Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing

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Abstract

Based on the *Manufacturing Energy Consumption Survey* (MECS) conducted by the U.S. Department of Energy, Energy Information Administration (EIA), this paper presents historical energy-related carbon dioxide emission estimates for energy-intensive sub-sectors and 23 industries. Estimates are based on surveys of more than 15,000 manufacturing plants in 1991, 1994, 1998, and 2002. EIA is currently developing its collection of manufacturing data for 2006.

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1. Introduction

Manufacturing is the single largest source of energy-related carbon dioxide emissions in the U.S. industrial sector, which also includes agriculture, forestry, fisheries, mining, and construction. The manufacturing sector accounted for about 84 percent of energy-related carbon dioxide emissions and 90 percent of the energy consumption in the industrial sector in 2002. The table below shows estimates of energy-related carbon dioxide emissions from manufacturing in 2002, based on the latest end-use energy consumption statistics from EIA's *Manufacturing Energy Consumption Survey* (MECS), which queries more than 15,000 manufacturing plants every 4 years. Previous surveys were conducted in 1985, 1988, 1991, 1994, and 1998; however, only the data collected after 1988 support industry estimates of emissions under the North American Industry Classification System (NAICS).[2] In 2007, EIA will again conduct the MECS, collecting energy consumption and expenditure data for 2006.

The tables in this paper present estimates of manufacturing emissions by fuel, based on statistics from the 1991, 1994, 1998 and 2002 surveys.[3] And for the first time, based on the latest available data, EIA reports on emissions by selected NAICS industries. Of the 473 6-digit NAICS industries, 23 industries are presented.[4] In addition to restrictions on the number of industry estimates, no historical industry-level series is presented because 1) critical non-fuel data are missing, as the 1998 MECS eliminated its industry-level non-fuel estimates and 2) the current historical MECS data series is missing a common industry classification system, as federal statistics, in 1997, replaced the Standard Industrial Classification (SIC) system with NAICS, a new classification designed by the U.S. Office of Management and Budget, North American governments, and other varied and interested party to provide new comparability in statistics about business activity across North America.

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[2] NAICS was developed in cooperation with the U.S. Economic Classification Policy Committee, Statistics Canada, and Mexico's Instituto Nacional de Estadistica, Geografia e Informatica.

[3] Even though a time series is not possible for detailed industries, this paper does present a time-series of energy-related carbon dioxide emissions for broad industry groups.

[4] The MECS is conducted under Title 13 of the U.S. Code. Title 13 strictly prohibits disclosing Title 13-protected information to any other federal, state, or local agency or any foreign government.

Table 1. Carbon Dioxide Emissions from Manufacturing by Industry and Industry Group, 2002 (units as noted)

Industry and Industry Group (NAICS[a])	Carbon Dioxide Emissions (Million Metric Tons)	Share of Total Manufac-turing Emissions (Percent)	Aggregate Carbon Dioxide Emission Coefficient (Million Metric Tons per Quadrillion Btu of Energy Consumed)
	[C]	% of [C]	[C]/[E]
Petroleum (324)	304.8	21.8	43.2
Petroleum Refineries (324110)	277.6	19.8	41.9
Chemicals (325)	311.0	22.2	41.5
Other Basic Organic Chemicals (325199)	80.5	5.7	40.5
Plastics Materials and Resins (325211)	63.3	4.5	32.2
Other Basic Inorganic Chemicals (325188)	23.9	1.7	60.8
Industrial Gases (325120)	17.0	1.2	52.9
Nitrogenous Fertilizers (325311)	12.4	0.9	23.8
Carbon Black (325182)	5.3	0.4	58.0
Cyclic Crudes and Intermediates (325192)	5.1	0.4	41.7
Noncellulosic Organic Fibers (325222)	5.0	0.4	62.0
Synthetic Rubber (325212)	3.5	0.2	50.5
Phosphatic Fertilizers (325312)	2.5	0.2	57.2
Primary Metals (331)	212.8	15.2	68.7
Iron and Steel Mills (331111)	126.0	9.0	75.4
Alumina and Aluminum (331300)	48.0	3.4	56.1
Foundries (331500)	17.9	1.3	65.8
Iron Foundries (331511)	10.2	0.7	71.4
Nonferrous Metals, less Aluminum (331400)	10.8	0.8	64.3
Electrometallurgical Ferroalloy (331112)	3.1	0.2	61.5
Paper (322)	102.4	7.3	36.5
Paper Mills, except Newsprint (322121)	44.4	3.2	38.4
Paperboard Mills (322130)	31.8	2.3	31.2
Food (311)	94.7	6.8	60.0
Wet Corn Milling (311221)	18.9	1.3	72.0
Sugar (311310)	5.3	0.4	46.1
Fruit and Vegetable Canning (311421)	3.4	0.2	55.6
Nonmetallic Mineral Products (327)	91.1	6.5	68.1
Cements (327310)	39.0	2.8	78.9
Glass Products (327200)	16.2	1.2	56.9
Glass Containers (327213)	5.2	0.4	56.9
Flat Glass (327211)	4.0	0.3	53.0
Lime (327410)	10.3	0.7	89.0
Mineral Wool (327993)	4.7	0.3	60.0
All Other Manufacturing Industries	284.3	20.3	57.7
Total	**1,401.2**	**100.0**	**49.5**

[a]North American Industry Classification System (2002).

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (2002).

Table 2. Carbon Dioxide Emissions from Manufacturing by Industry and Industry Group, 2002 (million metric tons, or as noted)
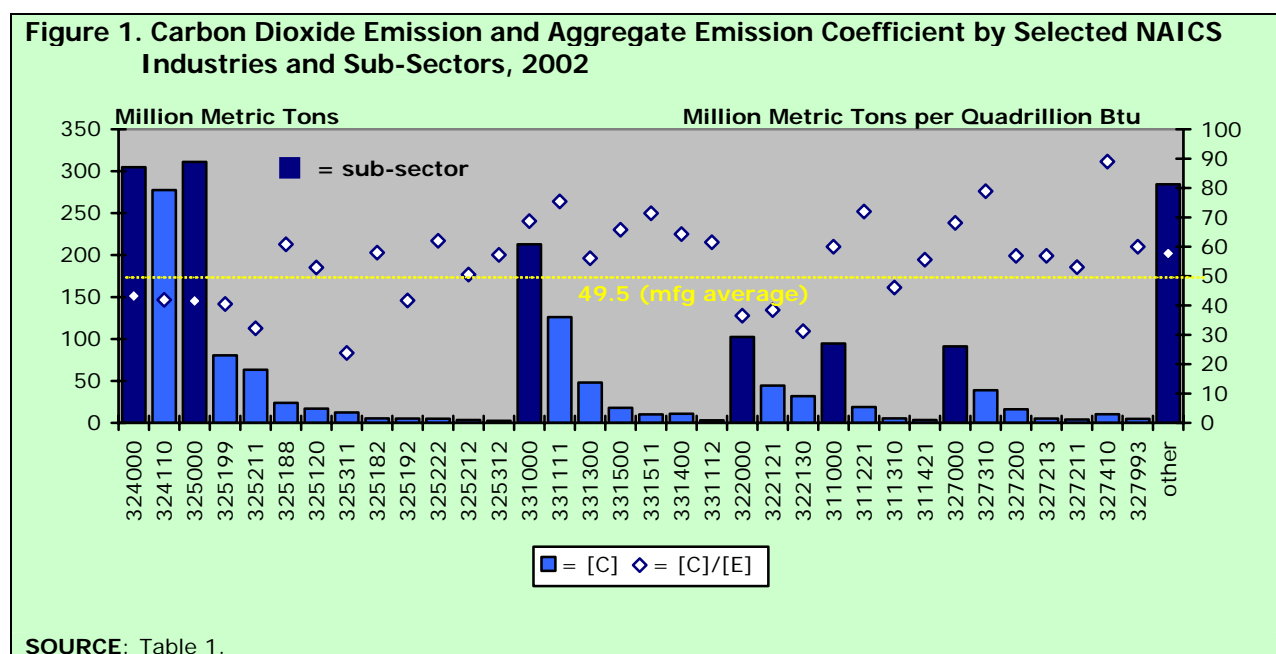
Industry and Industry Group[a]	Total	Net Electricity	Natural Gas	Petroleum	Coal	Other	Energy (Trillion Btu)
	[C]						[E]
Petroleum	304.8	24.6	46.4	153.9	19.3	60.8	7,057
Petroleum Refineries	277.6	23.0	43.3	151.2	*	60.1	6,631
Chemicals	311.0	99.4	106.2	70.2	32.8	2.4	7,499
Other Basic Organic Chemicals	80.5	14.8	31.0	W	W	1.0	1,988
Plastics Materials and Resins	63.3	13.9	21.9	24.8	2.5	0.2	1,966
Other Basic Inorganic Chemicals	23.9	16.7	4.1	0.9	2.0	0.1	392
Industrial Gases	17.0	W	W	0.3	0.0	0.1	321
Nitrogenous Fertilizers	12.4	2.3	10.0	0.1	*	0.0	521
Carbon Black	5.3	0.4	1.1	3.8	0.0	0.1	92
Cyclic Crudes and Intermediates	5.1	2.3	2.3	0.4	*	0.2	123
Noncellulosic Organic Fibers	5.0	W	1.6	0.4	W	0.0	81
Synthetic Rubber	3.5	1.1	1.5	0.3	0.5	0.0	69
Phosphatic Fertilizers	2.5	0.6	1.6	0.2	0.2	0.0	44
Primary Metals	212.8	93.8	37.2	2.4	72.4	7.0	3,097
Iron and Steel Mills	126.0	35.0	22.0	1.1	66.7	1.2	1,673
Alumina and Aluminum	48.0	36.7	7.1	0.1	0.0	4.0	855
Foundries	17.9	10.3	4.1	0.1	3.4	0.0	272
Iron Foundries	10.2	5.3	1.4	0.1	3.3	0.0	142
Nonferrous Metals, except Aluminum	10.8	6.5	2.3	0.2	1.8	0.1	168
Electrometallurgical Ferroalloy Products	3.1	2.3	0.4	*	0.5	0.0	51
Paper	102.4	42.4	26.6	10.0	22.5	0.8	2,805
Paper Mills, except Newsprint	44.4	14.8	10.9	4.8	13.4	0.4	1,157
Paperboard Mills	31.8	10.7	9.9	3.0	7.8	0.3	1,019
Food	94.7	43.8	30.7	2.9	17.3	0.1	1,579
Wet Corn Milling	18.9	4.4	3.2	*	11.3	0.0	263
Sugar	5.3	0.4	1.2	0.2	3.6	0.0	116
Fruit and Vegetable Canning	3.4	1.3	1.9	0.2	0.0	0.0	61
Nonmetallic Mineral Products	91.1	26.8	22.3	11.4	30.1	0.4	1,338
Cements	39.0	8.2	1.1	6.4	23.0	0.3	494
Glass and Glass Products	16.2	8.0	8.1	W	*	0.0	284
Glass Containers	5.2	2.5	2.7	*	0.0	0.0	92
Flat Glass	4.0	1.1	2.7	W	*	0.0	75
Lime	10.3	1.0	0.4	2.8	6.2	0.0	116
Mineral Wool	4.7	2.5	1.8	*	0.3	0.0	78
All Other Manufacturing Industries	284.3	209.9	56.5	6.8	8.3	2.8	4,923
Total	**1,401.2**	**540.7**	**325.9**	**257.6**	**202.8**	**74.2**	**28,298**

[a]North American Industry Classification System (2002). **Notes**: Emissions exclude processes and flaring. Emissions from energy inputs to produce electricity (including associated losses), derived by calculating the manufacturing share of the electric power sector's total carbon dioxide emissions based upon the weighted share of electricity retail sales to (receipts by) the manufacturing sector. W = withheld. * = estimate rounds to zero.
Sources: Energy Information Administration, "Manufacturing Energy Consumption Survey," and "Monthly Refinery Report" (2002).

2. Energy-Related Carbon Dioxide Emissions (2002)

Manufacturing is complex. Whether in its consuming energy or emitting carbon dioxide, it is clear from Figure 1 that manufacturing's 21 three-digit manufacturing sub-sectors and some of its 473 national industries operate and consume energy differently and that plants, on average, vary considerably between sub-sectors. Only a few of the eligible industries are displayed herein, mainly due to confidentiality and sample size constraints associated with sampling manufacturers and reporting on their activities. Table 1 provides estimates that relate emissions with primary energy consumption measures and Table 7 presents relationships between emissions and economic output: gross output. The complexity of these relationships is not only due to the prices paid for manufactured products, but also to the inputs and processes used in transforming raw or intermediate materials into manufactured products. Figure 1 reveals this lack of simplicity in manufacturing emissions.

Figure 1. Carbon Dioxide Emission and Aggregate Emission Coefficient by Selected NAICS Industries and Sub-Sectors, 2002

SOURCE: Table 1.

Petroleum Refineries Emit 277.6 Million Metric Tons of Carbon Dioxide

In the petroleum sub-sector (NAICS 324), the petroleum refining industry (NAICS 324110) dominates emission totals, accounting for over 90 percent in 2002, or 277.6 million metric tons of the 304.8 million metric tons emitted. Of the sources tracked and subsequently reported by refineries, the largest share of emitted carbon dioxide is from the use of petroleum – mostly in the form of by-product energy sources such as waste gas (commonly known as still or refinery gas) and petroleum coke – which represented over half, or 151.2 million metric tons,

of refineries' carbon dioxide emissions. The remaining emissions result mainly from the use of natural gas and electricity, though coal contributes a significant share to emissions by non-refinery establishments of the petroleum sub-sector.

Natural Gas and Electricity Account for Two-Thirds of Emissions in Chemicals

In 2002, the chemicals sub-sector emitted 311.0 million metric tons. Chemical plants are also heavy users of natural gas; and as a result, their aggregate carbon coefficients are lower than industries whose primary energy sources are more carbon-intensive. Although the shares of natural gas vary among chemical industries, it accounts for a little over one-third (106.2 million metric tons) of the sub-sector's energy-related emissions, with electricity contributing another third (99.4 million metric tons) and the remaining third attributed to a combined coal (32.8 million metric tons) and petroleum (70.2 million metric tons) use.

Chemical products can also sequester carbon, as do asphalt, lubricants and waxes produced at petroleum refineries. Nitrogenous fertilizer is one such chemical product, as its carbon content is presumed to be released during its ultimate use as an agricultural product for growing crops. Because of that sequestering process, in 2002, the nitrogenous fertilizer industry recorded an aggregate carbon coefficient of 23.8 million metric tons of carbon dioxide emitted per quadrillion British thermal units which is significantly lower than the overall manufacturing average: 49.5 million metric tons per quadrillion British thermal units. In addition, four of the chemical industries – other basic organic chemicals, plastics materials and resins, nitrogenous fertilizers, and cyclic crudes and intermediates – report an average aggregate carbon coefficient lower than the overall manufacturing, and these industries are also responsible for a little over half of the emissions from the chemicals sub-sector.

Iron and Steel Mills Emit 126.0 Million Metric Tons of Carbon Dioxide

Producing molten iron and steel products requires a mix of carbon-intensive energy sources: coal and electricity. Because of this use, over half of the energy-related carbon dioxide emitted by the primary metals sub-sector (NAICS 331) is due to production at iron and steel mills. In 2002, the primary metals sub-sector emitted 212.8 million metric tons of emissions, of which nearly 60 percent were from these mills. At 75.4 million metric tons per quadrillion British thermal units consumed, producing iron and steel ranks as one of the top carbon-rich outputs in manufacturing for use by consumers, largely because of its use of coal-based resources to reduce iron ores in blast furnaces or heat metal in electric arc furnaces.

Nonmetallic Mineral Products Rank as the Lowest of the Top-Six Emitters

With 91.1 million metric tons of carbon dioxide, in 2002, the nonmetallic mineral products sub-sector emitted 7 percent of energy-related manufacturing emissions. Petroleum (304.8), chemicals (311.0), primary metals (212.8), paper (102.4) and food (94.7) all emitted larger absolute amounts, but nonmetallic minerals, with an aggregate carbon coefficient of 68.1 million metric tons per quadrillion Btu, tops these sub-sectors for its use of carbon-intensive sources. Of the nonmetallic mineral industries, the cement and lime industries, based on their heavy use of coal, push the average coefficient higher -- just as the heavy use of coal by iron and steel mills (75.4) and wet corn milling (72.0) results in their higher-than-average carbon coefficients.

3. Trends (1991 to 2002)

The 1991 MECS reported energy consumption (for fuel and nonfuel purposes) that yielded carbon dioxide emissions from the manufacturing sub-sector as a whole totaling 1,251.4 million metric tons. The corresponding estimate for 2002 is 1,401.2 million metric tons — an increase of 150 million metric tons, growing at an annual rate of 1.0 percent. Over the same interval, the demand for manufacturing products (as measured by gross output[5]) increased by 1.3 percent per year. Therefore, the overall carbon intensity of U.S. manufacturing, measured as metric tons of carbon dioxide emitted per million 2000 dollars of gross output, was 420.4 in 1991 but had dropped to 358.4 by 2002, representing an average decrease of 1.4 percent per year.

The *overall carbon intensity* of the U.S. manufacturing sub-sector is the ratio of its total carbon dioxide emissions (*C*) to manufacturing output (*Y*), as measured by the gross output (in chained 2000 dollars). That ratio (*C/Y*) can be calculated as the product of the sub-sector's *aggregate carbon intensity of energy demand* — carbon dioxide emissions (*C*) per unit of energy consumed (*E*) — and its *energy intensity* — energy consumed (*E*) per unit of gross output (*Y*). That is:

$$\frac{C}{Y} = \frac{C}{E} * \frac{E}{Y}.$$

For the manufacturing sub-sector as a whole, energy intensity (the ratio *E/Y*) is a function primarily of the energy intensities of different production groups and their contributions

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[5] Consists of sales, or receipts, and other operating income, plus commodity taxes and changes in inventories.

to the total gross output mix in the sub-sector. The sub-sector's carbon intensity of energy supply (the ratio *C/E*) is determined primarily by the mix of energy fuel inputs and the mix of fuel and nonfuel (sequestering) uses of the inputs. Thus, the overall carbon intensity of manufacturing (*C/Y*) is a combination of the energy intensity of manufacturing gross output and the carbon intensity of the energy consumed to meet manufacturing's energy demand.[6]

The manufacturing *C/Y* ratio fell by 1.2 percent per year from 1991 to 2002 (not shown in Figure 1); however, the reduction was largely the result of a structural shift (i.e., a change in relative market shares in the sub-sector). In 1991 the four most energy-intensive industries (petroleum, chemicals, primary metals, and paper) accounted for 29.0 percent of total manufacturing gross output, but by 2002 their share had fallen to 23.9 percent. For three of the six manufacturing industry group categories, energy intensity increased from 1991 to 2002 (petroleum by 0.4 percent per year, chemicals 1.5 percent, and nonmetallic minerals 0.1 percent). For paper; primary metals; and other manufacturing, energy intensity declined by 0.4 percent per year, 0.9 percent, and 1.6 percent, respectively. The energy intensity for the "all other manufacturing" category declined by 1.0 percent per year, and at the same time its share of total manufacturing gross output grew from 3.2 percent per year, from $2.0 trillion in 1991 to $2.9 trillion (in chained 2000 dollars) in 2002, as newer, less energy-intensive industries accounted for an increasing share of manufacturing activity.

The mix and quantity of energy fuels consumed by manufacturers (for both fuel and nonfuel uses) affect the sub-sector's aggregate carbon intensity of energy supply. Overall, manufacturing industries had *C/E* ratios equal to 50.9 million metric tons carbon dioxide equivalent per quadrillion Btu in 1991 and 49.5 million metric tons carbon dioxide equivalent per quadrillion Btu in 2002; however, the carbon dioxide factors of the various industries differed markedly.

The petroleum and chemical industries both transform some energy products into products that sequester carbon, such as petrochemical feedstocks, asphalt, and plastics. Because of that use, both the petroleum and chemical industries have lower aggregate C/E ratios than the manufacturing average (45.3 and 43.2 million metric tons carbon dioxide

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[6] The ratios presented here are estimated as aggregations of several manufacturing industries. Specifically, 22 manufacturing industry groups were aggregated into 6 groups for calculations of industry-specified E/Y and C/Y ratios. Therefore, quantifying influences on the change in overall carbon intensity is valuable to extent that these groupings represent the changes occurring in the U.S. manufacturing sector. It should be noted, however, that these ratios are based on survey data that are subject to sampling errors and other uncertainties.

equivalent per quadrillion Btu for the petroleum industry and 45.8 and 41.5 for the chemicals industry in 1991 and 2002, respectively).

The paper industry makes extensive use of wood byproducts as an energy source. Carbon dioxide emissions from wood consumption are considered to be zero, because the carbon that is emitted has been sequestered recently, and the regrowing of trees will again sequester an equivalent amount of carbon dioxide. Consequently, the paper industry has a relatively low *C/E* ratio, at 37.4 and 36.5 million metric tons carbon dioxide equivalent per quadrillion Btu in 1991 and 2002, respectively. In contrast, the primary metals industry, which uses large amounts of coal and other carbon-intensive fuels (e.g., electricity), has a high *C/E* ratio: 68.2 in 1991 and 68.7 in 2002.

Between 1998 and 2002, manufacturing industries had decreases in carbon dioxide emissions associated with their use of electricity (20.9 million metric tons) and natural gas (49.0 million metric tons). Even with that decrease in emissions, electricity use continues to account for the largest share of manufacturers' energy-related carbon dioxide emissions: 37.8 percent (561.6 million metric tons) in 1994 and 38.6 percent (540.7 million metric tons) in 2002.

As a result of the above changes in energy intensity, in combination with the structural shift in the sub-sector, the overall manufacturing energy intensity (*E/Y*) declined by 1.2 percent per year from 1991 to 2002. When the influence of the structural shift is removed, however, decomposition analysis suggests that the aggregate energy intensity of the manufacturing sector is virtually unchanged.[7]

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[7] There are several approaches that, based on index number theory, can be used to decompose aggregate values. The values reported here are based on a discrete approximation of the Divisia integral index.

Table 3. Carbon Dioxide Emissions from Manufacturing by Fuel and Industry Group, 2002

Fuel Type	NAICS[a]					Other Mfg.	Total
	324	325	331	322	327		
2002							
CO2 Emissions (Million Metric Tons)							
Electricity	24.6	99.4	93.8	42.4	26.8	253.7	**540.7**
Natural Gas	46.4	106.2	37.2	26.6	22.3	87.3	**325.9**
Petroleum	153.9	70.2	2.4	10.0	11.4	9.6	**257.6**
Coal	19.3	32.8	72.4	22.5	30.1	25.6	**202.8**
Other	60.8	2.4	7.0	0.8	0.4	2.8	**74.2**
Total	**304.8**	**311.0**	**212.8**	**102.4**	**91.1**	**379.0**	**1,401.2**
Share of Total Gross Output (Percent)	5.9	10.5	3.6	3.9	2.2	73.9	**100.0**
Share of Total Energy Use (Percent)	24.9	26.5	10.9	8.4	4.7	24.5	**100.0**
Share of Total CO2 Emissions (Percent)	21.8	22.2	15.2	7.3	6.5	27.0	**100.0**

[a]North American Industry Classification System: 324, petroleum products; 325, chemicals; 331, primary metals; 322, paper; 327, nonmetallic minerals (includes stone, clay, and glass).

Notes: Totals may not equal sum of components due to independent rounding. To calculate intensity and consumption values, electricity was calculated as primary electricity: 10,436 Btu per kilowatthour for 1991, 10,316 for 1994, 10,346 for 1998, and 10,173 for 2002. These conversion factors represent the average energy input to the generation process for fossil-fired utility plants in the United States. See Energy Information Administration, "Monthly Energy Review," DOE/EIA-0035(2003/09) (Washington, DC, September 2003), Table A6. Emissions exclude processes and flaring. Emissions from energy inputs to produce electricity (including associated losses), derived by calculating the manufacturing share of the electric power sector's total carbon dioxide emissions based upon the weighted share of electricity retail sales to (receipts by) the manufacturing sector.

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (2002); and U.S. Department of Commerce, Bureau of Economic Analysis, Industry Economics Division. North American Industry Classification System (2002).

Table 4. Carbon Dioxide Emissions from Manufacturing by Fuel and Industry Group, 1998

Fuel Type	NAICS					Other Mfg.	Total
	324	325	331	322	327		
1998							
CO2 Emissions (Million Metric Tons)							
Electricity	22.9	103.2	101.8	45.6	24.4	263.7	**561.6**
Natural Gas	53.2	127.7	47.9	31.1	23.4	91.5	**374.9**
Petroleum	174.8	56.5	3.6	15.1	6.7	13.4	**270.1**
Coal	0.0	26.9	94.3	25.8	27.7	23.7	**198.3**
Other	69.5	4.9	3.4	0.8	0.7	1.6	**80.9**
Total	**320.4**	**319.2**	**251.0**	**118.4**	**82.9**	**393.9**	**1,485.8**
Share of Total Gross Output (Percent)	5.7	11.0	4.2	4.2	2.4	72.5	**100.0**
Share of Total Energy Use (Percent)	25.2	24.0	7.4	10.8	4.1	28.5	**100.0**
Share of Total CO2 Emissions (Percent)	21.6	21.5	16.9	8.0	5.6	26.5	**100.0**

[a]North American Industry Classification System: 324, petroleum products; 325, chemicals; 331, primary metals; 322, paper; 327, nonmetallic minerals (includes stone, clay, and glass).

Notes: Totals may not equal sum of components due to independent rounding. To calculate intensity and consumption values, electricity was calculated as primary electricity: 10,436 Btu per kilowatthour for 1991, 10,316 for 1994, 10,346 for 1998, and 10,173 for 2002. These conversion factors represent the average energy input to the generation process for fossil-fired utility plants in the United States. See Energy Information Administration, "Monthly Energy Review," DOE/EIA-0035(2003/09) (Washington, DC, September 2003), Table A6. Emissions exclude processes and flaring. Emissions from energy inputs to produce electricity (including associated losses), derived by calculating the manufacturing share of the electric power sector's total carbon dioxide emissions based upon the weighted share of electricity retail sales to (receipts by) the manufacturing sector.

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (1998); and U.S. Department of Commerce, Bureau of Economic Analysis, Industry Economics Division. North American Industry Classification System (2002).

Table 5. Carbon Dioxide Emissions from Manufacturing by Fuel and Industry Group, 1994

Fuel Type	NAICS					Other Mfg.	Total
	324	325	331	322	327		
1994							
CO2 Emissions (Million Metric Tons)							
Electricity	21.9	94.1	89.2	40.4	22.3	212.8	**480.6**
Natural Gas	42.8	117.7	42.8	30.4	22.8	86.4	**343.0**
Petroleum	174.8	42.3	4.9	15.7	7.4	14.3	**259.4**
Coal	0.0	28.5	96.1	28.6	26.4	28.5	**208.2**
Other	60.6	4.4	3.5	1.1	0.2	2.0	**71.8**
Total	**300.1**	**287.1**	**236.5**	**116.0**	**79.1**	**344.0**	**1,363.0**
Share of Total Gross Output (Percent)	6.3	11.7	4.4	5.0	2.4	70.1	**100.0**
Share of Total Energy Use (Percent)	24.4	23.6	12.8	11.5	4.4	23.3	**100.0**
Share of Total CO2 Emissions (Percent)	22.0	21.1	17.4	8.5	5.8	25.2	**100.0**

[a]North American Industry Classification System: 324, petroleum products; 325, chemicals; 331, primary metals; 322, paper; 327, nonmetallic minerals (includes stone, clay, and glass).

Notes: Totals may not equal sum of components due to independent rounding. To calculate intensity and consumption values, electricity was calculated as primary electricity: 10,436 Btu per kilowatthour for 1991, 10,316 for 1994, 10,346 for 1998, and 10,173 for 2002. These conversion factors represent the average energy input to the generation process for fossil-fired utility plants in the United States. See Energy Information Administration, "Monthly Energy Review," DOE/EIA-0035(2003/09) (Washington, DC, September 2003), Table A6. Emissions exclude processes and flaring. Emissions from energy inputs to produce electricity (including associated losses), derived by calculating the manufacturing share of the electric power sector's total carbon dioxide emissions based upon the weighted share of electricity retail sales to (receipts by) the manufacturing sector.

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (1994); and U.S. Department of Commerce, Bureau of Economic Analysis, Industry Economics Division. North American Industry Classification System (2002).

Table 6. Carbon Dioxide Emissions from Manufacturing by Fuel and Industry Group, 1991

Fuel Type	NAICS					Other Mfg.	Total
	324	325	331	322	327		
1991							
CO2 Emissions (Million Metric Tons)							
Electricity	19.8	83.1	94.3	38.0	19.8	192.7	**447.8**
Natural Gas	44.2	102.3	37.4	29.1	20.1	73.4	**306.6**
Petroleum	149.9	42.1	3.4	13.6	6.4	14.1	**229.6**
Coal	1.4	25.2	83.2	28.3	27.9	27.2	**193.2**
Other	61.0	9.7	3.0	0.2	0.0	0.5	**74.3**
Total	**276.3**	**262.4**	**221.3**	**109.2**	**74.3**	**307.8**	**1,251.4**
Share of Total Gross Output (Percent)	7.1	12.4	4.4	5.1	2.4	68.6	**100.0**
Share of Total Energy Use (Percent)	24.8	23.3	13.2	11.9	4.5	22.3	**100.0**
Share of Total CO2 Emissions (Percent)	22.1	21.0	17.7	8.7	5.9	24.6	**100.0**

[a]North American Industry Classification System: 324, petroleum products; 325, chemicals; 331, primary metals; 322, paper; 327, nonmetallic minerals (includes stone, clay, and glass).

Notes: Totals may not equal sum of components due to independent rounding. To calculate intensity and consumption values, electricity was calculated as primary electricity: 10,436 Btu per kilowatthour for 1991, 10,316 for 1994, 10,346 for 1998, and 10,173 for 2002. These conversion factors represent the average energy input to the generation process for fossil-fired utility plants in the United States. See Energy Information Administration, "Monthly Energy Review," DOE/EIA-0035(2003/09) (Washington, DC, September 2003), Table A6. Emissions exclude processes and flaring. Emissions from energy inputs to produce electricity (including associated losses), derived by calculating the manufacturing share of the electric power sector's total carbon dioxide emissions based upon the weighted share of electricity retail sales to (receipts by) the manufacturing sector.

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (1991); and U.S. Department of Commerce, Bureau of Economic Analysis, Industry Economics Division. North American Industry Classification System (2002).

Table 7. Changes in Key Measures of Carbon Intensity in Manufacturing, 1991-2002

Industry Group (NAICS[a])	1991			2002			Annual Percent Change, 1991-2002		
	[E]/[Y]	[C]/[E]	[C]/[Y]	[E]/[Y]	[C]/[E]	[C]/[Y]	[E]/[Y]	[C]/[E]	[C]/[Y]
Petroleum (324)	29	45.3	1,310.6	30	43.2	1,312.2	0.4	-0.4	*
Chemicals (325)	15	45.8	708.0	18	41.5	758.0	1.5	-0.9	0.6
Metals (331)	25	68.2	1,688.3	22	68.7	1,532.2	-0.9	0.1	-0.9
Paper (322)	19	37.4	717.9	18	36.5	668.2	-0.4	-0.2	-0.6
Minerals (327)	15	67.8	1,048.2	16	68.1	1,058.7	0.1	*	0.1
Other Mfg.	3	56.1	150.8	2	58.3	131.2	-1.6	0.3	-1.3
Total	**8**	**50.9**	**420.4**	**7**	**49.5**	**358.4**	**-1.2**	**-0.3**	**-1.4**
Total Without Structural Shift	**8**	**NA**	**NA**	**8**	**NA**	**NA**	*****	**NA**	**NA**

[a]North American Industry Classification System: 324, petroleum products; 325, chemicals; 331, primary metals; 322, paper; 327, nonmetallic minerals (includes stone, clay, and glass).

Notes: [E]/[Y] = energy consumed (thousand Btu) per chained 2000 dollar value of gross output. [C]/[E] = million metric tons carbon dioxide emitted per quadrillion Btu of energy consumed. [C]/[Y] = metric tons carbon dioxide emitted per million chained 2000 dollars of gross output. * = estimate rounds to zero. NA = not applicable. Annual percent change for [E]/[Y] is not statistically significant.

Sources: Energy Information Administration, Form EIA-846, "Manufacturing Energy Consumption Survey," and Form EIA-810, "Monthly Refinery Report" (1991 and 2002).

4. Abbreviations

Btu is British Thermal Units

EIA is Energy Information Administration

MECS is Manufacturing Energy Consumption Survey

NAICS is North American Industry Classification System

SIC is Standard Industrial Classification system

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