Production, Energy, and Carbon Emissions: A Data Profile of the Iron and Steel Industry

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ABSTRACT

The complexities of the manufacturing sector unquestionably make energy-use analysis more difficult here than in other energy-using sectors. Therefore, this paper examines only one energy-intensive industry within the manufacturing sector--blast furnaces and steel mills (SIC 3312). SIC 3312, referred to as the iron and steel industry in this paper, is profiled with an examination of the products produced, how they are produced, and energy used.

Energy trends from 1985 to 1994 are presented for three major areas of analysis. The first major area includes trends in energy consumption and expenditures.

The next major area includes a discussion of energy intensity--first as to its definition, and then its measurement. Energy intensities presented include the use of different (1) measures of total energy, (2) energy sources, (3) end-use energy measures, (4) energy expenditures, and (5) demand indicators --economic and physical values are used.

The final area of discussion is carbon emissions. Carbon emissions arise both from energy use and from certain industrial processes involved in the making of iron and steel. This paper focuses on energy use, which is the more important of the two. Trends are examined over time.

Introduction

Historically, the iron and steel industry has been fundamental to the economic growth of the United States.[2] Between 1860 and 1910, while the total growth in manufacturing grew by a factor of 9, the iron and steel industry grew by a factor of almost 20. In 1860, a blast furnace was producing only 7 to 10 tons of pig iron a day. In 1910, a blast furnace not only was producing 500 tons a day, but also was conserving energy by reusing the energy from the hot gases released during the process. During this time basic changes were taking place in the industry with new process inventions such as the Bessemer converter and the Siemens open-hearth furnace (OH). The OH steadily increased its presence in the industry, growing from 2 percent of production in 1870 to 70 percent by 1913.

The OH furnace, although it remained the technology of choice for many years, was displaced by two other technologies, the basic oxygen furnace (BOF) and the electric arc

[1] The opinions and conclusions expressed herein are solely those of the author and should not be construed as representing the opinions or policy of any agency of the United States Government.

[2] Information presented in this section may be found between pages 342-348 in Jonathan Hughes's *American Economic History*.

furnace (EAF). By 1976, OH accounted for only 18.3 percent of production. The process was extinct in the United States by 1992.[3]

In 1997, 56 percent of raw steel production was produced in the BOF and 44 percent produced in the EAF.[4] The large integrated steel mills use the BOF to produce large amounts of carbon steels. Most of the minimills use the EAF to produce alloy and specialty steels as well as carbon steels. In general, the EAF uses less energy per ton of steel than the BOF. Most of the EAF charge is scrap whereas the BOF uses iron ore and about 20 to 25 percent scrap.

During the past 20 years, the introduction of the EAF and the extinction of the OH furnace have been only two of the driving forces behind the decreased use of energy in the U.S. iron and steel industry. Older and less efficient establishments have been closed and there has been a consistent movement to the less energy-intensive continuous casting process rising from 13 percent of production in 1977 to 95 percent in 1997.[5]

The 1997 Kyoto Protocol has heightened interest in energy consumption--in the manufacturing sector more than 80 percent of the greenhouse gas emissions are due to energy use. To discuss carbon emissions targets, a background understanding is needed on the trends in energy consumption and expenditures, what energy sources are consumed and where, and the intensity of use as well as the associated emissions. This paper attempts to provide this understanding for the iron and steel industry.

Data Used

Most of the energy statistics used in this analysis are provided by the Manufacturing Energy Consumption Survey (MECS). The MECS, conducted by the Energy Information Administration, is the most comprehensive source of national-level data on energy-related information for the manufacturing sector. Two measures of manufacturing energy consumption will be used in this paper. These measures differ in terms of how offsite-produced energy, feedstocks, and byproduct energy are accounted for at the manufacturing site:

- **First Use of Energy for All Purposes.** The most comprehensive measure of energy consumption and represents the first use of energy sources no matter whether they are consumed as a fuel or as a nonfuel (raw material). This measure does not include byproduct fuels resulting from nonfuel use of energy sources.
- **Total Inputs of Energy for Heat, Power, and Electricity Generation.** It includes all energy sources, produced either offsite or onsite, that are used to produce heat and power and to generate electricity. It excludes raw materials and includes byproducts.[6]

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[3] Table 24, *Annual Statistical Report 1985* and Table 25, *Annual Statistical Report 1995*, American Iron and Steel Institute (AISI).

[4] Table 23, *Annual Statistical Report 1997*, AISI.

[5] Table 23, *Annual Statistical Report 1997* and Table 25, *Annual Statistical Report 1985*, AISI.

[6] EIA is investigating whether blast furnace gas is correctly being excluded from First Use and included in Total Inputs, as is the assumption in current calculations. The energy content of that gas may cause the counterintuitive result that Total Inputs were greater than First Use in 1988, 1991, and 1994.

EIA has fielded four manufacturing energy consumption surveys for data years 1985, 1988, 1991 and 1994. The analysis in this paper will mostly follow the MECS years.

Energy Consumption in the Iron and Steel Industry

Trends in Consumption

The iron and steel industry accounts for approximately two-thirds of the energy used in the primary metal industry (SIC 33). The primary metal industry, itself, ranks fourth behind the top energy-consuming industries: petroleum, chemical, and paper.

In this industry, energy consumption has fluctuated in recent years due to changes in the industry and the overall economic picture. Energy consumption, as measured by "Total First Use of Energy for All Purposes", fell from 1,689 trillion Btu in 1985 to 1,649 trillion Btu in 1994--a 2 percent decline in 10 years (Table 1). During these same years pig iron production rose from 50.4 million tons to 54.4 million tons, while raw steel production rose by 14 percent--88.3 million tons to 100.6 million tons.[7]

The increased use of the EAF is one reason for the reduction in energy consumption. The EAF used 32 million tons of scrap in 1985, growing to 41 million in 1994--a 28 percent increase.[8] Older establishments have closed and the use of energy-saving continuous casting has risen dramatically. Other process technology innovations and energy-management activities have also contributed to the drop in energy use.

Table 1. First Use of Energy for All Purposes by the Iron and Steel Industry (SIC 3312)

Energy Source	Units	MECS Survey Year			
		1985	1988	1991	1994
Total	Trillion Btu	1,689	1,729	1,425	1,649
Net Electricity	Million kWh	38,995	40,570	38,183	43,520
Residual Fuel Oil	1000 bbls	5,458	6,542	W	6,559
Distillate Fuel Oil	1000 bbls	988	1,100	W	W
Natural Gas	Billion Cu. Ft.	400	431	408	469
LPG	1000 bbls	5	12	74	W
Coal	1000 Short Tons	39,888	40,544	30,904	33,609
Coke and Breeze	1000 Short Tons	0	0	-202	2,056
Other	Trillion Btu	14	18	16	26

Note: The energy equivalent of energy sources (mostly coke) produced onsite and shipped offsite have been subtracted. Actual shipment data were available for 1991 and 1994. First use of coke, minus shipments, was assumed to be effectively zero for 1985 and 1988 (where shipments data were not available).
Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991,1994.

Specific Technology

The iron and steel industry uses some of the same technology as other industries, such as adjustable-speed motors, but most of the technology is very specific to the industry. It is difficult to find information on these technologies and on how many establishments in any given industry use the specific technology. However, for the 1991 and 1994 MECS, data

[7] Tables 25 and 27, *Annual Statistical Report 1988* and Tables 24 and 27, *Annual Statistical Report 1995*, AISI.
[8] Table 35, *Annual Statistical Report 1988* and Table 35, *Annual Statistical Report 1997*, AISI.

were collected on many of the specific technologies used in this industry. The data are reported in terms of the proportion of "Total Inputs of Energy for Heat, Power, and Electricity Generation" in establishments reporting specific technologies. For the first time, the 1994 MECS also estimated the number of establishments--out of the 284 total establishments in the industry in 1994--that had specific technologies.

Table 2 shows that in 1991, the iron and steel industry used 1,569 trillion Btu of energy--establishments using 73 percent of this energy had the continuous casting technology present. In 1994, the industry used 1,824 trillion Btu of energy--this technology was used in establishments using 86 percent of this energy.

Table 2. Total Inputs of Energy for Heat, Power, and Electricity Generation by the Iron and Steel Industry (SIC 3312)

Energy Source	Units	MECS Survey Year			
		1985	1988	1991	1994
Total	Trillion Btu	1,677	1,855	1,569	1,824
Net Electricity	Million kWh	38,995	40,570	38,183	43,520
Residual Fuel Oil	1000 bbls	5,458	5,754	4,986	6,659
Distillate Fuel Oil	1000 bbls	942	1,045	901	W
Natural Gas	Billion Cu. Ft.	400	425	387	462
LPG	1000 bbls	5	12	74	W
Coal	1000 Short Tons	2,183	1,573	1,075	1,598
Coke and Breeze	1000 Short Tons	21,856	29,987	21,690	26,503
Other	Trillion Btu	475	456	440	464

Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, and 1994.

A relatively small number of establishments account for a large proportion of the consumption in the industry. Therefore, looking at penetration of a technology by percent of energy consumption of establishments with that technology will give a different impression than looking at penetration from the point of view of number of establishments. For example, "preheating combustion air" was a technology present in 29 establishments, representing 82 percent of "Total Inputs," in 1994. Note that an apparent loss of penetration of a technology (e.g., continuous annealing) in terms of energy consumption may be due to the fact that some establishments without the technology account for a larger share of consumption in 1994 than in 1991.[9]

Table 3 shows penetration levels for specific technologies used in the iron and steel industry in terms of energy consumption and, for 1994, the number of establishments. For example, continuous casting, in place at establishments representing 73 percent of energy use in 1991, increased its penetration so that by 1994 it was in place at establishments accounting for 86 percent of energy use. While continuous casting brings with it a known energy-saving benefit, it is more difficult to assess the effects of other technologies that may improve energy efficiency. For example, oxygen injection into the blast furnace may have only minimal effect on energy consumption at ambient temperatures, but significant savings may be realized when the oxygen is heated to high temperatures. Indeed, technological improvements are being developed continuously. A new one could replace what was

[9] In fact, recent MECS microdata studies have shown some establishments reporting the presence of a technology in 1991 and then not reporting in 1994. Future survey editing procedures will help to determine whether these are in fact actual dropping of a technology, or an error in reporting.

recently a state-of-the-art technology, and so surveying for the presence of specific technologies is always a problem. However, the technologies shown in Table 3 do seem to have significant penetration in the industry.

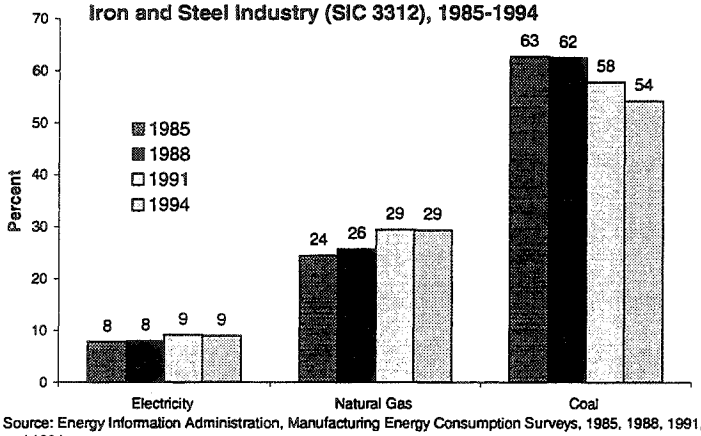
Table 3. Specific Technologies for the Iron and Steel Industry (SIC 3312)

Specific Technology	Percent of Total Energy Used		Number of Establishments
	1991	1994	1994
Hydrocarbon Injection to Maintain Blast Furnace Temperatures	72.8	71.6	10
Waste Heat Boilers/Heat Exchangers in Combination w/Reheat Furnaces	57.5	52.9	16
Preheating Combustion Air	78.9	81.7	29
Continuous Casting	73.4	85.8	40
Continuous Annealing	61.7	55.7	14
Oxygen Injection to Blast Furnace	63.5	73.7	14
Steel Ladle Metallurgy w/ Reheat Furnace	55.3	62.3	20

Note: "Total Inputs of Energy for Heat, Power, and Electricity Generation " is the energy measure used to calculate percentages.
Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1991 and 1994.

Trends in Energy Sources Used and Their Costs

Figure 1. Percent of First Use of Energy by Fuel for the Iron and Steel Industry (SIC 3312), 1985-1994



Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, and 1994.

The manufacturing sector uses a wide variety of energy sources to produce its output. However, in many industries, including iron and steel, a few are dominant. In 1994, three energy sources made up 92 percent of the "First Use of Energy" in the iron and steel industry, coal (54 percent), natural gas (29 percent), and net electricity (9 percent) (Figure 1).[10] From 1985 to 1994, an important change in energy consumption was a drop in the use of coal. The industry used 39.9 million short tons of coal in 1985 compared to 33.6 million short tons in 1994--a drop of 15 percent (Table 1). In 1985, coke consumption was 92 percent of coke production, with the rest being shipped to outside establishments. In 1994, coke production was 75 percent of coke consumption[11]--the shortage shipped in from coke-making facilities, other industry establishments, and imports.

In 1994, if feedstocks are not included in the energy measure and the use of byproducts fuels is included, four energy sources make up 95 percent of the energy used (Table 2). By this measure, the four are coke and breeze (36 percent), natural gas (26 percent), "other" which includes mostly byproducts, blast furnace and coke oven gas (25 percent), and net electricity (8 percent).

[10] Net electricity does not include electricity from cogeneration or generation from combustible energy sources as well as electricity sales and transfers to outside of the establishment.
[11] Table 32, *Annual Statistical Report 1988* and Table 32, *Annual Statistical Report 1995*, AISI.

Using this same energy measure (Total Inputs of Energy), 21.9 million of short tons of coke and breeze were used in 1985, rising to 26.5 million short tons in 1994, a 21 percent increase. Between these years, the consumption of coal dropped by 27 percent.

Table 4. Average Prices for Purchased Energy Sources for the Iron and Steel Industry (SIC 3312) (1992 Dollars per Physical Unit)

MECS SurveyYear	Electricity	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas	LPG	Coal
	(kWh)	(gallon)	(gallon)	(1000 cu ft)	(gallon)	(short ton)
1985	0.059	0.782	1.059	5.214	0.833	69.326
1988	0.045	0.389	0.668	2.641	0.424	53.868
1991	0.042	0.325	0.891	2.794	0.713	51.149
1994	0.043	0.371	0.636	2.515	0.404	51.302

Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, and 1994

Since coke making is very energy intensive, a substitution away from using coal for coke making and directly using coke saves energy costs for the establishment. The rising use in the EAF is reflected in the 11 percent increase in the amount of electricity the industry used in 1994 as compared to 1985. As new technology was replacing old during this time period--reducing energy requirements--energy prices were also falling. Most of the price declines took place between 1985 and 1988, while prices fell very slowly after 1988 (Table 4).

One of the most interesting price declines was that of natural gas--declining by 52 percent during a period of natural gas deregulation. During this time period, an increasing number of manufacturing establishments went to the wellhead themselves or used a broker to purchase the natural gas, arranged delivery to the city gate, and then arranged delivery to the establishment by the local natural gas utility. The iron and steel industry was no exception. Between 1988 and 1994, raw steel production was quite flat--100 million tons in 1988 versus 100.5 million tons in 1994.[12] This was true also of energy consumption--1,855

Table 5. Total Expenditures for Purchased Energy Sources in the Iron and Steel Industry (SIC 3312) (Million 1992 Dollars)

MECS Survey Year	Total	Net Electricity	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas	LPG	Coal	Coke and Breeze	Other
1988	6,038	1,756	98	30	1,325	5	1,843	885	28
1991	4,902	W	W	W	973	2	1,367	756	41
1994	5,712	1,620	105	24	1,168	W	1,496	W	65

W=Withheld to avoid disclosing data for individual establishments.
Source: Energy Information Administration, Manufacturing Energy Consumption Surveys 1988, 1991, and 1994

trillion Btu versus 1,824 trillion Btu in 1994 (Table 2).[13] However, energy expenditures did show a decline, from 6 billion real dollars in 1988 to 5.7 billion real dollars in 1994--a 5 percent difference. The three individual energy sources having the largest expenditures, electricity, natural gas and coal, experienced declines of 21 percent, 12 percent, and 19 percent, respectively (Table 5).[14]

[12] Table 24, *Annual Statistical Report 1995*, AISI.

[13] Energy expenditure data are not available for 1985.

[14] A recession was underway in 1991. Mainly for this reason, decreases in expenditures are pronounced between 1988 and 1991. Between 1991 and 1994, expenditure increases are just as pronounced as the iron and steel industry industry experienced a 14 percent growth in raw steel production.

Energy Intensities

Energy intensity is defined as the ratio of energy consumption to some measure of demand for energy services. In the manufacturing sector as well as other sectors, there are many potential energy-intensity measurements using different measures of energy and the demand for energy services. However, data availability usually decides which energy intensities actually can be developed, either because of resource constraints or because the data are inherently difficult to obtain.

The MECS provides data on several measures of energy consumption as illustrated in this paper. Additionally, the MECS provides data on energy expenditures and limited data for end uses such as boiler fuel and process heating. However the disaggregation level is only at the 4-digit SIC. Since an industry can be so diverse, the greater the disaggregation, the easier it is to interpret changes in the energy intensity.

Providing meaningful indictors of demand for energy services is problematic. If the demand indicator is an economic indicator (e.g., value of shipments), changes in the energy intensity could be due to many factors such as changes in the industry mix, energy prices, cost of capital, domestic and international taxes, consumer demand, and production cycles. From an engineering perspective, the demand indicator should be physical measures of output such as tons of steel, not economic value. Although there is a very good source of steel data from the American Iron and Steel Institute (AISI), AISI's reporting companies do not cover 100 percent of the steel output.

In this section energy intensities are presented for the iron and steel industry using both economic and physical demand indicators. Additionally, energy-expenditure intensities are given in this section, and carbon emission intensities are presented in the next section, to complete the intensity picture for the industry.

Value of Production as a Demand Indicator

Value of shipments (VS) is the value of all shipments from a manufacturer during a period of time and does not differentiate when the output was produced. Secondly, VS are influenced by the presence of inflation. Therefore, to use value of shipments as a demand indicator, it has to be adjusted for changes in inventory and inflation. The value of production (VP) adjusts for these two factors. Thus, VP is the economic demand indicator chosen for this analysis. An adjustment for the changing mix of products within this industry was not done since energy data are not available at the necessary product detail.

Energy intensity, as measured using "First Use of Energy for All Purposes" and VP, declined by 28 percent between 1985 and 1994 (Table 6). During this time period, VP was growing while energy use was declining--energy use declined by 4 percent while VP increased by 33 percent. Most of the other main energy-source intensities also declined—coal the most (37 percent). Coal use was 62 percent of total energy in 1985, declining to 52 percent by 1994. One of the influencing factors was the increasing use of the EAF, which reduced coke making, a very energy-intensive process. Other factors such as the rise in the use of energy-efficient technology, energy management initiatives, and the closing of inefficient establishments influenced the energy intensity results as well. Similar results are

found when the energy measure is "Total Inputs of Energy", the measure that excludes feedstocks and includes byproduct fuel use.[15]

Table 6. Energy Intensities for the Iron and Steel Industry (SIC 3312)

	1985	1988	1991	1994
First Use of Energy for All Purposes				
Total Energy/Value of Production (1000 Btu per Constant 1992 Dollar)	47	31	36	34
Total Energy/Tons of Steel (1000 Btu per Ton of Steel)	19,409	17,753	16,633	16,395
Electricity/Value of Production (1000 Btu per Constant 1992 Dollar)	4	2	3	3
Electricity/Tons of Steel (1000 Btu per Ton of Steel)	1,507	1,381	1,479	1,471
Natural Gas/Value of Production (1000 Btu per Constant 1992 Dollar)	11	8	10	10
Natural Gas/Tons of Steel (1000 Btu per Ton of Steel)	4,668	4,443	4,778	4,812
Coal/Value of Production (1000 Btu per Constant 1992 Dollar)	29	19	20	18
Coal/Tons of Steel (1000 Btu per Ton of Steel)	11,999	10,808	9,363	8,879
Total Inputs for Heat, Power, and Electricity Generation				
Total Energy/Value of Production (1000 Btu per Constant 1992 Dollar)	46	33	38	38
Total Energy/Tons of Steel (1000 Btu per Ton of Steel)	19,001	18,564	17,851	18,153
Electricity/Value of Production (1000 Btu per Constant 1992 Dollar)	4	2	3	3
Electricity/Tons of Steel (1000 Btu per Ton of Steel)	1,507	1,381	1,479	1,471
Natural Gas/Value of Production (1000 Btu per Constant 1992 Dollar)	11	8	10	10
Natural Gas/Tons of Steel (1000 Btu per Ton of Steel)	4,668	4,393	4,539	4,733
Coal/Value of Production (1000 Btu per Constant 1992 Dollar)	1	.6	.6	.7
Coal/Tons of Steel (1000 Btu per Ton of Steel)	544	350	273	348
Coke and Breeze/Value of Production (1000 Btu per Constant 1992 Dollar)	15	13	13	13
Coke and Breeze/Tons of Steel (1000 Btu per Ton of Steel)	6,141	7,446	6,121	6,502
Energy Expenditures				
Total Expenditures/Value of Production (Cents per Constant 1992 Dollar)	--	.107	.120	.118
Total Expenditures/Tons of Steel (Constant 1992 Dollar per Ton of Steel)	--	60	56	57
Electricity/Value of Production (Cents per Constant 1992 Dollar)	--	.031	W	.033
Electricity/Tons of Steel (Constant 1992 Dollar per Ton of Steel)	--	18	W	16
Natural Gas/Value of Production (Cents per Constant 1992 Dollar)	--	.024	.024	.024
Natural Gas/Tons of Steel (Constant 1992 Dollar per Ton of Steel)	--	13	11	12
Coal/Value of Production (Cents per Constant 1992 Dollar)	--	.033	.033	.031
Coal/Tons of Steel (Constant 1992 Dollar per Ton of Steel)	--	18	16	15
Coke and Breeze/Value of Production (Cents per Constant 1992 Dollar)	--	.016	.018	W
Coke and Breeze/Tons of Steel (Constant 1992 Dollar per Ton of Steel)	--	9	9	W

W=Withheld to avoid disclosing data for individual establishments.
Sources: Energy Information Administration, Manufacturing Energy Consumption Surveys 1988, 1991, and 1994; U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, 1991, and 1994; *Annual Statistical Reports*, 1985, 1990, 1995, American Iron and Steel Institute.

Tons of Steel as a Demand Indicator

Similar results are produced when the physical output "tons of steel" is used as the demand indicator in the energy-intensity measure. The energy-intensity measures using the energy measures still decline between 1985 and 1994. However this decline is substantially lower than when VP was used as the demand indicator. The iron and steel industry (SIC 3312) covers almost all of the steel production. The high degree of coverage should produce

[15] This entire section illustrates the importance of knowing the definition of the energy and demand indicator used in any energy-intensity measurement.

changes in economic-based energy intensities and output-based energy intensities that follow the same patterns.

End-Use Energy Intensities

End-use energy intensities of this type are not usually developed, especially since the data are very difficult to collect. However, in spite of the fragility of the data, they do present some insight into the intensity of use for particular energy sources major end uses in the iron and steel industry. Using MECS 1991 and 1994 end-use energy data, end–use intensities are developed. Boiler fuel intensities using natural gas and VP fell (20 percent) while increasing for coal (24 percent) (Table 7) reflecting the increase in VP and a large increase in the use of coal and a small drop in the use of natural gas as a boiler fuel. During this time, coal prices dropped from approximately $46 to $42 a short ton (1992 dollars) whereas natural gas prices remained almost flat.

End-use intensities using VP do seem to correlate with those developed using physical output. Exceptions are boiler fuel and process heating natural gas, and machine drive electricity-based intensities.

Table 7. End-Use Energy Intensities for the Iron and Steel Industry (SIC 3312)

	1991	1994	1991-1994 (Percent)
Boiler Fuel			
Coal/Value of Production (1000 Btu per Constant 1992 Dollar)	0.59	0.70	19.7
Coal/Tons of Steel (1000 Btu per Ton of Steel)	273.05	338.04	23.8
Residual Fuel Oil/Value of Production (1000 Btu per Constant 1992 Dollar)	0.59	0.60	2.1
Residual Fuel Oil/Tons of Steel (1000 Btu per Ton of Steel)	273.05	288.33	5.6
Natural Gas/Value of Production (1000 Btu per Constant 1992 Dollar)	1.54	1.24	-19.6
Natural Gas/Tons of Steel (1000 Btu per Ton of Steel)	3526.90	3658.82	3.7
Process Heating			
Electricity/Value of Production (1000 Btu per Constant 1992 Dollar)	1.29	1.28	-1.2
Electricity/Tons of Steel (1000 Btu per Ton of Steel)	602.99	616.43	2.2
Residual Fuel Oil/Value of Production (1000 Btu per Constant 1992 Dollar)	0.17	0.25	44.8
Residual Fuel Oil/Tons of Steel (1000 Btu per Ton of Steel)	79.64	119.31	49.8
Natural Gas/Value of Production (1000 Btu per Constant 1992 Dollar)	7.56	7.58	0.3
Natural Gas/Tons of Steel (1000 Btu per Ton of Steel)	3.53	3.66	3.7
Machine Drive			
Electricity/Value of Production (1000 Btu per Constant 1992 Dollar)	1.39	1.40	0.8
Electricity/Tons of Steel (1000 Btu per Ton of Steel)	0.65	0.68	4.3

Sources: Energy Information Administration, Manufacturing Energy Consumption Surveys 1988, 1991, and 1994; U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, 1991, and 1994; *Annual Statistical Reports*, 1985, 1990, 1995, American Iron and Steel Institute.

Energy Expenditures as a Substitute for Energy

Suggestions have been made to use energy expenditures instead of energy use in intensity measures as energy expenditures might be a more robust indicator of energy use--manufacturers react to prices and switch to lower cost energy sources or conserve energy. Total energy-expenditure intensity using VP as the demand indicator show an increase of 10

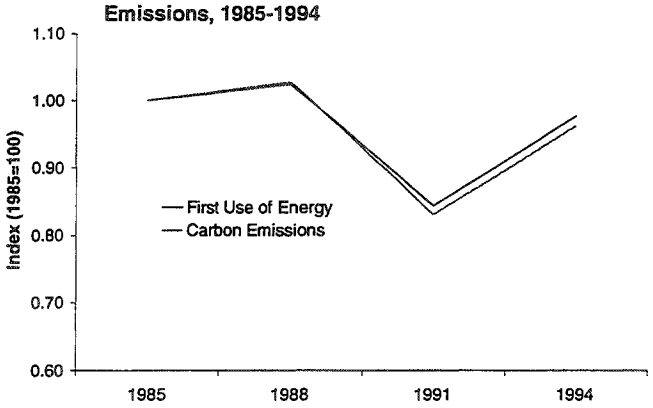
percent between 1988 and 1994 (Table 5). As seen earlier, most of the energy prices had their largest fall before 1988.

Total energy expenditure intensity using tons of steel as the demand indicator, produces different results—a 6 percent decrease in intensity between 1988 and 1994. This might be the result of a data problem--lower reported steel production than the actual total production. A potential reason is that some of the EAF output has not been part of the steel data from the beginning, and as EAF use increased, the amount of total steel reported has been falling. This could very well be problematic in any energy intensity that uses physical output as a demand indicator.

Energy-Related Carbon Emissions

Energy use in the industrial sector accounts for almost a third of U.S. carbon emissions. As is the case for energy consumption, manufacturing accounts for about 80 percent of the total industrial sector emissions.

Figure 2. First Use of Energy and Associated Carbon Emissions, 1985-1994



Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, and 1994.

In 1994, energy use in the iron and steel industry emitted 39.8 million metric tons (MMT) of carbon, 10 percent of all manufacturing energy-related carbon emissions. Carbon missions closely follow energy consumption (Figure 2). The main drivers of energy consumption are also the main drivers of carbon emissions.

However, carbon emissions do not track energy consumption exactly. Despite a slight rise between 1985 and 1988, the carbon intensity of energy used in the iron and steel industry has decreased somewhat. In 1985, 24.48 MMT of carbon were emitted for every quadrillion Btu of energy consumed. By 1994, carbon emissions per Btu of energy consumed were 1.3 percent lower, 24.16 MMT per quadrillion Btu.

The decline in carbon intensity was due to changes in both the fuel mix (Figure 1) and the carbon content of fuels (Table 8). Natural gas, with relatively low carbon intensity, increased its share of the iron and steel industry's energy consumption by 5 percent, while coal's share of energy use decreased 7 percent. Furthermore, although the electricity share increased by 1 percent, the electricity carbon intensity decreased by over 10 percent, partially mitigating the effect of the increased electricity share.[16]

Over the period 1985 to 1994, carbon emissions per ton of steel decreased, in line with energy consumption. The iron and steel industry produced 14 percent more raw steel and 8 percent more pig iron in 1994 as in 1988, but with 4 percent less carbon emissions.

[16] As nuclear reactors are retired from service, the carbon intensity of electricity has been increasing since the last MECS was conducted in 1994 (Figure ES2 in Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997*).

Table 8. Carbon Content of Main Energy Sources Used in the Iron and Steel Industry, 1985-1994

Energy Source	Carbon Intensity (MMT per Quadrillion Btu)			
	1985	1988	1991	1994
All Energy Sources	24.48	24.55	24.06	24.16
Electricity	55.36	54.11	50.25	49.35
Natural Gas	14.40	14.40	14.40	14.40
Coal	25.24	25.23	25.31	25.34

SUMMARY

The iron and steel industry has a strong history of growth—from 10 tons of pig iron a day in 1860 to 150,000 tons a day in 1997. While growth in raw steel production was growing 14 percent between 1985 and 1994, energy declined by 4 percent even though energy prices were falling. New technology such as the EAF and continuous casting were factors contributing to the slow energy growth as well as other factors such as the closing of inefficient establishments. Energy intensities were declining by as much as 28 percent over the 1985 to 1994 time period. Total energy-related carbon emissions declined by 4 percent, despite increased production of raw steel and pig iron.

The iron and steel industry continues to grow. Significant new markets such as framing for residential housing units are emerging, but at the same time the industry faces new challenges from steel substitutes such as aluminum and plastics and steel made outside of the country.

REFERENCES

American Iron and Steel Institute. 1996. Annual Statistical Report 1995. Washington, D.C.

__. 1991. Annual Statistical Report 1990. Washington, D.C.

__. 1986. Annual Statistical Report 1985. Washington, D.C.

Energy Information Administration. 1998. *Emissions of Greenhouse Gases in the United States, 1997.* Washington, D.C.

__. 1997. *Manufacturing Consumption of Energy 1994.* Washington, D.C.

__. 1994. *Manufacturing Consumption of* Energy *1991.* Washington, D.C.

__. 1991. *Manufacturing Consumption of Energy 1988.* Washington, D.C.

__. 1988. *Manufacturing Consumption of Energy 1985.* Washington, D.C.

__. 1995. *Measuring Energy Efficiency in the United States' Economy, A Beginning.* Washington, D.C.

Hughes, Jonathan. 1983. *American Economic History*. Glenview, Illinois.:Scott, Foresman and Company.

Margolis, Nancy and Sousa, Louis. 1997. "Energy and Environmental Profile of the U.S. Iron and Steel Industry." *In Proceedings of the 1997 ACEEE Summer Study on Energy Efficiency in Industry*. Saratoga Springs, New York, Washington, D.C.: American Council for an Energy Efficient Economy.

Pacific Northwest National Laboratory. 1996. *Measuring Industrial Energy Efficiency: Physical Volume Versus Economic Value*. Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency.

U.S. Department of Commerce. 1996. *Statistics for Industry Groups and Industries.* (1994). Washington, D.C.: Bureau of the Census.

__. 1992. *Statistics for Industry Groups and Industries.* (1991). Washington, D.C.: Bureau of the Census.

__. 1988. *Statistics for Industry Groups and Industries.* (1986). Washington, D.C.: Bureau of the Census.

__. 1986. *Statistics for Industry Groups and Industries.* (1984). Washington, D.C.: Bureau of the Census.