	8	58	0
MI	MUSKEGON	SEALED POWER	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
MI	MUSKEGON	TEXTRON	318.3	0.00	0.00	0.00	1.08	0.00	1.08	18	119	0
MI	OAKLAND	GENERAL MOTORS	185.4	0.00	0.00	0.00	0.63	0.00	0.63	10	70	0
MI	SAGINAW	GENERAL MOTORS	533.0	0.00	0.00	0.00	1.80	0.00	1.80	29	200	0
MI	TUSCOLA	EATON CORP	170.0	0.00	0.00	0.00	0.57	0.00	0.57	9	64	0
Total - MI			1,759.5	0.00	0.00	0.00	5.95	0.00	5.95	97	660	0
NJ	BERGEN	ABEX CORP	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
NJ	BURLINGTON	AMSTED INDUSTR	154.5	0.00	0.00	0.00	0.52	0.00	0.52	8	58	0
NJ	WARREN	ATLANTIC STATES	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
Total - NJ			266.3	0.00	0.00	0.00	0.90	0.00	0.90	15	100	0
NY	ERIE	GENERAL MOTORS	525.3	0.00	0.00	0.00	1.78	0.00	1.78	29	197	0
NY	ERIE	IRONWORTH-WORTH	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
NY	ONONDAGA	CROUSE-HINDS	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
Total - NY			621.6	0.00	0.00	0.00	2.10	0.00	2.10	34	233	0
NC	MECKLENBURG	CHARLOTTE PIPE	241.0	0.00	0.00	0.00	0.81	0.00	0.81	13	90	0
NC	WAYNE	DEWEY BROTHERS	74.2	0.00	0.00	0.00	0.25	0.00	0.25	4	28	0
Total - NC			315.2	0.00	0.00	0.00	1.07	0.00	1.07	17	118	0
OH	ASHLAND	U-BRAND CORP	142.1	0.00	0.00	0.00	0.48	0.00	0.48	8	53	0
OH	COLUMBIANA	RELIANCE ELEC	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
OH	COLUMBIANA	WALLACE-MURRAY	41.1	0.00	0.00	0.00	0.14	0.00	0.14	2	15	0
OH	COSHOCTON	CLOW CORP	115.3	0.00	0.00	0.00	0.39	0.00	0.39	6	43	0
OH	CUYAHOGA	FORD MOTOR CO	540.8	0.00	0.00	0.00	1.83	0.00	1.83	30	203	0
OH	CUYAHOGA	FOREST CITY FND	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
OH	CUYAHOGA	GENERAL MOTORS	213.2	0.00	0.00	0.00	0.72	0.00	0.72	12	80	0
OH	HAMILTON	BUCKEYE FOUNDRY	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
OH	HAMILTON	CINTI MILACRON	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
OH	LAWRENCE	DAYTON MALL	51.0	0.00	0.00	0.00	0.17	0.00	0.17	3	19	0
OH	MONTGOMERY	DAYTON MALL	67.5	0.00	0.00	0.00	0.23	0.00	0.23	4	25	0
OH	MONTGOMERY	NIBCO INC	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
OH	MUSKINGUM	BURNHAM CORP	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0

(continued)

TABLE A.28-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
OH	SCIOTO	OSCO INDUSTRIES	36.0	0.00	0.00	0.00	0.12	0.00	0.12	2	14	0
Total - OH			1,502.3	0.00	0.00	0.00	5.08	0.00	5.08	83	563	0
PA	ALLEGHENY	US STEEL CORP	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
PA	BERKS	EASTERN FOUNDRY	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
PA	BERKS	UNICAST	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
PA	BERKS	ROCKWELL INTL	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
PA	ERIE	URICK FOUNDRY	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
PA	ERIE	ZURN INDUSTRIES	33.0	0.00	0.00	0.00	0.11	0.00	0.11	2	12	0
PA	LANCASTER	ITT GRINNELL	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
PA	LEHIGH	INGERSOLL-RAND	224.3	0.00	0.00	0.00	0.76	0.00	0.76	12	84	0
PA	MONTGOMERY	STANLEY & FLAGG	123.6	0.00	0.00	0.00	0.42	0.00	0.42	7	46	0
PA	TIOGA	JP WARD FNDRY	92.7	0.00	0.00	0.00	0.31	0.00	0.31	5	35	0
PA	WASHINGTON	COMBUSTION ENGR	43.3	0.00	0.00	0.00	0.15	0.00	0.15	2	16	0
PA	WESTMORELAND	VULCAN INC	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
PA	WESTMORELAND	HOCKENSMITH	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
PA	YORK	DONSCO INC	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
Total - PA			910.5	0.00	0.00	0.00	3.08	0.00	3.08	50	341	0
RI	KENT	NEW ENGLAND	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
SC	SPARTANBURG	ROCKWELL INTL	68.0	0.00	0.00	0.00	0.23	0.00	0.23	4	25	0
TN	HAMILTON	NORTH AMERICAN	386.3	0.00	0.00	0.00	1.31	0.00	1.31	21	145	0
TN	HAMILTON	US PIPE & FNDRY	75.0	0.00	0.00	0.00	0.25	0.00	0.25	4	28	0
Total - TN			461.3	0.00	0.00	0.00	1.56	0.00	1.56	25	173	0
VA	CAMPBELL	GRIFFIN PIPE	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
VA	CAMPBELL	LYNCHBURG FNDRY	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
VA	CAMPBELL	LYNCHBURG FNDRY	284.3	0.00	0.00	0.00	0.96	0.00	0.96	16	107	0
VA	PULASKI	LYNCHBURG FNDRY	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
Total - VA			462.0	0.00	0.00	0.00	1.56	0.00	1.56	25	173	0
WI	GREEN LAKE	MCQUAY-PERFEX	34.0	0.00	0.00	0.00	0.11	0.00	0.11	2	13	0
WI	MILWAUKEE	BRIGGS & STRATT	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
WI	MILWAUKEE	MOTOR CASTINGS	57.0	0.00	0.00	0.00	0.19	0.00	0.19	3	21	0
WI	MILWAUKEE	VILTER MFG CORP	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
WI	RACINE	JI CASE CO	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
WI	ROCK	BELOIT CORP	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
WI	WAUKESHA	GREDE FOUNDRIES	92.7	0.00	0.00	0.00	0.31	0.00	0.31	5	35	0
WI	WAUPACA	WAUPACA FOUNDRY	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0

(continued)

TABLE A.28-1 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
WI	WINNEBAGO	NEENAH FOUNDRY	231.8	0.00	0.00	0.00	0.78	0.00	0.78	13	87	0
WI	WINNEBAGO	UNIVERSAL FNDRY	38.6	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
Total - WI			699.5	0.00	0.00	0.00	2.36	0.00	2.36	38	262	0
Total Study Area			10,550.1	0.00	0.00	0.00	35.66	0.00	35.66	580	3,956	0

TABLE A.28-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION AND NO_x, SO_x,
AND HC EMISIONS FOR 99 IRON FOUNDRIES LOCATED
EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MI	OAKLAND	All	185.4	0.00	0.00	0.00	0.63	0.00	0.63	10	70	0
MI	SAGINAW	All	533.0	0.00	0.00	0.00	1.80	0.00	1.80	29	200	0
MI	TUSCOLA	All	170.0	0.00	0.00	0.00	0.57	0.00	0.57	9	64	0
Total - MI			1,759.5	0.00	0.00	0.00	5.95	0.00	5.95	97	660	0
NJ	BERGEN	All	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
NJ	BURLINGTON	All	154.5	0.00	0.00	0.00	0.52	0.00	0.52	8	58	0
NJ	WARREN	All	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
Total - NJ			266.3	0.00	0.00	0.00	0.90	0.00	0.90	15	100	0
NY	ERIE	All	559.8	0.00	0.00	0.00	1.89	0.00	1.89	31	210	0
NY	ONDONAGA	All	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
Total - NY			621.6	0.00	0.00	0.00	2.10	0.00	2.10	34	233	0
NC	MECKLENBURG	All	241.0	0.00	0.00	0.00	0.81	0.00	0.81	13	90	0
NC	WAYNE	All	74.2	0.00	0.00	0.00	0.25	0.00	0.25	4	28	0
Total - NC			315.2	0.00	0.00	0.00	1.07	0.00	1.07	17	118	0
OH	ASHLAND	All	142.1	0.00	0.00	0.00	0.48	0.00	0.48	8	53	0
OH	COLUMBIANA	All	75.6	0.00	0.00	0.00	0.26	0.00	0.26	4	28	0
OH	COSHOCTON	All	115.3	0.00	0.00	0.00	0.39	0.00	0.39	6	43	0
OH	CUYAHOGA	All	815.8	0.00	0.00	0.00	2.76	0.00	2.76	45	306	0
OH	HAMILTON	All	107.3	0.00	0.00	0.00	0.36	0.00	0.36	6	40	0
OH	LAWRENCE	All	51.0	0.00	0.00	0.00	0.17	0.00	0.17	3	19	0
OH	MONTGOMERY	All	97.5	0.00	0.00	0.00	0.33	0.00	0.33	5	37	0
OH	MUSKINGUM	All	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
OH	SCIOTO	All	36.0	0.00	0.00	0.00	0.12	0.00	0.12	2	14	0
Total - OH			1,502.3	0.00	0.00	0.00	5.08	0.00	5.08	83	563	0
PA	ALLEGHENY	All	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
PA	BERKS	All	111.9	0.00	0.00	0.00	0.38	0.00	0.38	6	42	0
PA	ERIE	All	79.4	0.00	0.00	0.00	0.27	0.00	0.27	4	30	0
PA	LANCASTER	All	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
PA	LEHIGH	All	224.3	0.00	0.00	0.00	0.76	0.00	0.76	12	84	0
PA	MONTGOMERY	All	123.6	0.00	0.00	0.00	0.42	0.00	0.42	7	46	0
PA	TIOGA	All	92.7	0.00	0.00	0.00	0.31	0.00	0.31	5	35	0
PA	WASHINGTON	All	43.3	0.00	0.00	0.00	0.15	0.00	0.15	2	16	0
PA	WESTMORELAND	All	91.8	0.00	0.00	0.00	0.31	0.00	0.31	5	34	0
PA	YORK	All	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
Total - PA			910.5	0.00	0.00	0.00	3.08	0.00	3.08	50	341	0

(continued)

TABLE A.28-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	CALHOUN	All	210.1	0.00	0.00	0.00	0.71	0.00	0.71	12	79	0
AL	JEFFERSON	All	1,313.8	0.00	0.00	0.00	4.44	0.00	4.44	72	493	0
AL	TALLADEGA	All	105.6	0.00	0.00	0.00	0.36	0.00	0.36	6	40	0
AL	TALLAPOOSA	All	67.1	0.00	0.00	0.00	0.23	0.00	0.23	4	25	0
AL	TUSCALOOSA	All	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
Total - AL			1,767.6	0.00	0.00	0.00	5.97	0.00	5.97	97	663	0
CT	FAIRFIELD	All	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IL	BOONE	All	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	COOK	All	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	HENRY	All	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
IL	ROCK ISLAND	All	45.0	0.00	0.00	0.00	0.15	0.00	0.15	2	17	0
IL	VERMILION	All	602.6	0.00	0.00	0.00	2.04	0.00	2.04	33	226	0
IL	WINNEBAGO	All	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
Total - IL			774.6	0.00	0.00	0.00	2.62	0.00	2.62	43	290	0
IN	BARTHOLOMEW	All	35.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	HAMILTON	All	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
IN	KOSCIUSKO	All	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
IN	LAKE	All	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
IN	LA PORTE	All	91.2	0.00	0.00	0.00	0.31	0.00	0.31	5	34	0
IN	MARION	All	160.7	0.00	0.00	0.00	0.54	0.00	0.54	9	60	0
IN	NOBLE	All	70.0	0.00	0.00	0.00	0.24	0.00	0.24	4	26	0
IN	WAYNE	All	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
Total - IN			561.9	0.00	0.00	0.00	1.90	0.00	1.90	31	211	0
KY	HARRISON	All	36.0	0.00	0.00	0.00	0.12	0.00	0.12	2	14	0
KY	JEFFERSON	All	222.5	0.00	0.00	0.00	0.75	0.00	0.75	12	83	0
Total - KY			258.5	0.00	0.00	0.00	0.87	0.00	0.87	14	97	0
MA	HAMPDEN	All	52.5	0.00	0.00	0.00	0.18	0.00	0.18	3	20	0
MI	BERRIEN	All	106.6	0.00	0.00	0.00	0.36	0.00	0.36	6	40	0
MI	BRANCH	All	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
MI	CALHOUN	All	30.0	0.00	0.00	0.00	0.10	0.00	0.10	2	11	0
MI	CHARLEVOIX	All	77.3	0.00	0.00	0.00	0.26	0.00	0.26	4	29	0
MI	DICKINSON	All	37.1	0.00	0.00	0.00	0.13	0.00	0.13	2	14	0
MI	KENT	All	46.4	0.00	0.00	0.00	0.16	0.00	0.16	3	17	0
MI	MACOMB	All	154.5	0.00	0.00	0.00	0.52	0.00	0.52	8	58	0
MI	MUSKEGON	All	348.3	0.00	0.00	0.00	1.18	0.00	1.18	19	131	0

(continued)

TABLE A.28-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
RI	KENT	All	34.5	0.00	0.00	0.00	0.12	0.00	0.12	2	13	0
SC	SPARTANBURG	All	68.0	0.00	0.00	0.00	0.23	0.00	0.23	4	25	0
TN	HAMILTON	All	461.3	0.00	0.00	0.00	1.56	0.00	1.56	25	173	0
VA	CAMPBELL	All	390.9	0.00	0.00	0.00	1.32	0.00	1.32	21	147	0
VA	PULASKI	All	71.1	0.00	0.00	0.00	0.24	0.00	0.24	4	27	0
Total - VA			462.0	0.00	0.00	0.00	1.56	0.00	1.56	25	173	0
WI	GREEN LAKE	All	34.0	0.00	0.00	0.00	0.11	0.00	0.11	2	13	0
WI	MILWAUKEE	All	117.0	0.00	0.00	0.00	0.40	0.00	0.40	6	44	0
WI	RACINE	All	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
WI	ROCK	All	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
WI	WAUKESHA	All	92.7	0.00	0.00	0.00	0.31	0.00	0.31	5	35	0
WI	WAUPACA	All	61.8	0.00	0.00	0.00	0.21	0.00	0.21	3	23	0
WI	WINNEBAGO	All	270.4	0.00	0.00	0.00	0.91	0.00	0.91	15	101	0
Total - WI			699.5	0.00	0.00	0.00	2.36	0.00	2.36	38	262	0
Total Study Area			10,550.1	0.00	0.00	0.00	35.66	0.00	35.66	580	3,956	0

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INDUSTRY: PRIMARY NONFERROUS METALS

PLANT/FACILITY: PRIMARY ALUMINUM SMELTERS

PLANT POPULATION

The analyses of direct-fired fuel in primary aluminum smelters is limited to those that employ prebaked electrodes. While the primary aluminum industry ranks among the top six industrial energy consumers, most of its energy requirements are supplied by electrical power.^{1,2} Of three types of primary aluminum smelters: prebake, horizontal-stud Soderberg, and vertical-stud Soderberg, only the pre-bake type aluminum plants consume significant amounts of direct-fired energy. There are 23 prebake primary aluminum producers in the United States.^{1,3,4,5} The 12 plants located east of the Mississippi were included in this analysis. These have a capacity range of from 113,000 to 280,000 tons/yr and an average production of 189,300 tons/yr. The smallest plant in the study area produces 113,400 tons of aluminum and consumes 200×10^9 Btu per year in direct fired natural gas.

COMBUSTION PROCESSES

Fuel is used in prebake plants in production of carbon anodes that are subsequently used in the electrolytic production of aluminum. Fuel burning for anode baking takes place in ring-type furnaces or tunnel kilns, although the ring type furnace is

reported to be the predominate type of equipment used in this industry.¹

PRODUCTION AND FUEL CONSUMPTION

Production

Specific plant capacity data were obtained from a number of published sources.^{1,3,4,5} Production estimates were made by multiplying each plant's production capacity by a national average capacity factor since actual production by plant or by region of the U.S. could not be obtained. The national average capacity factor was based on the most recent available production data, i.e., 1980 Bureau of Mines estimates. These data estimate 1980 domestic primary aluminum industry production at 5,129,699 tons. Based on a total U.S. production capacity of 5,503,000 tons/yr, this translates to an average capacity factor of 93.22 percent. The resulting estimates of plant production in the study area show a range of between 106,000 and 261,000 tons per year.

Energy Consumption - Fuel Type

The direct fired energy required during anode baking was estimated to approximately 2.1×10^6 Btu/ton of aluminum.² This is an average weighted energy factor for both the ring-type furnace (predominately used in this industry) and the tunnel type kiln. Total plant energy consumption was calculated by multiplying production by the unit energy consumption. Natural gas is the only fuel fired during anode baking.² Energy consumption estimates for individual plants range from 220 to 510×10^9 Btu/yr.

EMISSION ESTIMATES

Emission Factors

Estimated SO_x , NO_x , and HC emission factors are all based on industrial default factors for natural gas combustion since no specific emission factors could be obtained for anode baking. The estimated SO_x and HC emission factors are 8.57×10^{-4} and 1.43×10^{-2} lb/ton, respectively,⁶ while NO_x emissions are calculated based on an equation derived from the Mills et. al.⁷ The plants were assumed to operate 8,166 hr/yr, based on the national average capacity factor of 93.22 percent.

Plant Emissions

Plant emission ranges in tons/yr are shown below:

	Low	High
NO_x	18	53
SO_x	Negligible	
HC	1	3

Table A.29-1 summarizes annual plant production, fuel consumption and emissions of NO_x , SO_x and HC, for each of the 12 plants analyzed. Table A.29-2 presents the same data as Table A.29-1, but summarized by county.

TABLE A.29-1. SUMMARY OF 1980 PREBAKE ALUMINUM PLANT PRODUCTION,
FUEL USE AND SO₂, NO_x, AND HC EMISSIONS FOR 12 PLANTS
EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NO _x	SO _x	HC
AL	JACKSON	REVERE COPPER	105.8	0.00	0.00	0.22	0.00	0.00	0.22	18	0	1
IN	VANDERBURGH	ALCOA	261.0	0.00	0.00	0.55	0.00	0.00	0.55	53	0	2
KY	HANCOCK	NATL-SOUTHWIRE	186.4	0.00	0.00	0.39	0.00	0.00	0.39	36	0	1
KY	WEBSTER	ANACONDA ALUM	167.8	0.00	0.00	0.35	0.00	0.00	0.35	31	0	1
Total - KY			354.2	0.00	0.00	0.74	0.00	0.00	0.74	67	0	3
MD	FREDERICK	EASTALCO ALUM	203.9	0.00	0.00	0.43	0.00	0.00	0.43	40	0	1
NY	ST LAWRENCE	ALCOA	214.9	0.00	0.00	0.45	0.00	0.00	0.45	42	0	2
NC	STANLY	ALCOA	167.3	0.00	0.00	0.35	0.00	0.00	0.35	31	0	1
OH	WOMPOE	ORMET CORP	242.4	0.00	0.00	0.51	0.00	0.00	0.51	48	0	2
SC	BERKELEY	ALUMAX	183.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
TN	BLOUNT	ALCOA	251.7	0.00	0.00	0.53	0.00	0.00	0.53	51	0	2
TN	MUMPHREYS	CONSOL ALUMINUM	134.7	0.00	0.00	0.28	0.00	0.00	0.28	24	0	1
Total - TN			386.4	0.00	0.00	0.81	0.00	0.00	0.81	75	0	3
WV	JACKSON	KAISER ALUM	151.9	0.00	0.00	0.32	0.00	0.00	0.32	28	0	1
Total Study Area			2,271.5	0.00	0.00	4.75	0.00	0.00	4.75	437	1	16

TABLE A.29-2: SUMMARY OF 1980 PREBAKE ALUMINUM PLANT PRODUCTION, FUEL USE AND SO_x, NO_x, AND HC EMISSIONS BY COUNTY FOR 12 PLANTS EAST OF THE MISSISSIPPI

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Total	Emissions, Tons/Year		
				Coal	Oil	Nat Gas	Coke	Other		NO _x	SO _x	HC
AL	JACKSON	All	105.8	0.00	0.00	0.22	0.00	0.00	0.22	18	0	1
IN	VANDERBURGH	All	261.0	0.00	0.00	0.55	0.00	0.00	0.55	53	0	2
KY	HAMCOCK	All	186.4	0.00	0.00	0.39	0.00	0.00	0.39	36	0	1
KY	WEBSTER	All	167.8	0.00	0.00	0.35	0.00	0.00	0.35	31	0	1
Total - KY			354.2	0.00	0.00	0.74	0.00	0.00	0.74	67	0	3
MD	FREDERICK	All	203.9	0.00	0.00	0.43	0.00	0.00	0.43	40	0	1
NY	ST LAWRENCE	All	214.9	0.00	0.00	0.45	0.00	0.00	0.45	42	0	2
NC	STANLY	All	167.3	0.00	0.00	0.35	0.00	0.00	0.35	31	0	1
OH	MONROE	All	242.4	0.00	0.00	0.51	0.00	0.00	0.51	48	0	2
SC	BERKELEY	All	183.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
TN	BLOUNT	All	251.7	0.00	0.00	0.53	0.00	0.00	0.53	51	0	2
TN	MURPHREYS	All	134.7	0.00	0.00	0.28	0.00	0.00	0.28	24	0	1
Total - TN			386.4	0.00	0.00	0.81	0.00	0.00	0.81	75	0	3
WV	JACKSON	All	151.9	0.00	0.00	0.32	0.00	0.00	0.32	28	0	1
Total Study Area			2,271.5	0.00	0.00	4.75	0.00	0.00	4.75	437	1	16

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INDUSTRY: PRIMARY NONFERROUS METALS

PLANT/FACILITY: COPPER SMELTERS AND REFINERIES

PLANT POPULATION

In 1980, the domestic primary copper industry consisted of 16 primary smelters and 11 primary refineries. Since then, there have been several plant closings. Only two primary smelters and three refineries are located east of the Mississippi River. One smelter and one refinery met the energy consumption criteria of 100×10^9 Btu/yr. Secondary materials, often in the form of scrap, are processed at both the smelter and refinery, the processing of scrap at primary plants has been included in this analysis.

The estimated 1980 capacities of the 2 plants analyzed were 80,525 and 275,950 tons. Production for these 2 plants totalled 309,700 tons in 1980, compared to a national production of 2.6×10^6 tons. The smaller of the 2 plants analyzed had an estimated 1980 direct-fired energy consumption of 310×10^9 Btu.

COMBUSTION PROCESSES

Primary copper smelters recover copper metal mostly from copper ore concentrates by pyrometallurgical processing.

Direct-fired energy is consumed at a primary copper smelter in the following processes:

- Drying
- Smelting
- Converting
- Fire refining

The exact plant processing configuration varies, depending on the type of smelter (reverberatory, electric, Noranda, or flash) and the desired end product (anode or fire-refined). The one smelter plant evaluated was the reverberatory type configuration, and consisted of the 4 direct-fired processes listed above. Natural gas, fuel oil, and minor amounts of coal are used as direct-fired fuel.

Electrolytic refineries use electricity as the major source of energy, although some direct-fired energy is consumed during cathode melting, the only direct-fired process at the one refinery plant analyzed. Natural gas is the primary fuel used in the cathode melting process.

PRODUCTION AND ENERGY CONSUMPTION

Production

Plant capacity data were obtained through published sources.¹ Production for the 1 smelter plant analyzed was estimated using a 1980 capacity factor of 53.4 percent. This factor was calculated as a national average using U.S. capacity and production for smelters.^{1,2}

A capacity factor of 60.7 percent was estimated and applied to plant capacity thereby obtaining 1980 production for the 1 refinery plant analyzed.² The 1980 production estimate for the

2 plants evaluated was 309,700 tons, with individual plant production of 43,000 and 167,500 tons.

Energy Consumption - Fuel Type

Unit energy consumptions are shown in Table A.30-1 by process and fuel type.³ These energy consumption factors are multiplied by production to obtain each plant's direct-fired energy consumption.

Natural gas was assumed to be the only fuel used in the cathode melting process for the one copper refinery analyzed.² For the one copper smelter analyzed, a national average estimate of fuel breakdown was used to allocate fuels. The breakdown was 61 percent gas, 38.5 percent oil, and 0.5 percent coal.³

The 1980 direct-fired energy consumption for the 2 plants analyzed was estimated to be 310×10^9 Btu and $1,280 \times 10^9$.

EMISSION ESTIMATES

Emission Factors

Table A.30-2 presents emission factors by process and fuel type.⁴⁻⁷ Available copper emission factors primarily account for process emissions (i.e., sulfur in ore), while the default emission factors used here represent only fuel combustion.⁴⁻⁷

Plant Emissions

The range in annual emissions (in tons/yr) for the 2 plants analyzed, is shown below:

TABLE A.30-1. UNIT ENERGY CONSUMPTION FOR THE
PRIMARY COPPER INDUSTRY BY PROCESS AND TYPES OF FUELS³
(10⁶ Btu/ton)

	Dryer	Reverberatory furnace	Converter	Fire refining/ anode furnace	Cathode melting
Natural gas	1.40	12.80	0.85	3.14	1.87
Fuel oil	-	11.22	0.04	0.23	-
Coal	-	-	-	0.13	-
Total	1.40	24.02	0.89	3.50	1.87

TABLE A.30-2. EMISSION FACTORS BY PROCESS AND FUEL⁴⁻⁹
(lb/ton)

	Dryer	Reverberatory furnace	Converter	Fire refining/ anode furnace	Cathode melting
Natural gas					
SO _x	5.56×10^{-4}	5.24×10^{-3}	3.48×10^{-4}	1.288×10^{-3}	7.76×10^{-4}
NO _x	a	a	a	a	a
HC	9.58×10^{-3}	8.576×10^{-2}	5.82×10^{-3}	2.148×10^{-2}	1.27×10^{-3}
Fuel oil					
SO _x	-	$1.23 \times 10^1(S)^b$	$4.4 \times 10^{-2}(S)^b$	$2.55 \times 10^{-1}(S)^b$	-
NO _x	-	a	a	a	-
HC	-	2.266×10^{-1}	4.64×10^{-3}	4.64×10^{-3}	-
Coal					
SO _x	-	-	-	$1.02 \times 10^{-4}(S)^b$	-
NO _x	-	-	-	8.84×10^{-5}	-
HC	-	-	-	1.626×10^{-4}	-

^a Equation derived from graphs appearing in Mills, et al.⁶

^b When (S) equals percent sulfur in fuel. Percent sulfur obtained for oil and coal by state.^{8,9}

	Low	High
NO _x	30	186
SO _x	0	368
HC	0	8

Tables A.30-3 and A.30-4 summarize production, energy consumption by fuel, and NO_x, SO_x, and HC emissions for the 5 plants analyzed, by plant and county respectively.

TABLE A.30-3. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
 NO_x, SO_x, AND HC EMISSIONS FOR TWO COPPER SMELTING AND REFINING PLANTS
 LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MD	BALTIMORE	KENNECOTT COP	167.5	0.00	0.00	0.31	0.00	0.00	0.31	30	0	0
MI	ONTONAGON	COPPER RANGE	43.0	0.01	0.49	0.78	0.00	0.00	1.28	186	368	8
Total Study Area			210.5	0.01	0.49	1.10	0.00	0.00	1.59	216	368	8

TABLE A.30-4. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
 AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR TWO COPPER SMELTING AND
 REFINING PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
MD	BALTIMORE	All	167.5	0.00	0.00	0.31	0.00	0.00	0.31	30	0	0
MI	ONTONAGON	All	43.0	0.01	0.49	0.78	0.00	0.00	1.28	186	368	8
Total Study Area			210.5	0.01	0.49	1.10	0.00	0.00	1.59	216	368	8

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INDUSTRY: PRIMARY NONFERROUS

PLANT/FACILITY: ZINC SMELTERS

PLANT POPULATION

In 1980, four out of the six primary zinc smelters in the U.S. were located east of the Mississippi.¹ These plants range in capacity from 82,000 and 250,200 tons/year.² Total estimated 1980 production for the four plants was 254,900 tons, compared to a national total of 369,500 tons. The smallest plant analyzed produced 62,600 tons in 1980, and had an estimated direct-fired energy consumption of 170×10^9 Btu/year.

COMBUSTION PROCESSES

Domestic smelters are one of three basic types that utilize one of three processes to produce primary zinc:

- ° Electrothermic
- ° Vertical retort
- ° Electrolytic

The electrothermic and vertical retort processes employ retort furnaces that are direct-fired. The electrolytic process consumes electricity. All three basic processes employ some direct-fired auxiliary processes in conjunction with the metal production process. These include the following:³

- ° Dryer - used to dry concentrate or secondary metal, feedstocks generally fired with natural gas or oil.

- ° Roaster - used to drive off sulfur and convert zinc concentrate into calcine, generally fired with natural gas.
- ° Sinter line - used to harden and permeate retort furnace feed in the electrothermic and vertical retort processes. A combination of natural gas, oil, and coal is generally fired.
- ° Retorts - used for briquetting and/or reduction in the electrothermic and vertical retort processes. Generally a combination of natural gas, coal, and coke is burned.
- ° Melter - used to melt the metal prior to casting in the electrolytic process, generally fired with natural gas.

In the eastern U.S., one electrothermic, one vertical retort, and two electrolytic plants operated during 1980. The types of equipment employed at each is shown along with energy consumption factors in Table A.31-1.

PRODUCTION AND ENERGY CONSUMPTION

Production

Domestic primary zinc smelters produced 369,850 tons of slab zinc in 1980. The Bureau of Mines reported 1980 plant production for all plants east of the Mississippi.⁴ Zinc plants included in this analysis produced a total of 369,500 tons, with a plant range of 45,000 to 73,650 tons.

Energy Consumption-Fuel Types

Table A.31-1 presents fuel use information as well as energy consumption factors for electrothermic, vertical retort, and electrolytic smelters.² Total estimated 1980 energy consumption for the 4 plants analyzed was 4900×10^9 Btu with a plant range of 170 to 3290×10^9 Btu.

TABLE A.31-1. ENERGY CONSUMPTION FACTORS FOR PRIMARY ZINC SMELTERS³
(10⁶ Btu/ton)

	Dryer	Roaster	Sinter line	Briquette machine	Retort furnace	Melter
Electrothermic						
Gas	0.202	1.060	0.314	-	0.578	-
Oil	-	-	-	-	-	-
Coal	-	-	-	-	-	-
Coke	-	-	3.990	-	21.450	-
Vertical retort						
Gas	-	0.130	0.330	-	13.75	-
Oil	0.671	-	0.585	-	-	-
Coal	-	-	6.277	24.10	-	-
Coke	-	-	-	-	-	-
Electrolytic						
Gas	1.321	1.050	-	-	-	-
Oil	-	-	-	-	-	-
Coal	-	-	-	-	-	-
Coke	-	-	-	-	-	-

EMISSION ESTIMATES

Emission Factors

Table A.31-2 presents emission factors by process and fuel type.⁴⁻⁶ Since test data on process-specific fuel combustion were not available, these emission factors were calculated using industrial default factors from the literature.⁴⁻⁶ Process heat input (10^6 Btu/t from Table A.31-1) as well as the appropriate heating value for each fuel were incorporated into the emission factor, which are expressed in lb/ton of product. Since all eastern zinc smelters utilize acid plants to control their SO_x emissions, a removal efficiency of 99 percent was assumed and applied to the uncontrolled emission rates shown in Table A.31-2.

Plant Emissions

The range in emissions for the four eastern zinc smelters is shown below (in tons/year):

	Low	High
NO_x	12	1609
SO_x	0	37
HC	1	

Tables A.31-3 and A.31-4 summarize production, energy consumption by fuel, and emissions for the four eastern U.S. plants by plant and county respectively.

TABLE A.31-2. PRIMARY ZINC UNCONTROLLED EMISSION FACTORS BY PROCESS AND FUEL TYPE⁴⁻⁷
(lb/ton)

	Dryer	Roaster	Sinter line	Briquette machine	Retort furnaces	Melter
Electrothermic						
NO _x : Gas ^a	a	a	a	-	a	-
Coke ^b	-	-	1.32×10^{-1}	-	7.08×10^{-1}	-
SO _x : ^c Gas ^d	8.28×10^{-5}	4.35×10^{-4}	1.29×10^{-4}	-	2.37×10^{-4}	-
Coke ^e	-	-	8.78×10^{-1}	-	4.72	-
HC: Gas ^d	1.38×10^{-3}	7.25×10^{-3}	2.15×10^{-3}	-	3.95×10^{-3}	-
Coke ^e	-	-	0	-	0	-
Vertical retort						
NO _x : Gas ^a	-	a	a	-	a	-
Oil ^g	g	-	g	-	-	-
Coal ^h	-	-	8.54	32.78	-	-
SO _x : ^c Gas ^d	-	5.33×10^{-5}	1.35×10^{-4}	-	5.64×10^{-3}	-
Oil ^d	$7.38(S) \times 10^{-1}$	-	$6.44(S) \times 10^{-1}$	-	-	-
Coal ⁱ	-	-	9.79(S)	37.6(S)	-	-
HC: Gas ^d	-	8.89×10^{-4}	2.26×10^{-3}	-	9.41×10^{-2}	-
Oil ^d	1.36×10^{-2}	-	1.18×10^{-2}	-	-	-
Coal ^h	-	-	2.51×10^{-2}	9.64×10^{-2}	-	-
Electrolytic						
NO _x : Gas ^a	a	a	-	-	-	a
SO _x : ^c Gas ^d	5.42×10^{-4}	4.31×10^{-4}	-	-	-	1.35×10^{-4}
HC: Gas ^d	9.04×10^{-3}	7.18×10^{-3}	-	-	-	2.26×10^{-3}

^a Derived from gas NO_x emission graph in Mills, et al, 1961.

^b Derived from coke foundry emission factor in Mills, et al, 1961.

^c Derived from coke foundry emission factor in U.S. EPA, 1977. Assumes 0.6% sulfur content in coke.

^d U.S. Environmental Protection Agency Air Pollution Engineering Manual. AP-40. Research Triangle Park, North Carolina, 1973.

^e Assumed a 99% control efficiency for acid plant.

^f Derived from hand-fired coal boiler emission factor in U.S. EPA, 1977.

^g Derived from oil NO_x emission graph in Mills, et al, 1961.

^h Derived from wet-bottom, pulverized coal-fired boiler emission factor in U.S. EPA, 1977.

TABLE A.31-3. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS FOR 4 PRIMARY NONFERROUS ZINC SMELTER PLANTS *
LOCATED EAST OF THE MISSISSIPPI RIVER

		Prod 1000	Fuel Consumption, Trillion Btu/Year						Emissions, Tons Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
IL	ST CLAIR	AMAX INC	62.6	0.00	0.00	0.17	0.00	0.00	0.17	12	0	1
PA	BEAVER	ST JOE MINERALS	45.0	0.00	0.00	0.10	1.14	0.00	1.24	26	1	0
PA	CARBON	NEW JERSEY ZINC	71.7	2.18	0.00	1.02	0.00	0.00	3.29	1,609	37	9
Total - PA			116.7	2.18	0.00	1.12	1.14	0.00	4.53	1,635	38	9
TN	MONTGOMERY	JERSEY MINIERE	75.6	0.00	0.00	0.20	0.00	0.00	0.20	14	0	1
Total Study Area			254.9	2.18	0.00	1.49	1.14	0.00	4.90	1,661	38	10

TABLE A.31-4. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 4 PRIMARY NONFERROUS ZINC SMELTER PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

*****												
			Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility		Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC

IL	ST CLAIR	All	62.6	0.00	0.00	0.17	0.00	0.00	0.17	12	0	1
PA	BEAVER	All	45.0	0.00	0.00	0.10	1.14	0.00	1.24	26	1	0
PA	CARBON	All	71.7	2.18	0.09	1.02	0.00	0.00	3.29	1,605	35	0
Total - PA			116.7	2.18	0.09	1.12	1.14	0.00	4.53	1,631	38	9

TN	MONTGOMERY	All	75.6	0.00	0.00	0.20	0.00	0.00	0.20	14	0	1
Total Study Area			254.9	2.18	0.09	1.49	1.14	0.00	4.90	1,661	38	10
*****												

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INDUSTRY: SECONDARY NONFERROUS METALS

PLANT/FACILITY: ALUMINUM SMELTING

PLANT POPULATION

The Bureau of Mines estimated 1980 production for this industry at 760,000 tons.¹ Approximately 89 secondary aluminum smelters were operating in the U.S., with 65 being located east of the Mississippi.^{2,3} However, only 10 out of the 65 plants met the established energy consumption criteria of 100×10^9 Btu/year. Therefore, the remaining 55 plants were excluded from further consideration.

Capacity data were not available for the 10 plants evaluated. Hence, production capacity was estimated from shipments data that indicated that the total estimated 1980 production of the ten plants in 1980 was approximately 239,000 tons with a plant range of 15,300 to 49,400. The smallest plant had an estimated 1980 direct-fired energy consumption of 130×10^9 Btu.

COMBUSTION PROCESSES

The secondary aluminum industry processes aluminum-bearing scrap to recover aluminum metal. The major direct-fired equipment in this industry are sweating furnaces and reverberatory furnaces. Both furnaces fire either natural gas or oil.^{4,5}

PRODUCTION AND FUEL CONSUMPTION

Production

The plants were divided into two categories: 1) those producing aluminum only, and 2) those producing aluminum plus other secondary nonferrous metals. Because plant-specific production or capacity data was not available in published literature for the 32 secondary smelters producing only aluminum, production was estimated on the basis of plant shipments and an average reported price per ton for secondary smelter's alloyed ingot. Shipment data and the average 1980 price for alloyed ingot of \$1780/ton were obtained from the EIS report on shipments and the Bureau of Mines respectively.^{1,6} Assuming that each plant's shipments in dollars is directly equatable with production, each plant's production was estimated simply by dividing the plant's reported yearly shipments in dollars by the average \$1780/ton price for secondary smelter's alloyed ingot. The 22 plants whose shipments were less than 21.7 million dollars did not meet the established energy consumption criteria and were therefore excluded from further consideration.

Since a breakdown of the metals produced on a plant-specific basis was not available in the literature for the 33 plants producing other secondary nonferrous metals in addition to aluminum, an average production figure of 8500 tons/year of aluminum was assumed. This average production rate was estimated by dividing the total number of operating plants in the U.S. (89) into the estimated 1980 production (760,000 tons). Based on this estimated average production figure, however, these plants were excluded from further consideration because they failed to

meet the established energy consumption figure of 100×10^9 Btu.

Total 1980 production of the ten plants which met the established energy consumption criteria was estimated to be approximately 239,000 tons, with a plant range of 15,300 to 49,400 tons.

Energy Consumption - Fuel Type

The average unit energy consumption in Btu/ton for the sweating furnace and the reverberatory furnace is 1.31×10^6 and 6.90×10^6 , respectively.^{4,7} Both furnaces fire natural gas or oil. The split between these two fuels is generally 75 percent for natural gas and 25 percent for fuel oil.^{4,5,8} Since plant specific data was not available, this split was applied to each plant analyzed. Therefore, the total 1980 energy consumption for the ten plants was estimated to be 1.96×10^{12} Btu, with a plant range of 130×10^9 to 410×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Nitrogen dioxide emissions for both the sweating and the reverberatory furnaces were estimated using equations derived by Mills et al.⁹ The plants were assumed to operate 5,344 hr/yr, based on an average weighted capacity factor for other secondary nonferrous smelters (copper and lead) since no other data were available.

The SO_x and HC emission factors for natural gas-fired sweating furnaces and reverberatory furnaces as obtained from the U.S. EPA's AP-40 publication are: 0.42 and $7.0 \text{ lb}/10^6 \text{ ft}^3$

natural gas, respectively.¹⁰ The emission factors converted to lb/ton for the sweating furnace based on its energy consumption of 1.31×10^6 Btu/ton and a heating value of 1024 Btu/ft³ for natural gas¹¹ are: 5.37×10^{-4} and 8.96×10^{-3} for SO_x and HC, respectively. For a natural gas-fired reverberatory furnace with an energy consumption of 6.9×10^6 Btu/ton the emission factors converted to lb/ton are: 2.83×10^{-3} and 4.72×10^{-2} for SO_x and HC, respectively.

The SO_x and HC emission factors for oil-fired sweating furnaces and reverberatory furnaces as obtained from the U.S. EPA's AP-40 publication are: 7000 (S) lb/10³ bbl (where S = sulfur content of oil in weight percent) and 127.0 lb/10³ bbl, respectively.¹⁰ The emission factors converted to lb/ton for the sweating furnace and reverberatory furnace based on their respective energy consumptions and a heating value of 6.3×10^6 Btu/bbl for residual fuel oil¹¹ are: 1.46 (S) and 7.67 (S) for SO_x and 2.64×10^{-2} and 1.39×10^{-1} for HC, respectively.

As mentioned previously, when estimating emissions for both furnaces, each plant was assumed to fire 75 percent natural gas and 25 percent fuel oil.

Plant Emissions

The range in total annual emissions (in tons/year) for the ten plants is shown below:

	Low	High
NO _x	11	42
SO _x	25	80
HC	1	2

Tables A.32-1 and A.32-2 summarize the plants estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by plant and county respectively.

TABLE A.32-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 10 SECONDARY ALUMINUM SMELTING
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	FRANKLIN	US REDUCTION	26.0	0.00	0.05	0.16	0.00	0.00	0.21	20	57	1
IN	WABASH	WABASH ALLOYS	34.0	0.00	0.07	0.21	0.00	0.00	0.28	27	51	1
MI	OSCEOLA	CONALCO TUBELT	19.2	0.00	0.04	0.12	0.00	0.00	0.16	14	30	1
MS	PIKE	CROFT ALUMINUM	28.3	0.00	0.06	0.17	0.00	0.00	0.23	22	62	1
NJ	UNION	VULCAN MATLS	16.6	0.00	0.03	0.10	0.00	0.00	0.14	12	27	1
OH	CUYAHOGA	ALUM SMELTING	49.4	0.00	0.10	0.30	0.00	0.00	0.41	42	80	2
OH	CUYAHOGA	WABASH ALLOYS	15.8	0.00	0.03	0.10	0.00	0.00	0.13	11	25	1
OH	ERIE	VULCAN MATLS	17.0	0.00	0.03	0.10	0.00	0.00	0.14	12	27	1
OH	LUCAS	US REDUCTION	17.4	0.00	0.04	0.11	0.00	0.00	0.14	12	28	1
Total - OH			99.6	0.00	0.20	0.61	0.00	0.00	0.82	78	160	4
PA	ALLEGHENY	VULCAN MATLS	19.3	0.00	0.03	0.09	0.00	0.00	0.13	11	25	1
Total Study Area			239.0	0.00	0.49	1.47	0.00	0.00	1.96	183	412	10

TABLE A.32-2: SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS FOR 10 SECONDARY ALUMINIUM SMELTING PLANTS
LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	FRANKLIN	All	26.0	0.00	0.05	0.16	0.00	0.00	0.21	20	57	1
IN	WABASH	All	34.0	0.00	0.07	0.21	0.00	0.00	0.28	27	51	1
MI	OSCEOLA	All	19.2	0.00	0.04	0.12	0.00	0.00	0.16	14	30	1
MS	PIKE	All	28.3	0.00	0.06	0.17	0.00	0.00	0.23	22	62	1
NJ	UNION	All	16.6	0.00	0.03	0.10	0.00	0.00	0.14	12	27	1
OH	CUYAHOGA	All	65.2	0.00	0.13	0.40	0.00	0.00	0.54	53	105	3
OH	ERIE	All	17.0	0.00	0.03	0.10	0.00	0.00	0.14	12	27	1
OH	LUCAS	All	17.4	0.00	0.04	0.11	0.00	0.00	0.14	12	28	1
Total - OH			99.6	0.00	0.20	0.61	0.00	0.00	0.82	78	160	4
PA	ALLEGHENY	All	15.3	0.00	0.03	0.09	0.00	0.00	0.13	11	25	1
Total Study Area			239.0	0.00	0.49	1.47	0.00	0.00	1.96	183	412	10

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INDUSTRY: SECONDARY NONFERROUS METALS

PLANT/FACILITY: COPPER SMELTING AND REFINING

PLANT POPULATION

Secondary copper can be produced at primary copper smelters, secondary copper smelters, as an alloy at brass and bronze mills, and at secondary copper foundries.¹ Only secondary copper smelters producing refined copper are considered here. Secondary copper produced at primary smelters and refineries is included separately in that industry. Brass and bronze mills and copper foundries were eliminated from consideration because they failed to meet the established energy consumption criteria of 100×10^9 Btu/year.

The Bureau of Mines estimates that domestic secondary copper smelters in 1980 recovered 595,000 tons of refined copper, copper alloys and other copper products from copper-based scrap.² Refined copper from copper-based scrap accounts for approximately 220,000 tons.² Approximately 43 secondary copper smelters were operating in the U.S in 1980.³ Of these secondary smelters, 8 produced refined copper, and were located east of the Mississippi.^{4,5} Only 6 of these 8 plants, however, met the energy consumption criteria of 100×10^9 Btu/year. Estimated 1980 capacities for the 6 plants ranged from 36,000 to 191,000 tons. Total estimated 1980 production of the 6 plants analyzed was 209,900 tons compared to a national total of 220,000 tons. The

smallest plant had an estimated 1980 plant production of 14,400 tons with an energy consumption of 130×10^9 Btu.

COMBUSTION PROCESSES

Generally, direct-fired energy at a secondary copper smelter is consumed during drying, insulation burning, sweating, blast furnace (cupola)/reverberatory smelting, converter smelting, and fire-refining. Of these direct-fired processes, only sweating, blast furnace/reverberatory smelting, and fire-refining (reverberatory furnace) is considered. These processes represent a typical plant configuration and meet the established energy consumption criteria.¹ Actual configurations of the plants considered are unknown. Coke is the fuel used in both the blast and reverberatory smelting furnaces.^{1,6} Sweating and fire-refining furnaces utilize coke, natural gas, fuel oil, and coal.

PRODUCTION AND FUEL CONSUMPTION

Production

Production data for this industry were not available. Estimated capacities in tons/month were available in the literature only for the U.S. smelters producing refined copper.⁴ Production for U.S. smelters producing refined copper was estimated by multiplying the plant capacities in tons/year by a 40 percent utilization factor. The utilization factor was calculated by dividing the domestic refined copper production (220,000 tons/year) by capacity (548,880 tons/year).⁴ Therefore, total estimated 1980 production of the six smelter plants analyzed was 209,900 tons with a plant range of 14,400 to 76,400 tons.

The methodology used for evaluating the remaining 35 plants (19 of which were located east of the Mississippi) was as follows: an average production rate (10,700 tons/year) for the plants was estimated by subtracting the 220,000 tons of refined copper from the 595,000 tons of total production and dividing by the number of plants (35) involved only in smelting. However, since the estimated average plant production produced an energy consumption number $<100 \times 10^9$ Btu/year, it was assumed that all plants in this group would fail to meet the established energy consumption criteria. Therefore, these 35 plants were not analyzed.

Energy Consumption - Fuel Type

Unit energy consumption for the sweating furnace, blast furnace, smelting furnace, and fire-refining reverberatory furnace are 0.43×10^6 , 2.10×10^6 , 5.92×10^6 , and 0.67×10^6 Btu/ton of product, respectively.^{1,6} Coke is the fuel used in both the blast and reverberatory smelting furnaces.^{1,6} Data on the types of fuels consumed by the sweating and fire-refining furnaces were not available; estimates were based on Census data for the industry.⁷ These estimates indicate an overall ratio of fuel use for the direct-fired processes as 89 percent coke, 7 percent natural gas, 2 percent oil, and 2 percent coal.⁷ Since plant-specific data was not available in the literature, this split was applied to both the sweating and fire-refining furnaces to each plant analyzed. Therefore, the total estimated 1980 energy consumption for the six plants analyzed was 1.91×10^{12} Btu, with a plant range of 130×10^9 to 700×10^9 Btu.

EMISSION ESTIMATES

Emission Factors

Default emission factors from the literature were assumed for all the furnaces because no other process specific factors were available.

Nitrogen oxide emissions for all four furnaces when coke is the fuel fired, were assumed to be equivalent to that of gray iron cupolas firing coke. The NO_x emission factor for coke-fired gray iron cupolas has been identified as 0.11 lb/ton of product.^{8,9} Assuming an energy consumption factor of 3.38×10^6 Btu/ton for gray iron cupolas,¹⁰ the emission factor converts to 3.25×10^{-2} lb/ 10^6 Btu. Utilizing the respective energy consumption factors for the furnaces, the NO_x emission factor converted to lb/ton of copper product for the sweating furnace, blast furnace, smelting furnace, and fire-refining furnace are 1.40×10^{-2} , 6.83×10^{-2} , 1.92×10^{-1} , and 2.18×10^{-2} , respectively, NO_x emission factors for natural gas and oil-fired sweating furnaces and fire-refining furnaces were estimated using the Mills NO_x equations based on total heat input in Btu/hr for gas and oil-fired equipment.⁹ Plant specific operating hours per year were obtained in the literature.⁴ Nitrogen oxide emissions for coal-fired sweating furnaces and fire-refining furnaces were assumed to be equivalent to that of wet bottom coal-fired boilers. The NO_x emission factor for wet bottom coal-fired boilers as obtained from the U.S. EPA's AP-42 publication is 34.0 lb/ton of coal fired.¹¹ Assuming a heating value of 25×10^6 Btu/ton

for bituminous coal,¹² the emission factor converts to 1.36 lb/10⁶ Btu. Utilizing the respective energy consumption factors, the NO_x emission factor converted to lb/ton of copper product for the sweating furnace and fire-refining furnace is 5.85×10^{-1} and 9.11×10^{-1} , respectively.

Sulfur oxide emissions for all four furnaces when coke is the fuel fired was also assumed to equivalent to that of gray iron cupolas firing coke. The SO_x emission factor for coke-fired gray iron cupolas as obtained from the U.S. EPA's AP-42 publication is 1.25 (S).¹¹ The (S) represents the sulfur content of the coke in weight percent. Assuming that coke has a 0.6 percent sulfur content¹³ and an energy consumption factor of 3.38×10^6 Btu/ton for gray iron cupolas,¹⁰ the emission factor converts to 0.22 lb/10⁶ Btu. Utilizing the respective energy consumption factors for the furnaces, the SO_x emission factor converted to lb/ton of copper product for the sweating furnace, blast furnace, smelting furnace, and fire-refining furnace are 9.46×10^{-2} , 4.62×10^{-1} , 13.0×10^{-1} , and 1.47×10^{-1} respectively. SO_x emission factors for natural gas and oil-refining furnaces as obtained from the U.S. EPA's AP-40 publication are: 0.42 lb/10⁶ ft³ natural gas and 7000 (S) lb/10³ bbl oil (where S is the sulfur content of oil in weight percent), respectively.¹⁴ The SO_x emission factors converted to lb/ton for both the sweating furnace and fire-refining furnace based on their respective energy consumption factors and heating values of 1024 Btu/ft³ for natural gas¹² and 6.3×10^6

Btu/bbl for residual fuel oil¹² are: 1.76×10^{-4} and 2.75×10^{-4} for natural gas and 0.478 (S) and 0.744 (S) for fuel oil, respectively. Sulfur oxide emissions for coal-fired sweating furnaces and fire-refining furnaces were assumed to be equivalent to that of wet bottom coal-fired boilers. The SO_x emission factor for wet bottom coal-fired boilers as obtained from the U.S. EPA's AP-42 publication is 39.0 (S) lb/ton of coal-fired.¹¹ The (S) represents the sulfur content of the coal in weight percent. Assuming a heating value of 25×10^6 Btu/ton for bituminous coal, the emission factor converted to lb/ 10^6 Btu is 1.56 (S). Utilizing the respective energy consumption factors, the SO_x emission factor converted to lb/ton of copper product for the sweating furnace and fire-refining furnace is 0.671 (S) and 1.05 (S), respectively.

Hydrocarbon emissions for all four furnaces where coke is the fuel fired were assumed to be negligible.¹¹ Hydrocarbon emission factors for natural gas and oil-fired sweating furnaces and fire-refining furnaces as obtained from the U.S. EPA's AP-40 publication are: $7.0 \text{ lb}/10^6 \text{ ft}^3$ for natural gas and $127.0 \text{ lb}/10^3 \text{ bbl oil}$, respectively.¹⁴ The HC emission factors converted to lb/ton for both the sweating furnace and fire-refining furnace based on their respective energy consumption factors and heating values of $1024 \text{ Btu}/\text{ft}^3$ for natural gas and $6.3 \times 10^6 \text{ Btu}/\text{bbl}$ for residual fuel oil are: 2.94×10^{-3} and 4.58×10^{-3} for natural gas and 8.67×10^{-3} and 1.35×10^{-2} for fuel oil, respectively.

Hydrocarbon emissions for coal-fired sweating furnaces and fire-refining furnaces were assumed to be equivalent to that of coal-fired overfeed stokers. The HC emission factor for overfeed stokers as obtained from the U.S. EPA's AP-42 publication is 0.1 lb/ton of coal-fired.¹¹ Assuming a heating value of 25×10^6 Btu/ton for bituminous coal, the emission factor converted to lb/ 10^6 Btu is 4.0×10^{-3} . Utilizing the respective energy consumption factors, the HC emission factor converted to lb/ton of copper product for the sweating furnace and fire-refining furnace is 1.72×10^{-3} and 2.68×10^{-3} , respectively.

Plant Emissions

Tables A.33-1 and A.33-2 summarize the plants estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by plant and county respectively. The range in total annual emissions in tons/year for the six plants is shown below:

	Low	High
NO_x	4	24
SO_x	19	98
HC	Negligible	

TABLE A.33-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 6 SECONDARY COPPER SMELTING
AND REFINING PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod 1000	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
St	County	Facility	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
GA	CARROLL	SOUTHWIRE	14.4	0.00	0.00	0.01	0.12	0.00	0.13	4	19	0
IL	MADISON	CHEMICO METALS	14.4	0.00	0.00	0.01	0.12	0.00	0.13	4	19	0
IL	ST CLAIR	CERRO COPPER	21.1	0.00	0.00	0.01	0.17	0.00	0.19	6	27	0
Total - IL			35.5	0.01	0.01	0.02	0.29	0.00	0.32	11	46	0
NJ	MIDDLESEX	US METALS REF	76.4	0.01	0.02	0.05	0.62	0.00	0.70	24	98	0
PA	BERKS	READING METALS	33.6	0.01	0.01	0.02	0.27	0.00	0.31	10	45	0
SC	LEXINGTON	MASSAU RECYCL	50.0	0.01	0.01	0.03	0.40	0.00	0.46	16	66	0
Total Study Area			209.9	0.04	0.05	0.14	1.69	0.00	1.91	66	275	1

TABLE A.33-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 6 SECONDARY COPPER
SMELTING AND REFINING PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

		Prod 1000	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year			
State	County	Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC	
GA	CARROLL	All	14.4	0.00	0.00	0.01	0.12	0.00	0.13	4	19	0
IL	MADISON	All	14.4	0.00	0.00	0.01	0.12	0.00	0.13	4	19	0
IL	ST CLAIR	All	21.1	0.00	0.00	0.01	0.17	0.00	0.19	6	27	0
Total - IL			35.5	0.01	0.01	0.02	0.29	0.00	0.32	11	46	0
NJ	MIDDLESEX	All	76.4	0.01	0.02	0.05	0.62	0.00	0.70	24	98	0
PA	BERKS	All	33.6	0.01	0.01	0.02	0.27	0.00	0.31	10	45	0
SC	LEXINGTON	All	50.0	0.01	0.01	0.03	0.40	0.00	0.46	16	66	0
Total Study Area			209.9	0.04	0.05	0.14	1.69	0.00	1.91	66	275	1

REFERENCES

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INDUSTRY: SECONDARY NONFERROUS METALS

PLANT/FACILITY: LEAD SMELTERS

PLANT POPULATION

The secondary lead smelting industry processes lead-bearing scrap to produce a variety of products.¹ Secondary lead is produced at primary or secondary smelters and refineries; that produced at primary smelters is included separately in that industry.

The Bureau of Mines estimates that 58 secondary lead plants² recovered 740,800 tons³ of metallic lead and lead alloys in 1980. Only 2 of the 58 secondary lead smelters were located east of the Mississippi and met the established energy consumption criteria of 100×10^9 Btu/year. Sixteen additional plants, (10 of which were located east of the Mississippi) did not meet the minimum energy consumption requirement. The estimated 1980 capacities and production of these two plants were 50,000 and 60,000 tons, and 33,500 and 40,200 tons, respectively. The smaller of the two plants had a direct-fired energy consumption of 110×10^9 Btu.

COMBUSTION PROCESSES

The type of processing equipment used varies from plant to plant depending on the desired end product. The major direct-fired process equipment in this industry includes blast furnaces, reverberatory furnaces. Based on available energy consumption

data and a typical plant processing configuration, only the blast and reverberatory furnaces were considered.^{1,4} Coke is the primary fuel direct-fired in the blast furnace, while natural gas or fuel oil is generally direct-fired in the reverberatory furnace.^{1,4}

PRODUCTION AND FUEL CONSUMPTION

Production

Production capacities are available for most plants (42 out of 58 plants). Plant specific production for these plants were estimated by applying a utilization factor of 67 percent. This factor was determined based on the fact that the secondary lead plants with a published production capacity of 996,300 tons in 1980, represented approximately 90 percent of the total 1980 production of 740,800 tons.^{2,3,5}

The remaining 16 plants, 10 of which were located east of the Mississippi, accounts for the remaining 10 percent of 1980 production, or 74,800 tons. The average production rate for these plants was 4,600 tons. Since this average production rate is far below the established energy consumption cut-off of 100×10^9 Btu/yr, and it is unlikely that any one plant would be above the energy consumption cut-off, these 16 plants were excluded from consideration.

Total 1980 production of the two secondary lead smelters analyzed was estimated to be 73,700 tons. The individual plant production estimates are 33,500 and 40,200 tons, respectively.

Energy Consumption - Fuel Type

Unit energy consumption for the reverberatory furnace and blast furnace are 4.76×10^6 and 1.64×10^6 Btu/ton of product, respectively.¹ The blast furnace is fired by coke, while the reverberatory furnace is generally fired by natural gas or oil. Since data concerning the actual percentage of the two fuels being fired by lead reverberatory furnaces was not available in the literature, a percentage split was estimated based on Census data for the industry. These estimates indicate an overall ratio of fuel use in lead reverberatory furnaces as 75 percent natural gas and 25 percent fuel oil.⁶ This split was applied to the reverberatory furnaces for each plant analyzed. In addition, soft/semisoft lead and hard lead each account for about 50 percent of total production.¹ Assuming all soft and semisoft lead is produced in a reverberatory furnace and hard lead in a blast furnace, a 50/50 plant production split between the two furnaces was applied to each plant analyzed.

Therefore, the total 1980 energy consumption for the two plants is estimated to be 240×10^9 Btu. The individual plant energy consumptions are 110×10^9 and 130×10^9 Btu/year, respectively.

EMISSION ESTIMATES

Emission Factors

Nitrogen oxide emissions for natural gas and oil-fired reverberatory furnaces were estimated using the Mills NO_x equations based on total heat input in Btu/hr for natural gas and

oil-fired equipment.⁷ The plants were assumed to operate 5870 hours/year. This was obtained by multiplying the total available hours in a year by the utilization factor of 67 percent. Nitrogen oxide emissions for coke-fired blast furnaces was assumed to be equivalent to that of gray iron cupolas firing coke. The NO_x emission factor for coke-fired gray iron cupolas have been identified as 0.11 lb/ton of product.^{7,8} Assuming an energy consumption factor of 3.38×10^6 Btu/ton for gray iron cupolas,⁹ the emission factor converts to lb/ 10^6 Btu is 3.25×10^{-2} . Utilizing the energy consumption factor of 1.64×10^6 Btu/ton for blast furnaces, the emission factor converted to lb/ton of product is 5.33×10^{-2} .

The SO_x emission factors for natural gas and oil-fired reverberatory furnaces as obtained from the U.S. EPA's AP-40 publication are: $0.42 \text{ lb}/10^6 \text{ ft}^3$ natural gas and $7000 (S) \text{ lb}/10^3 \text{ bbl oil}$ (where S is the sulfur content of oil in weight percent), respectively.¹⁰ The SO_x emission factors converted to lb/ton for the reverberatory furnace based on its energy consumption factor of 4.76×10^6 Btu/ton and heating values of $1024 \text{ Btu}/\text{ft}^3$ for natural gas¹¹ and $6.3 \times 10^6 \text{ Btu}/\text{bbl}$ for residual fuel oil¹¹ are: 1.95×10^{-3} and $5.29 (S)$ for natural gas and fuel oil, respectively. SO_x emissions for coke-fired blast furnaces was also assumed to be equivalent to that of gray iron cupolas firing coke. The SO_x emission factor for coke fired gray iron cupolas as obtained from the U.S. EPA's AP-42 publication is $1.25 (S)$.¹² The (S) represents the sulfur

content of the coke in weight percent. Assuming that coke has a 0.6 percent sulfur content¹³ and an energy consumption factor of 3.38×10^6 Btu/ton for gray iron cupolas, the emission factor converted to lb/ 10^6 Btu is 0.22. Utilizing the 1.64×10^6 Btu/ton energy consumption factor for blast furnaces, the SO_x emission factor converted to lb/ton of product is 3.61×10^{-1} .

The HC emission factors for natural gas and oil-fired reverberatory furnaces as obtained from the U.S. EPA's AP-40 publication are: 7.0 lb/ 10^6 ft³ natural gas and 127.0 lb/ 10^3 bbl oil, respectively.¹⁰ The HC emission factors converted to lb/ton for the reverberatory furnace based on its energy consumption factor and heating values of 1024 Btu/ft³ for natural gas and 6.3×10^6 Btu/bbl for residual fuel oil are: 3.25×10^{-2} and 9.60×10^{-2} for natural gas and fuel oil, respectively. The HC emissions for coke-fired blast furnaces was assumed to be negligible.¹²

Plant Emissions

The range in total annual emissions in tons/year for the two plants is shown below:

	Low	High
NO_x	7	9
SO_x	19	29
HC	Negligible	

Table A.34-1 summarizes the 2 plants' estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by county.

TABLE A.34-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR TWO SECONDARY LEAD SMELTER PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

			Prod	Fuel Consumption, Trillion Btu/Year						Emissions, Tons/Year		
St	County	Facility	1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	PIKE	All	40.2	0.00	0.07	0.02	0.03	0.00	0.13	9	29	0
NJ	SALEM	All	33.5	0.00	0.06	0.02	0.03	0.00	0.11	7	19	0
Total Study Area			73.7	0.00	0.13	0.04	0.06	0.00	0.24	16	48	0

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INDUSTRY: PRIMARY ALUMINUM FABRICATION

PLANT/FACILITY: ALUMINUM SHEET, PLATE AND FOIL

PLANT POPULATION

In 1980, approximately 63 aluminum sheet, plate, and foil fabrication plants operated in the U.S.; 51 were located east of the Mississippi.¹ However, only 47 out of the 51 plants met the established energy consumption criteria of 100×10^9 Btu/year. Therefore, the remaining four plants were excluded from further consideration. Capacity data were not available for the plants evaluated. Hence, production was estimated from shipments data, which indicated that total estimated 1980 production of the 47 plants was 2.65×10^6 tons,¹ compared with a national total of 3.4×10^6 tons.² The range in production was from 4,100 to 333,900 tons and the smallest plant had an estimated 1980 direct-fired energy consumption of 100×10^9 Btu.

COMBUSTION PROCESSES

During aluminum fabrication, direct-fired energy is consumed in the reverberatory melting furnace and the heat treating furnace.³

The reverberatory furnace is a box-like direct-fired furnace with a holding capacity of 10 to 50 tons.³ Fabricating plants generally operate these furnaces near 100 percent capacity. Process rates of modern reverberatory furnaces may be as high as

5 tons per hour.³ Reverberatory furnaces are normally fired with either natural gas or oil.^{3,4}

Heat treating furnaces employ two firing methods. In some furnaces the burners are encased in radiant tubes, which prevent combustion products from contacting the furnace charge. Radiant tube furnaces are used in cases where high product quality is necessary. In the second firing configuration the burners are located in the side walls and discharge directly into the fire box allowing products of combustion to contact the furnace charge. Heat treating furnaces are fired exclusively with natural gas.^{3,4}

PRODUCTION AND FUEL CONSUMPTION

Production

Plant specific capacity and production data were not available. Plant production was estimated by apportioning the total U.S. production of 3.4×10^6 tons for 1980 to each plant based on its share of the U.S. market using the EIS report¹ on shipments. This report estimates each company's shipments and their share (based on shipments) of the U.S. market. Assuming that each company's market share (of total U.S. shipments) is directly equatable with production, plant-specific production was estimated by multiplying this share or percentage times the total U.S. production. Total estimated 1980 production for the 47 plants was 2.65×10^6 tons, with a plant range of 4,100 to 333,900 tons.

Energy Consumption - Fuel Type

The reverberatory melting furnace consumes 11.0×10^6 Btu of direct-fired energy per ton of product.^{3,4} This furnace is

fired with either natural gas or oil. The overall division between these two fuels is generally 90 percent natural gas and 10 percent fuel oil.^{3,4} Since plant specific data were not available, however, it was assumed that only natural gas was fired. The heat treating furnace consumes an average 13.6×10^6 Btu of direct-fired energy per ton of product, and is fired exclusively with natural gas.^{3,4} The total estimated 1980 energy consumption for the 47 plants was 65.3×10^{12} Btu, with a plant range of 100×10^9 to $8,200 \times 10^9$ Btu.

EMISSION FACTORS

Emission Factors

Industrial combustion default emission factors from published literature were used for both the reverberatory melting furnace and heat treating furnace.

Emissions of NO_x for both furnace types were estimated using the Mills NO_x equation based on total heat input in Btu/h for gas-fired equipment.⁵ Industry experts report that the plants are currently operating approximately 4000 hours/year.⁶

The SO_x and HC emission factors for natural gas fired heat treating furnaces and reverberatory furnaces as obtained from the U.S. EPA's AP-40 publication are: 0.42 and $7.0 \text{ lb}/10^6 \text{ ft}^3$ natural gas, respectively.⁷ The emission factors converted to lb/ton for the heat treating furnace based on its energy consumption of 13.6×10^6 Btu/ton and a heating value of $1024 \text{ Btu}/\text{ft}^3$ for natural gas⁸ are: 5.58×10^{-3} and 9.30×10^{-2} for SO_x and HC, respectively.

For a natural gas-fired reverberatory furnace with an energy consumption of 11.0×10^6 Btu/ton the emission factors converted to lb/ton are: 4.51×10^{-3} and 7.52×10^{-2} for SO_x and HC, respectively.

Plant Emissions

The range in total annual emissions in tons/year for the 47 plants are shown below:

	Low	High
NO_x	7	1,265
SO_x	Neg.	2
HC	Neg.	28

Tables A.35-1 and A.35-2 summarize the plants estimated production, energy consumption by fuel, and NO_x , SO_x , and HC emissions by plant and county respectively.

TABLE A.35-1. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION,
AND NO_x, SO_x, AND HC EMISSIONS FOR 47 ALUMINUM SHEET, PLATE, AND FOIL
PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	COLBERT	REYNOLDS METALS	174.8	0.00	0.00	4.30	0.00	0.00	4.30	593	1	15
AL	JACKSON	REVERE COPPER	82.3	0.00	0.00	2.02	0.00	0.00	2.02	246	0	7
AL	MORGAN	DECATUR ALUM	53.7	0.00	0.00	1.32	0.00	0.00	1.32	149	0	5
Total - AL			310.8	0.00	0.00	7.64	0.00	0.00	7.64	988	2	26
CT	FAIRFIELD	REPUBLIC FOIL	15.0	0.00	0.00	0.37	0.00	0.00	0.37	33	0	1
CT	NEW HAVEN	UNITED ALUMINUM	11.2	0.00	0.00	0.28	0.00	0.00	0.28	24	0	1
Total - CT			26.2	0.00	0.00	0.64	0.00	0.00	0.64	57	0	2
IL	COOK	REYNOLDS METALS	174.8	0.00	0.00	4.30	0.00	0.00	4.30	593	1	15
IL	GRUNDY	ALUMAX MILL	77.2	0.00	0.00	1.90	0.00	0.00	1.90	228	0	6
IL	LAKE	ALUMINUM MILLS	10.9	0.00	0.00	0.27	0.00	0.00	0.27	23	0	1
IL	MADISON	HIGHLAND MFG	15.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
Total - IL			278.5	0.00	0.00	6.85	0.00	0.00	6.85	879	1	23
IN	VIGO	ANACONDA ALUM	170.0	0.00	0.00	4.18	0.00	0.00	4.18	574	1	14
KY	HANCOCK	MARTIN MARIETTA	155.7	0.00	0.00	3.83	0.00	0.00	3.83	518	1	13
KY	JEFFERSON	ANACONDA ALUM	57.3	0.00	0.00	1.41	0.00	0.00	1.41	161	0	5
KY	JEFFERSON	ANACONDA ALUM	49.0	0.00	0.00	1.20	0.00	0.00	1.20	134	0	4
KY	JEFFERSON	REYNOLDS METALS	54.1	0.00	0.00	1.33	0.00	0.00	1.33	150	0	5
KY	JEFFERSON	ROLLER DIE	7.5	0.00	0.00	0.18	0.00	0.00	0.18	15	0	1
Total - KY			323.7	0.00	0.00	7.96	0.00	0.00	7.96	979	2	27
MD	BALTIMORE	ATLANTIC COPPER	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
NH	ROCKINGHAM	ZURBACH STEEL	13.3	0.00	0.00	0.33	0.00	0.00	0.33	29	0	1
NJ	CAMDEN	ALUMINUM SHAPES	15.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
NJ	GLOUCESTER	EXCO PRODUCTS	23.8	0.00	0.00	0.59	0.00	0.00	0.59	58	0	2
NJ	MURSON	SIDAL ALUMINUM	7.8	0.00	0.00	0.19	0.00	0.00	0.19	16	0	1
NJ	MIDDLESEX	ALCAN ALUMINUM	30.6	0.00	0.00	0.75	0.00	0.00	0.75	77	0	3
NJ	MIDDLESEX	NEW JERSEY ALUM	13.9	0.00	0.00	0.34	0.00	0.00	0.34	31	0	1
NJ	SOMERSET	MEADOWBROOK INV	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
NJ	UNION	METAL FOIL PROD	4.1	0.00	0.00	0.10	0.00	0.00	0.10	7	0	0
Total - NJ			100.6	0.00	0.00	2.48	0.00	0.00	2.48	232	1	8
NY	KINGS	REVERE COPPER	9.5	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
NY	OSWEGO	ALCAN ALUMINUM	110.8	0.00	0.00	2.73	0.00	0.00	2.73	348	1	9
Total - NY			120.4	0.00	0.00	2.96	0.00	0.00	2.96	368	1	10

(continued)

TABLE A.35-1 (continued)

St	County	Facility	Prod	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
			1000 Tons	Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
NC	FORSYTHE	RJR ARCHER	329.8	0.00	0.00	8.11	0.00	0.00	8.11	1,247	2	28
NC	ROMAN	REPUBLIC FOIL	21.8	0.00	0.00	0.54	0.00	0.00	0.54	52	0	2
Total - NC			351.6	0.00	0.00	8.65	0.00	0.00	8.65	1,299	2	30
OH	COLUMBIANA	STANDARD ALUM	42.2	0.00	0.00	1.04	0.00	0.00	1.04	112	0	4
OH	MAHONING	CALEX CORP	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
OH	MAHONING	IDI METALS	7.8	0.00	0.00	0.19	0.00	0.00	0.19	16	0	1
OH	MONROE	CONALCO	97.2	0.00	0.00	2.39	0.00	0.00	2.39	299	0	8
OH	TRUMBULL	ALCAN SHEET	43.2	0.00	0.00	1.06	0.00	0.00	1.06	116	0	4
Total - OH			195.2	0.00	0.00	4.80	0.00	0.00	4.80	551	1	16
PA	CHESTER	ALLIANCE ALUM	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
PA	LANCASTER	HOWMET CORP	68.0	0.00	0.00	1.67	0.00	0.00	1.67	197	0	6
PA	LEBANON	ALCOA	25.8	0.00	0.00	0.64	0.00	0.00	0.64	63	0	2
Total - PA			98.6	0.00	0.00	2.43	0.00	0.00	2.43	269	0	8
RI	PROVIDENCE	AM SCHALER	5.4	0.00	0.00	0.13	0.00	0.00	0.13	10	0	0
SC	GREENVILLE	JM TULL METAL	10.9	0.00	0.00	0.27	0.00	0.00	0.27	23	0	1
TN	ANDERSON	SPRAGUE ELEC	8.8	0.00	0.00	0.22	0.00	0.00	0.22	18	0	1
TN	BLOUNT	ALCOA	129.9	0.00	0.00	3.20	0.00	0.00	3.20	419	1	11
TN	CARROLL	RJR ARCHER	21.1	0.00	0.00	0.52	0.00	0.00	0.52	50	0	2
TN	MADISON	CONSOL ALUM	48.6	0.00	0.00	1.20	0.00	0.00	1.20	133	0	4
Total - TN			208.4	0.00	0.00	5.13	0.00	0.00	5.13	620	1	18
VA	HENRICO	REYNOLDS METALS	24.5	0.00	0.00	0.60	0.00	0.00	0.60	59	0	2
VA	HENRICO	REYNOLDS METALS	29.6	0.00	0.00	0.73	0.00	0.00	0.73	74	0	2
Total - VA			54.1	0.00	0.00	1.33	0.00	0.00	1.33	134	0	5
WV	JACKSON	KAISER ALUM	333.9	0.00	0.00	8.21	0.00	0.00	8.21	1,265	2	28
WV	MARION	ALCAN ALUM	37.1	0.00	0.00	0.91	0.00	0.00	0.91	97	0	3
Total - WV			370.9	0.00	0.00	9.13	0.00	0.00	9.13	1,362	2	31
WI	FOND DU LAC	MID-STATES ALUM	9.5	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
Total Study Area			2,652.7	0.00	0.00	65.26	0.00	0.00	65.26	8,402	13	223

TABLE A.35-2. SUMMARY OF 1980 PRODUCTION, ENERGY CONSUMPTION, AND
NO_x, SO_x, AND HC EMISSIONS BY COUNTY, FOR 47 ALUMINUM SHEET, PLATE,
AND FOIL PLANTS LOCATED EAST OF THE MISSISSIPPI RIVER

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
AL	COLBERT	All	174.8	0.00	0.00	4.30	0.00	0.00	4.30	593	1	15
AL	JACKSON	All	82.3	0.00	0.00	2.02	0.00	0.00	2.02	246	0	7
AL	MORGAN	All	53.7	0.00	0.00	1.32	0.00	0.00	1.32	149	0	5
Total - AL			310.8	0.00	0.00	7.64	0.00	0.00	7.64	988	2	26
CT	FAIRFIELD	All	15.0	0.00	0.00	0.37	0.00	0.00	0.37	33	0	1
CT	NEW HAVEN	All	11.2	0.00	0.00	0.28	0.00	0.00	0.28	24	0	1
Total - CT			26.2	0.00	0.00	0.64	0.00	0.00	0.64	57	0	2
IL	COOK	All	174.8	0.00	0.00	4.30	0.00	0.00	4.30	593	1	15
IL	GRUNDY	All	77.2	0.00	0.00	1.90	0.00	0.00	1.90	228	0	6
IL	LAKE	All	10.9	0.00	0.00	0.27	0.00	0.00	0.27	23	0	1
IL	MADISON	All	15.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
Total - IL			278.5	0.00	0.00	6.85	0.00	0.00	6.85	879	1	23
IN	VIGO	All	170.0	0.00	0.00	4.18	0.00	0.00	4.18	574	1	14
KY	HANCOCK	All	155.7	0.00	0.00	3.83	0.00	0.00	3.83	518	1	13
KY	JEFFERSON	All	168.0	0.00	0.00	4.13	0.00	0.00	4.13	460	1	14
Total - KY			323.7	0.00	0.00	7.96	0.00	0.00	7.96	979	2	27
MD	BALTIMORE	All	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
NH	ROCKINGHAM	All	13.3	0.00	0.00	0.33	0.00	0.00	0.33	29	0	1
NJ	CAMPDEN	All	15.6	0.00	0.00	0.38	0.00	0.00	0.38	35	0	1
NJ	GLOUCESTER	All	23.8	0.00	0.00	0.59	0.00	0.00	0.59	58	0	2
NJ	HUDSON	All	7.8	0.00	0.00	0.19	0.00	0.00	0.19	16	0	1
NJ	MIDDLESEX	All	44.5	0.00	0.00	1.10	0.00	0.00	1.10	108	0	4
NJ	SOMERSET	All	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
NJ	UNION	All	4.1	0.00	0.00	0.10	0.00	0.00	0.10	7	0	0
Total - NJ			100.6	0.00	0.00	2.48	0.00	0.00	2.48	232	1	8
NY	KINGS	All	9.5	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
NY	OSWEGO	All	110.8	0.00	0.00	2.73	0.00	0.00	2.73	348	1	9
Total - NY			120.4	0.00	0.00	2.96	0.00	0.00	2.96	368	1	10
NC	FORSYTHE	All	329.8	0.00	0.00	8.11	0.00	0.00	8.11	1,247	2	28
NC	ROWAN	All	21.8	0.00	0.00	0.54	0.00	0.00	0.54	52	0	2
Total - NC			351.6	0.00	0.00	8.65	0.00	0.00	8.65	1,299	2	30

(continued)

TABLE A.35-2 (continued)

St	County	Facility	Prod 1000 Tons	Fuel Consumption, Trillion Btu/Year					Emissions, Tons/Year			
				Coal	Oil	Nat Gas	Coke	Other	Total	NOx	SOx	HC
OH	COLUMBIANA	All	42.2	0.00	0.00	1.04	0.00	0.00	1.04	112	0	4
OH	MAHONING	All	12.6	0.00	0.00	0.31	0.00	0.00	0.31	24	0	1
OH	MONROE	All	97.2	0.00	0.00	2.39	0.00	0.00	2.39	299	0	8
OH	TRUMBULL	All	43.2	0.00	0.00	1.06	0.00	0.00	1.06	116	0	4
Total - OH			195.2	0.00	0.00	4.80	0.00	0.00	4.80	551	1	16
PA	CHESTER	All	4.8	0.00	0.00	0.12	0.00	0.00	0.12	9	0	0
PA	LANCASTER	All	68.0	0.00	0.00	1.67	0.00	0.00	1.67	197	0	6
PA	LEBANON	All	25.8	0.00	0.00	0.64	0.00	0.00	0.64	63	0	2
Total - PA			98.6	0.00	0.00	2.43	0.00	0.00	2.43	269	0	8
RI	PROVIDENCE	All	5.4	0.00	0.00	0.13	0.00	0.00	0.13	10	0	0
SC	GREENVILLE	All	10.9	0.00	0.00	0.27	0.00	0.00	0.27	23	0	1
TN	ANDERSON	All	8.8	0.00	0.00	0.22	0.00	0.00	0.22	18	0	1
TN	BLOUNT	All	129.9	0.00	0.00	3.20	0.00	0.00	3.20	419	1	11
TN	CARROLL	All	21.1	0.00	0.00	0.52	0.00	0.00	0.52	50	0	2
TN	MADISON	All	48.6	0.00	0.00	1.20	0.00	0.00	1.20	133	0	4
Total - TN			208.4	0.00	0.00	5.13	0.00	0.00	5.13	620	1	16
VA	HENRICO	All	54.1	0.00	0.00	1.33	0.00	0.00	1.33	134	0	5
Total - VA			54.1	0.00	0.00	1.33	0.00	0.00	1.33	134	0	5
WV	JACKSON	All	333.9	0.00	0.00	8.21	0.00	0.00	8.21	1,265	2	28
WV	MARION	All	37.1	0.00	0.00	0.91	0.00	0.00	0.91	97	0	3
Total - WV			370.9	0.00	0.00	9.13	0.00	0.00	9.13	1,362	2	31
WI	FOND DU LAC	All	9.5	0.00	0.00	0.23	0.00	0.00	0.23	20	0	1
Total Study Area			2,652.7	0.00	0.00	65.26	0.00	0.00	65.26	8,402	13	223

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APPENDIX B

A. COMPREHENSIVE INVENTORY OF
AIR POLLUTION SOURCES

Prepared by
Paul W. Spaite©*

Pursuant to U.S. Environmental Protection Agency
Contract No. 68-02-3197

April 25, 1982
(Revised August 1, 1983)

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A COMPREHENSIVE INVENTORY OF AIR POLLUTION SOURCES

INTRODUCTION

Since air pollution was first addressed by the Federal government on a national scale in the mid-1950's, there has been concern over identification and ranking of sources of pollution, from the standpoint of the seriousness of their contribution to overall pollution levels. In the earliest days attention was focused on problems perceived to be of greatest importance. First, motor vehicle emissions, then sulfur oxides from power plants and later, other major pollution sources came under consideration. By the late 1960's, the most significant air pollution sources (judged in terms of national annual emissions of major pollutants such as NO_x and SO_x) had been identified and put in some perspective. Unfortunately, there was still no data bank that contained information on the size, type and amount of pollution, location, etc., for all major air pollution sources. Work to develop a more comprehensive inventory was begun in the late 1960's and early 1970's and was provided impetus by enactment of the Clean Air Act of 1970. The Act required development of State Implementation Plans, which in turn required considerably more information than was applicable on the population of sources within many states. The need for further information triggered source inventory activities on the part of both the State and

Federal groups. In 1971 the National Emissions Data System (NEDS) was established to provide a comprehensive data bank containing information on pollutant discharges from all types of area and point sources. Data generated primarily by State agencies have been incorporated in what is basically a "bottom-up" inventory. Data are supplied by the States and entered in the NEDS computerized data base for general use. The quality of the data is controlled by the adequacy of resources available to the State to collect information from the operators of the facilities producing pollution. While input data are to some extent screened, the accuracy of the various data base elements has not been well defined. Some who have used NEDS feel that certain parts, such as the data on power plants and iron and steel plants, are well documented. Data for other more fragmented categories, many of which are associated with small sources, such as foundries, industrial boilers, etc. appear to be poorly documented. Hence, it appears that the State agencies have never supplied NEDS the detailed information needed for an inventory of uniform accuracy.

Over the years, the NEDS has served the needs that have arisen and any quality problems that may exist do not appear to have caused serious problems. In the past several years, however, the need for better and more comprehensive regional and local inventories has been considered in several quarters. The data base for industrial and commercial boilers, for example, has been assessed and is felt to be inadequate, considering the nature of the pollution problem they are not believed to present. Several

studies, by EPA and others, have put this problem in as much perspective as the available data permits. DOE efforts to conduct a "Major Fuel Burning Installation" survey that could have provided useful perspective for major facilities was a limited success. Plans for a follow-up survey have been curtailed as an economy measure. Hence, there remains a gap in the information needed for full understanding of the problem. Studies of acid rain have also generated pressure for more accurate inventory data. Earlier assessments, that suggested large coal-burning sources were the major contributors to acid rain, are being questioned. The search for data on emissions from small sources to assess the role of local sources on regional pollution has been disappointing. At present, a number of groups have been searching for better answers.

The need for an independently derived, comprehensive, regionalized source inventory for a variety of uses was considered early in the present "NO_x reassessment" project being developed by IERL/RTP. It was decided to investigate the feasibility of a "top down" assessment that would utilize data on energy consumption that have been developed and refined in recent years to develop an inventory of fuel consumption* that would not be primarily

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* The investigation was limited to combustion sources for demonstration purposes. It was, however, conducted in a manner that would allow conversion of fuel burning estimates to pollutant discharges. Also, it is expected the method investigated would be applicable to other types of inventories such as VOC sources.

dependent on information supplied by fuel users. The investigation that followed demonstrated the practicality of developing State or regional inventories that would be more complete than any done previously in identification and location of major combustion sources. Also, it demonstrated the feasibility of developing fuel consumption and pollution production estimates for individual facilities.

THE GENERAL APPROACH

The approach as it has been conceived is novel in that it will begin with an analysis of all consumption of major fossil fuels to:

- 1) identify all fuel usage categories, and
- 2) identify the kinds of combustion equipment used within each category.

This analysis will provide a frame of reference for the balance of the study and will permit using an energy accounting methodology to quantify the degree to which the inventoried sources in individual consuming sectors are complete and representative of the total population for the sector.

As a first step, the latest data on fuel consumption available by consuming sector (residential, commercial, industrial, electric utility, and transportation) will be broken down into major usage categories. The first subdivisions for analysis and the amounts of fuel represented by each sector-fuel type category are shown in Table A-1. These categories represent almost 95 percent of the total of 67.7×10^{15} Btu of fossil fuel burned in

1979. The balance of about 5 percent is used in applications too small to be of concern or in applications that do not directly contribute to pollution of ambient air (e.g., aircraft fuel, seagoing vessels, etc.).

Fuel consumption and pollution emission studies in recent years have produced the data necessary to further divide the categories in Table B-1 according to usage. For example, the residential sector historically consumes gas for space heating (70%), water heating (21%), and cooking (7%), with the balance (2%) being used for clothes drying. Most other categories in Table B-1 lend themselves to similar analysis with data that are now available for energy usage. In addition, individual categories lend themselves to more detailed analysis in which major types of combustion equipment for each category are identified, e.g., the gas burned for residential space heating can be assessed to determine the extent to which different types of space heating equipment (hot air furnace, steam, hot water, and others) are employed.

In summary, it appears that except for the industrial sector, all sectors can be analyzed without unreasonable effort to develop combustion source inventories that are translatable into emission estimates. Most categories except industrial and utility will involve area sources. For the utility sector all plants with boilers greater than 50 MW in capacity will be treated as major point sources. This will involve investigating 400 to 500 plants for which extensive data are available from the Federal Power

TABLE B-1. FOSSIL FUEL BURNING BY CONSUMING SECTOR

Sector	Fuel	Quantity, 10 ¹² Btu
Residential	Gas (natural and LPG)	5,511
	Oil (distillate and kerosene)	1,842
Commercial	Gas (natural and LPG)	2,917
	Oil (distillate)	574
	Oil (residual)	511
Transportation	Gas (natural and LPG)	619
	Oil (distillate)	2,858
	Motor gasoline	13,221
Electric utility	Gas (natural)	3,609
	Oil (light distillate and jet fuel)	288
	Oil (residual)	3,060
	Coal	11,263
Industrial	Gas (natural and LPG)	10,143
	Oil (distillate and kerosene)	1,883
	Oil (residual)	1,674
	Coal	3,702
Total		63,675

Commission, hence, no problems in this connection are anticipated. Thus, the problems in assessing all fuel combustion are mainly those associated with the industrial sector.

APPROACH TO INDUSTRIAL ASSESSMENT

The many analyses of industrial energy consumption that have been conducted in recent years present data that are either broad and general (e.g., overall energy consumption for industry sectors) or provide background on only a part of the total problem (e.g., industrial boilers). The present study will be the first to take overall energy consumption by industry and divide it into segments for orderly analysis of the combustor population. The approach to be used is discussed briefly below, beginning with a discussion of fuel use data for 1977.*

Fuel Consumption by Fuel Type and Industry Group

All industrial consumption of fossil fuel amounted to about 17.7×10^{15} Btu in 1977. Consumption of electricity amounted to the fuel equivalent of about 7.0×10^{15} Btu, bringing the total industrial consumption to about 24.7×10^{15} Btu. This consumption is shown by fuel type and major industry group, as defined by the Standard Industrial Classification Manual (SIC's) in Table B-2. All values except those in the "Non-purchased fuels" column are from the 1977 Census of Manufacturers conducted by the Bureau of Census. Data for non-purchased fuels were supplied by industrial sources. Non-purchased fuels account for about 7.5×10^{15} Btu.

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* More recent data will be used for the study. 1977 data were used here for convenience.

TABLE B-2. FUEL AND ELECTRICITY USED IN MANUFACTURING

Industry	Electricity ^a	Distillate oil	Residual oil	Coal	Coke & Brexze	Natural gas	Other ^{b,c}	Sub-total	Non-purchased fuels	Total
20 Food and kindred	820.4	75.3	120.4	88.7	1.4	436.7	93.3 (82.4)	1236.2	-	1236.2
21 Tobacco	13.2	1.6	5.5	7.0 ^d	-	2.4	-	29.7	-	29.7
22 Textiles	289.9	29.0	73.2	31.6	-	75.8	35.4 (33.5)	534.9	-	534.9
23 Apparel	69.5	4.5	4.2	1.8	-	15.6	16.9 (2.1)	112.5	-	112.5
24 Lumber and wood	169.6	33.6	15.3	17.9 ^d	-	65.5	40.3 (40.3)	342.2	-	342.2
25 Furniture	43.7	5.3	2.8	2.9	-	18.4	9.1 (8.6)	82.2	-	82.2
26 Paper	486.1	33.4	472.8	226.9	-	358.4	64.3 (61.5)	1624.4	953 ^e	2577.4
27 Printing	110.8	5.9	2.8	12.0 ^d	-	29.1	6.5 (6.5)	167.1	-	167.1
28 Chemicals	1565.8	118.9	286.2	342.1	59.0 ^{j,f}	1519.6	141.9 (143.9)	4035.0	2479 ^g	6514.5
29 Petroleum	316.7	22.4	61.0	4.8	-	1076.2	12.9 (12.9)	1494.0	2176 ^h	3670.0
30 Rubber	237.0	18.5	47.2	23.9	-	73.0	32.7 (28.1)	432.3	-	432.3
31 Leather	35.1	2.1	5.3	1.2	-	5.6	4.0 (3.8)	33.3	-	33.3
32 Stone, clay, glass	323.7	80.9	82.2	344.4	9.7	536.1	93.3 (75.8)	1470.3	-	1470.3
33 Primary metals	1656.2	72.5	259.6	135.4	496.2	927.3	110.2 (106.0)	3657.4	1456.1	5113.5
34 Fabricated metals	277.3	27.2	22.2	10.8	1.6	188.7	54.7 (50.1)	582.5	-	582.5
35 Machinery	298.8	20.0	21.6	18.5	2.8	131.0	48.6 (44.2)	541.3	-	541.3
36 Electronics	262.2	16.1	15.2	14.3	0.3	86.4	31.8 (29.2)	426.3	-	426.3
37 Transportation	325.3	16.6	35.2	48.3	5.4	140.9	37.8 (36.2)	609.5	-	609.5
38 Instruments	58.2	3.4	9.3	25.8 ^d	-	18.1	2.9 (2.9)	117.7	-	117.7
39 Miscellaneous	43.4	4.4	5.3	7.4 ^d	-	15.1	2.8 (2.8)	78.4	-	78.4
Total	6964.9	591.6	1547.3	1365.7	576.4	5719.9	541.9	17607.6	7064.1	24671.7

Note: All base numbers are from the Bureau of Census Annual Survey of Manufacturers, 1977, Part 1. Conversion factors are as follows:
 Coal - 26.194E6 Btu/ton; Coke - 25.993E6 Btu/ton; Residual oil - 6.285E6 Btu/bbl; Distillate oil - 5.824E6 Btu/bbl; Natural gas - 1024 Btu/ft³; Other - 478E3 Btu/S.

^aElectric quantities were converted from kWh to Btu by the factor 10500 Btu/kWh.

^bDifferences in reported fuels and the total Census quantities were adjusted in the "other" fuels column.

^cItems in parenthesis represent the total as indicated by Census Data.

^dFigure not reported by the Census; derived by difference.

^eByproduct fuel as reported by API (5).

^fActual reported coking coal use was 85×10^{12} Btu (6); assuming 70 percent conversion the coke consumption would be 59.5×10^{12} Btu.

^gFeedstock as reported by Shell (6).

^hByproduct as reported by the Bureau of Census (8).

ⁱEstimated by PEDCo, based on 1978 DOE data (7).

This includes byproduct fuels in the paper industry (953×10^{12} Btu), feedstocks for the chemical industry (2479×10^{12} Btu), byproduct fuels from petroleum refining (2176×10^{12} Btu), and coal for steelmaking (1952×10^{12} Btu).^{*} These blocks of consumption represent uses that are for the most part well documented as far as process characteristics and location of facilities are concerned, hence, development of a source inventory from readily available data will be possible without undue difficulty. The balance of the industrial fuel-burning (purchased fuels in the amount of 10.6×10^{15} Btu) is documented in the Bureau of Census data in detail beyond that shown in Table B-2, and as discussed later, lends itself to orderly analysis of fuel use and associated pollution.

Strategy for Industrial Sector Analysis

The present project will result in a combustion source inventory that is comprehensive in that all significant consumers of fuel are identified and detailed from the standpoint of geographical distribution of fuel burning sources. To keep the effort involved in development of the inventory modest, a strategy for analysis has been developed and tested.

For the inventory all combustion sources will be ultimately divided into two types: "major point sources", that will be located specifically within individual counties and states, and "area sources", for which fuel consumption will be quantified by

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^{*} Includes coal consumed in making coke and byproduct fuels (1456×10^{12} Btu) and coke used to make steel (496×10^{12} Btu).

type on a county-by-county basis. This is the classic approach, and is consistent with the NEDS treatment, so that direct comparisons will be possible even though an independent approach will be used.

Major Point Sources--

A primary step in developing the inventory will be building the major point source data base. In the past few years a number of studies have provided new perspective on the hardware associated with industrial fuel burning. Studies of direct-fired processes have shown that some 19 major processes consume about 70 percent of the estimated 6.0×10^{15} Btu that goes into direct-fired processes (see Table B-3). Studies of the industrial boiler population produced a large body of information on the size, type, and location of the large industrial boilers. Taken together these studies have shown that the total number of processes that are major point sources is smaller than might have been expected and because many plants or facilities employ a number of processes, the different types of plants that must be considered is limited. For example, a petroleum refinery is a plant or facility that employs one or more of the eight individual refinery processes (atmospheric distillation, catalytic reforming, vacuum distillation, etc.) that have been shown to be in the group of 29 processes that consume almost 70 percent of all fuel burned in direct-fired processes. Table B-4 shows the type and approximate number of facilities that employ processes that can be considered to be major sources of sufficient importance to be given individual

TABLE B-3. SUMMARY OF MAJOR ENERGY CONSUMING
DIRECT-FIRED PROCESSES

Industry	Process/Operation	10 ¹² Btu/yr
Petroleum refining	Atmospheric distillation	529.3
Iron and steel	Slabbing and blooming	427.8
	- reheat furnaces (271.5)	
	- soaking pit (156.3)	
Petroleum refining	Catalytic reforming	407.1
Hydraulic cement	Calcining	324.5
Petroleum refining	Vacuum distillation	296.5
Iron and steel	Blast furnace	267.3
Petroleum refining	Coking (delayed)	266.2
Petroleum refining	Fluid bed catalytic cracker	229.2
Glass	Melting	227.2
Organic chemicals	Ethylene/propylene (thermal cracking)	194.5
Lime	Calcining	145.9
Iron and steel	Coking	144.8
Agricultural chemicals	Ammonia steam reforming	139.0
Petroleum refining	Gas/oil hydrotreating	119.9
Iron and steel	Heat treatment	111.5
Iron and steel	Steelmaking	86.2
	- open hearth furnace (71.8)	
	- basic oxygen furnace (14.4)	
Petroleum refining	Naphtha hydrotreating	77.8
Brick	Drying/firing	52.8
Organic chemicals	Benzene	44.8
Petroleum refining	Alkylation	42.6
Iron and steel	Cast iron melting	37.8
	- cupola furnace (21.7)	
	- induction furnace (16.1)	
Carbon black	Furnace process	35.7
Primary nonferrous metals	Copper smelting	34.7
Primary nonferrous metals	Alumina calcining	30.0
Total		4,273.3

TABLE B-4. TYPES OF MAJOR INDUSTRIAL FACILITIES AND
APPROXIMATE NUMBER IN THE UNITED STATES

Industrial boilers (200-300)
Iron and steel plants (50)
Refineries (300)
Cement plants (150)
Major chemical plants (200)
Brick plants (465)
Glass plants (150)
Lime plants (150)
Primary nonferrous smelters (30)
Pulp mills (200)

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attention in a combustion source inventory. Preliminary investigation shows that plants of the type shown in Table B-3 can be located geographically and that fuel consumption estimates can be developed for each. This investigation suggests also that while the list is likely to be modified as the study progresses, the changes are likely to be modest and incremental so that the present figures are a reasonable basis for planning.

Census of Manufacturers--

A second fundamental step in developing the inventory for major point sources involves analysis of the 450 "industries" defined by the Standard Industrial Classification Manual (SIC's). The SIC's collect data on number of establishments, number of employees, etc. as well as data on fuel consumption by type, and geographically by state, for each industry that is identified by a 4-digit code. These data provide a basis for classification of all industrial combustion sources as either point source or area sources. For purposes of analysis they can be divided into three groups. One is comprised of sixteen industries that employ major point source processes (e.g., 3321 - blast furnace and steel mills). Another involves over 300 industries that do not employ major point sources. The third is made up of 80 to 90 industries that will require some further analysis.

The SIC categories associated with major point sources consumed almost 50 percent of the industrial purchased fuel (4.8×10^{15} Btu/yr) in 1977. The balance of 5.8×10^{12} is consumed in over 400 SIC industry categories. Fortunately, analysis of the

consumption can be simplified by eliminating over 300 industries in which individual establishments consume less than 100×10^9 Btu/yr.* Industries in this category include SIC categories such as 2016 - poultry dressing plants, 2451 - mobile homes, 3161 - luggage, 3444 - sheetmetal work, etc. The total fuel consumption for this group came to 2.3×10^{15} Btu in 1977. This limits the categories for further analysis to around 80 to 90 industries that consumed about 3.5×10^{12} Btu in 1977.

All the industries that consume over 100×10^9 Btu/establishment/year are shown in Table B-5. The data include those industries that are known to have large point sources (marked with an asterisk), in addition to the 80 to 90 that will be examined further. These data are suggestive of the kinds of analysis that will be required.

For industries such as cement, lime and brick, etc., that are known to be associated with major point sources, it appears that the major processes involved represent most of the fuel consumption, thus simplifying the analysis. Glass comparisons are slightly more complicated in that the 4-digit industries reflect statistics for different product types. The data for iron and steel apparently reflect exclusion of reductant coke for blast furnaces from the purchased fuel report, while the data for petroleum refining reflects the refinery use of byproduct fuels not covered by the purchased fuel report.

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* This is the equivalent of the heat input to a very small boiler (2-3 MW equivalent) operated about half time. This limit eliminated over 300 categories and was felt to be low enough to prevent missing a few large sources in industries with a large number of facilities.

TABLE B-5. STANDARD INDUSTRIAL CLASSIFICATION CODES
WITH CONSUMPTION OF FOSSIL FUELS GREATER THAN 100×10^9 Btu PER YEAR

	Average 1977 consumption per establishment, 10^9 Btu	
	All establish- ments	Establishments with 20 or more employees
SIC 20 - Food and kindred products		
2023 - Condensed and evaporated milk	88.7	159.4
2032 - Canned specialties	84.7	195.4
2034 - Dehydrated fruits, vegetables, and soups	72.8	154.0
2037 - Frozen fruits and vegetables	104.2	140.4
2043 - Cereal breakfast foods	170.8	234.2
2046 - Wet corn milling	2,023.0	2,922.2
2061 - Raw cane sugar	189.2	223.6
2062 - Cane sugar refining	802.5	1,188.8
2063 - Beet sugar	1,294.7	1,419.2
2066 - Chocolate and cocoa products	64.2	133.3
2075 - Soybean oil mills	334.7	465.5
2076 - Vegetable oil mills, N.E.C. ^a	47.6	105.2
2077 - Animal and marine fats and oils	54.2	134.8
2079 - Shortening and cooking oils	229.3	312.5
2082 - Malt beverages	329.7	474.7
2083 - Malt	210.0	311.1
2085 - Distilled liquor, except brandy	139.4	188.3
SIC 21 - Tobacco products		
2111 - Cigarettes	750.0	807.6
SIC 22 - Textile mill products		
2211 - Weaving mills, cotton	66.8	109.3
2261 - Finishing plants, cotton	116.6	260.6
2262 - Finishing plants, synthetics	148.0	223.2
2272 - Tufted carpets and rugs	61.6	110.3
2296 - Tire cord and fabric	125.0	125.0

(continued)

TABLE B-5 (continued)

	Average 1977 consumption per establishment, 10 ⁹ Btu	
	All establish- ments	Establishments with 20 or more employees
SIC 24 - Lumber and wood products		
2436 - Softwood veneer and plywood	99.6	113.8
2492 - Particleboard	87.3	107.8
SIC 26 - Paper and allied products		
2611 - Pulp mills	1,882.2	2,016.6
2621 - Paper mills, except building paper	1,518.8	1,794.0
2631 - Paperboard mills	1,792.3	1,923.7
2641 - Building paper and board mills	444.8	486.7
2646 - Pressed and molded pulp goods	150.0	211.1
SIC 28 - Chemicals and allied products		
2812 - Alkalies and chlorine	1,795.9	2,666.6
2813 - Industrial gases	54.4	300.0
2816 - Inorganic pigments	389.6	625.7
2819 - Industrial inorganic chemicals, N.E.C.	409.3	801.7
2821 - Plastic materials and resins	381.1	488.0
2822 - Synthetic rubber	619.0	1,300.0
2823 - Cellulosic manmade fibers	5,670.0	5,670.0
2824 - Organic fibers, noncellulosic	1,850.0	2,105.1
2833 - Medicinals and botanicals	141.8	330.2
2834 - Pharmaceutical preparations	39.8	102.7
2841 - Soap and other detergents	35.7	100.8
2843 - Surface active agents	49.7	103.5
2861 - Gum and wood chemicals	79.8	256.7
2865 - Cyclic crudes and intermediates	795.8	1,196.8
2869 - Industrial organic chemicals, N.E.C.	1,784.7	2,934.9
2873 - Nitrogenous fertilizers	1,538.1	2,656.8
2874 - Phosphatic fertilizers	583.5	769.5
2879 - Agricultural chemicals, N.E.C.	57.4	194.2
2892 - Explosives	158.7	290.5
2895 - Carbon black	877.4	877.4
2899 - Chemical preparations, N.E.C.	32.4	138.5

(continued)

TABLE B-5 (continued)

	Average 1977 consumption per establishment, 10 ⁹ Btu	
	All establish- ments	Establishments with 20 or more employees
SIC 29 - Petroleum refining and related industries		
2911 - Petroleum refining	3,225.5	4,034.7
2951 - Paving mixtures and blocks	32.7	203.0
2952 - Asphalt felts and coatings	103.6	173.7
2999 - Petroleum and coal products, N.E.C.	104.2	317.3
SIC 30 - Rubber and miscellaneous plastic products		
3011 - Tires and inner tubes	324.0	514.2
3041 - Rubber and plastic hose and belting	76.7	108.7
SIC 32 - Stone, clay, glass, and concrete products		
3211 - Flat glass	893.5	1,731.2
3221 - Glass containers	1,022.2	1,038.7
3229 - Pressed and blown glass, N.E.C.	157.5	481.6
3241 - Cement, hydraulic	2,087.0	2,621.8
3251 - Brick and structural clay tile	190.3	255.7
3253 - Ceramic wall and floor tile	79.7	131.2
3255 - Clay refractories	118.5	190.3
3259 - Structural clay products, N.E.C.	155.7	308.7
3261 - Vitreous plumbing fixtures	115.7	213.1
3262 - Vitreous china food utensils	100.0	200.0
3263 - Fine earthenware food utensils	82.6	111.7
3274 - Lime	1,014.8	1,514.2
3275 - Gypsum products	339.8	537.0
3292 - Asbestos products	61.7	100.0
3295 - Minerals, ground or treated	64.5	199.3
3296 - Mineral wool	305.2	518.8
3297 - Nonclay refractories	145.8	240.9
3299 - Nonmetallic mineral products, N.E.C.	10.9	108.5

(continued)

TABLE B-5 (continued)

	Average 1977 consumption per establishment, 10 ³ Btu	
	All establish- ments	Establishments with 20 or more employees
SIC 33 - Primary metal industries		
3312 - Blast furnaces and steel mills	2,696.4	5,436.0
3316 - Cold finishing of steel shapes	94.1	155.3
3317 - Steel pipe and tubes	98.3	124.6
3321 - Gray iron foundries	98.6	142.1
3322 - Malleable iron foundries	178.7	222.6
3325 - Steel foundries, N.E.C.	73.0	103.0
3331 - Primary copper	2,211.1	2,211.1
3332 - Primary lead	1,671.4	1,671.4
3333 - Primary zinc	2,700.0	3,085.7
3334 - Primary aluminum	3,334.3	3,334.3
3339 - Primary nonferrous metals, N.E.C.	224.7	734.6
3341 - Secondary nonferrous metals	74.3	171.0
3351 - Copper rolling and drawing	129.2	182.8
3353 - Aluminum sheet, plate, and foil	1,096.2	1,291.1
3354 - Aluminum extruded products	89.1	117.8
3355 - Aluminum rolling and drawing, N.E.C.	290.9	426.6
3356 - Nonferrous rolling and drawing, N.E.C.	51.7	103.4
SIC 34 - Fabricated metal products, except machinery and transportation equipment		
3431 - Enameled iron and metal sanitary ware	51.4	140.5
3462 - Iron and steel forgings	121.2	187.8
3463 - Nonferrous forgings	104.2	158.0
3482 - Small arms ammunition	47.6	193.7
3483 - Ammunitions, except small arms, N.E.C.	72.8	120.4
3489 - Ordnance and accessories, N.E.C.	49.4	107.3

(continued)

TABLE B-5 (continued)

	Average 1977 consumption per establishment, 10 ⁹ Btu	
	All establish- ments	Establishments with 20 or more employees
SIC 35 - Machinery, except electrical		
3511 - Turbines and turbine generator sets	78.5	173.6
3519 - Internal combustion engines, N.E.C.	71.1	125.9
3562 - Ball and roller bearings	79.8	114.4
3599 - Machinery, except electrical, N.E.C.	101.9	183.3
SIC 36 - Electrical and electronic machinery, etc.		
3624 - Carbon and graphite products	133.7	206.2
3631 - Household cooking equipment	53.1	204.0
3632 - Household refrigerators and freezers	233.3	392.0
3633 - Household laundry equipment	200.0	258.3
3639 - Household appliances, N.E.C.	66.2	132.5
SIC 37 - Transportation equipment		
3711 - Motor vehicles and car bodies	283.8	768.0
3721 - Aircraft	103.4	245.9
3764 - Space propulsion units and parts	119.2	134.7
3743 - Railroad equipment	63.6	108.4
3795 - Tanks and tank components	120.8	161.1
SIC 38 - Measuring, analyzing, etc.		
3861 - Photographic equipment and supplies	43.7	129.2
SIC 39 - Miscellaneous manufacturing industries		
3996 - Hard surface floor coverings	147.6	238.4

^a N.E.C. = not elsewhere classified.

Other categories where major point sources have not yet been assessed will also present a variety of problems. Some, such as those categories involving foundries, are known to be classifiable as major point sources when they are large, but probably are not when they are small. These will require a significant amount of study for classification. Others, such as those in Major Group 20 - Food and Kindred Products, are expected to be dropped after cursory investigation confirms major point sources are not employed in their operations. It is felt, however, that in all situations known sources of information, or other readily available sources, will be adequate for the necessary evaluations.

In summary, the analysis of Census data will permit systematic identification of all direct-fired processes employed by industry* that should be classified as major point sources. Boilers, as indicated earlier, will be handled separately.

Industrial Boilers--

Because of the large amount of past work to characterize the large industrial boiler population, they will be analyzed using data bases that have been developed for other purposes. Past studies have shown that about 200 to 300 industrial boilers have heat input greater than that for a 50-MW utility boiler. While the procedures for handling large boilers as major point sources

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* Only those SIC codes associated with manufacturing will be assessed. All of industrial consumption also includes consumption in agriculture and mining, but the relative amounts are small and major point sources are not involved.

have not been developed, it appears, considering the known data base available and the limited number of facilities involved, that large boilers can be assessed to the same level of detail as direct-fired processes.

SUMMARY AND CONCLUSIONS

In summary the methodology described involves the following steps:

First, the total fossil fuel consumption for all consuming sectors is quantified.

Consumption in the residential, commercial, and transportation sectors is assessed using conventional methodology for area sources.

Consumption in the utility sector is assessed using extensive documentation that is available.

Fuel use in agriculture, construction and mining (classified as industrial) will be assessed as area source consumption using conventional methodology. This reduces the fuel use to be assessed to the manufacturing sector.

The balance of the consumption in the industrial sector is assessed as subcategories involving use of fuel in: 1) boilers, 2) direct-fired processes, and 3) miscellaneous.

Non-purchased fuel use in manufacturing (byproduct fuels in papermaking and petroleum refining) is well documented and will be assessed using easily available data.

Purchased fuel use in manufacturing sector is documented in the Census of Manufacturing, which presents data for 450 industries as defined by the Standard Industrial Classification Codes. Most of these can be eliminated on the basis of insignificant fuel consumption per establishment per year.

Industrial boilers are assessed independently utilizing existing data bases, even though they are associated with the use of both non-purchased and purchased fuels.

The fuel consumption for analysis is thus reduced to a remaining small fraction (about 5%) of the annual fossil fuel consumption in the U.S. This is further reduced by assessment of some 16 SIC industries known to have major point sources that can be assessed using demonstrated methodology.

The remaining 80 to 90 SIC industries are reviewed to identify additional combustors that should be classified as major point sources.

Additional point sources are analyzed as such. Categories with no major point sources are grouped with those eliminated on the basis of low consumption and treated as area sources.

The above procedure systematically reduces the fossil fuel consumption to units that lend themselves to the kind of analysis that is needed for complete coverage of all fossil fuel consumption in the U.S. to produce a complete inventory of major point sources without excessive effort.

The inventory to be developed will be complete from the standpoint of identification and location of major point sources and area source fuel consumption. Fuel consumption estimates for major point sources will be developed from open literature and will provide reasonable approximations for initial inventory purposes.

The inventory will be analagous to the NEDS system and will, as far as possible, utilize NEDS data to supplement data from the open literature. In addition, the inventory will be used to make comparisons that will identify the strengths and weaknesses of both approaches.