

Highlights:

Manufacturing Consumption of Energy 1991

Two major industry groups—the chemicals and allied products industry and the petroleum and coal products industry—accounted for more than half of U.S. 1991 manufacturing primary energy consumption, which totaled 20.3 quadrillion Btu (Table 1). Those two groups and four others (paper and allied products; primary metals; food and kindred products; and stone, clay, and glass products) accounted for 88 percent of the 1991 total.

Those are among the results of the 1991 Manufacturing Energy Consumption Survey (MECS), which is one of four major energy end-use surveys conducted by the Energy

Information Administration (EIA)¹ and the only comprehensive source of national-level data on U.S. manufacturing energy use. The 1991 MECS is the third in an ongoing series of surveys conducted at 3-year intervals through 1994. Pursuant to a provision of the Energy Policy Act of 1992, the MECS will be conducted biannually beginning in 1994 in order to determine trends in manufacturing energy use more accurately.

¹EIA also conducts the Residential Energy Consumption Survey, the Residential Transportation Energy Survey, and the Commercial Buildings Energy Consumption Survey.

Table 1. U.S. Total Primary Consumption of Energy for All Purposes by Industry Group, 1991
(Trillion Btu)

Industry	Net Electricity ^a	Residual Fuel Oil	Distillate		LPG ^d	Coal	Coke and Breeze		U.S. Total	Percent of U.S. Total
			Fuel Oil ^b	Natural Gas ^c			Other ^e			
Food and Kindred Products	169	27	17	W	5	154	W	W	956	<i>4.7</i>
Tobacco Products	3	1	s	4	s	15	0	s	24	<i>0.1</i>
Textile Mill Products	101	12	6	108	2	31	0	13	274	<i>1.4</i>
Apparel and Other Textile Prod. . . .	19	Q	1	19	1	2	0	1	44	<i>0.2</i>
Lumber and Wood Products	61	2	16	41	4	2	0	325	451	<i>2.2</i>
Furniture and Fixtures	17	1	1	19	1	4	0	26	68	<i>0.3</i>
Paper and Allied Products	201	156	9	W	5	296	W	W	2,506	<i>12.4</i>
Printing and Publishing	53	s	2	48	1	0	0	4	108	<i>0.5</i>
Chemicals and Allied Products . . .	440	W	14	2,227	W	W	10	526	5,051	<i>24.9</i>
Petroleum and Coal Products . . .	105	65	21	838	W	W	W	4,864	5,967	<i>29.5</i>
Rubber and Misc. Plastics	116	8	3	96	3	7	0	6	238	<i>1.2</i>
Leather and Leather Products	3	1	1	5	s	Q	0	1	12	<i>0.1</i>
Stone, Clay, and Glass Prod. . . .	105	9	20	381	W	293	W	W	880	<i>4.3</i>
Primary Metals Industries	499	W	11	708	W	853	278	72	2,467	<i>12.2</i>
Fabricated Metals Products	102	3	6	175	4	5	W	W	307	<i>1.5</i>
Industrial Machinery and Equip. . .	101	3	4	109	2	11	1	5	237	<i>1.2</i>
Electronics and Other Electronic Equipment	102	4	2	79	1	W	W	W	212	<i>1.0</i>
Transportation Equipment	118	12	7	133	2	W	W	17	323	<i>1.6</i>
Instruments and Related Equip. . . .	42	3	W	26	Q	W	0	W	98	<i>0.5</i>
Misc. Manufacturing Industries . . .	12	1	W	15	s	1	0	Q	32	<i>0.2</i>
U.S. Total	2,370	454	146	6,095	1,574	2,006	308	7,304	20,257	100.0
<i>Percent of U.S. Total</i>	<i>11.7</i>	<i>2.2</i>	<i>0.7</i>	<i>30.1</i>	<i>7.8</i>	<i>9.9</i>	<i>1.5</i>	<i>36.1</i>	<i>100.0</i>	—

^a"Net Electricity" is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from onsite cogeneration or generation from combustible fuels because that energy has already been included as generation fuel (for example, coal).

^b"Distillate Fuel Oil" includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

^c"Natural Gas" includes natural gas obtained from utilities, transmission pipelines, and any other supplier(s), such as brokers and producers.

^dLPG=Liquefied petroleum gases.

^e"Other" includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power and as feedstocks or raw material inputs.

—=Not applicable.

s=Estimate less than 0.5. Data are included in totals.

W=Withheld to avoid disclosing data for individual establishments. Data are included in totals.

Q=Withheld because relative standard error is greater than 50 percent. Data are included in totals.

Notes: • Major industry groups shown are listed in order of their Standard Industrial Classification numbers. • Italicized values are percents. • Totals may not equal sum of components due to independent rounding. • The derived estimates presented in this table are for the primary consumption of energy for heat and power and as feedstocks or raw material inputs. Primary consumption is defined as the consumption of the energy that was originally produced offsite or was produced onsite from input materials not classified as energy. Examples of the latter are hydrogen produced from the electrolysis of brine; the output of captive (onsite) mines or wells; woodchips, bark, and woodwaste from wood purchased as a raw material input; and waste materials, such as wastepaper and packing materials. Primary consumption excludes quantities of energy that are produced from other energy inputs and, therefore, avoids the error of double counting.

Source: Energy Information Administration (EIA), *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Table A1.

The MECS surveys a nationally representative sample of manufacturing establishments by means of mailed questionnaires. On the basis of payroll, the 1991 MECS sample represented 98 percent of the U.S. manufacturing sector universe, which consists of all manufacturing establishments in the 50 States and the District of Columbia. Compared with the 1988 MECS, the designed sample size for 1991 was increased from roughly 12 thousand manufacturing establishments to 16,054 establishments. This increase allowed EIA to derive separate estimates of energy use for 42 industries and industry groups in addition to the 20 major groups. The actual sample size, after subtraction of nonrespondents and establishments that were out of scope or out of business, was 14,299. The response rate was 91 percent.

This “Highlights” focuses on 1991 MECS data concerning three of the most important aspects of manufacturing energy use: consumption, end uses, and fuel-switching capability.

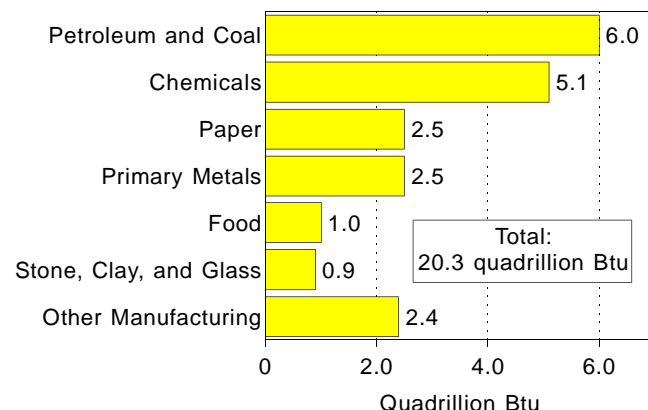
Consumption

Because of the complexity of manufacturing energy use, EIA uses several measures of end-use energy consumption. The two most important are primary energy consumption for all purposes and input of energy for heat, power, and electricity generation.

Primary energy consumption for all purposes.

Primary energy consumption is a comprehensive measure that represents the first use of energy for all purposes. It includes nonfuel uses of energy sources (e.g., natural gas) as raw material feedstocks for making nonenergy products, as well as fuel uses. It excludes the energy produced at industrial sites from other energy inputs. For example, a steel works may use coal as a raw material to make coal coke, which is then used as a fuel. To avoid the error of double counting, only the coal is counted in the primary energy consumption total. The U.S. manufacturing primary energy consumption total of 20.3 quadrillion Btu represented about one-third of total end-use energy consumed in the United States in 1991. Nonfuel consumption accounted for about one-third of that total (6.4 quadrillion Btu). Six industry groups accounted for 17.8 quadrillion Btu (Figure 1), 88

Figure 1. Primary Consumption of Energy for All Purposes by Industry, 1991



Note: Total does not equal sum of components due to independent rounding.
Source: EIA, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Table A1.

percent of the total primary consumption of energy in the manufacturing sector, as noted earlier.

In terms of energy content, U.S. manufacturers consumed more natural gas (6.1 quadrillion Btu) than any other single energy source in 1991 (Figure 2). Natural gas consumption, which accounted for 30 percent of manufacturing primary energy consumption, was heavily concentrated in the chemicals and allied products industry group, where natural gas is used as both fuel and feedstock. This group consumed 2.2 quadrillion Btu of natural gas in 1991, about 37 percent² of the total primary consumption of natural gas. Somewhat more than one-fourth of this quantity (0.6 quadrillion Btu) was used as a raw material, much of it for the manufacture of nitrogenous fertilizers.

Total primary consumption of net electricity (expressed as site consumption³) was 2.4 quadrillion Btu in 1991. Four industry groups (food and kindred products, paper and allied products, chemicals and allied products, and primary metals) accounted for 1.3 quadrillion Btu, 55 percent of the total. The primary metals industry alone consumed 0.5 quadrillion Btu of net electricity.

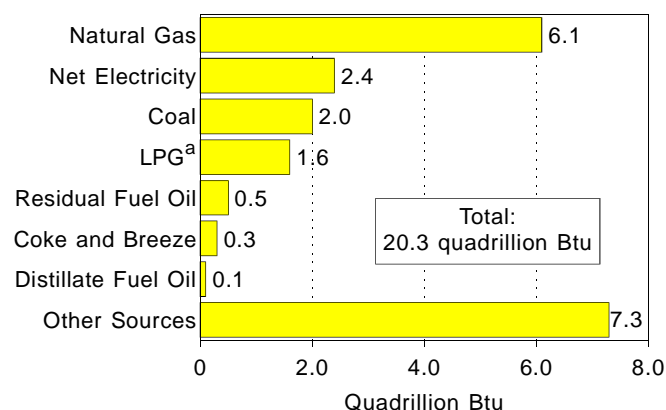
Primary consumption of coal in the manufacturing sector in 1991 was 2.0 quadrillion Btu. The production of coke accounted for 0.8 quadrillion Btu, 40 percent of the total. U.S. manufacturers consumed 1.6 quadrillion Btu of liquefied petroleum gases (LPG) in 1991; 94 percent of that total was used as a petrochemical feedstock. Manufacturers' use of residual and distillate fuel oil, as in the past, was relatively insignificant (0.5 quadrillion Btu and 0.1 quadrillion Btu, respectively). Total fuel oil consumption accounted for about 3 percent of primary consumption.

Primary consumption of other energy sources accounted for 7.3 quadrillion Btu, 36 percent of the 1991 total. That quantity

²Percentages are calculated from unrounded data.

³Site consumption is the amount of electricity actually consumed at a site, in contrast to embodied electricity, which is a reflection of the content of the energy inputs used to produce the site electricity. Primarily because of generation losses, the delivery of 1 kilowatt-hour of electrical energy for site consumption requires, on average, energy inputs equivalent to about 3 kilowatt-hours of electricity at the point of generation. Electricity consumption numbers in this “Highlights,” unless otherwise noted, refer to site electricity.

Figure 2. Primary Consumption of Energy for All Purposes by Energy Source, 1991



^a LPG=Liquefied petroleum gases.

Source: EIA, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Table A1.

comprised net steam and other energy sources used as either fuel or raw material inputs (4.4 quadrillion Btu) and the energy content of certain products made by petroleum refiners, such as asphalt, road oil, solvents, lubricants, and waxes (2.9 quadrillion Btu).

Total inputs of energy for heat, power, and electricity generation. Total inputs of energy in the manufacturing sector were 15.0 quadrillion Btu in 1991 (Figure 3). The total-input measure includes all energy consumed as a fuel, regardless of how that energy was produced. It does not include nonfuel uses of energy sources.⁴ The most heavily used source of fuel energy in the manufacturing sector was natural gas, which accounted for 5.5 quadrillion Btu.

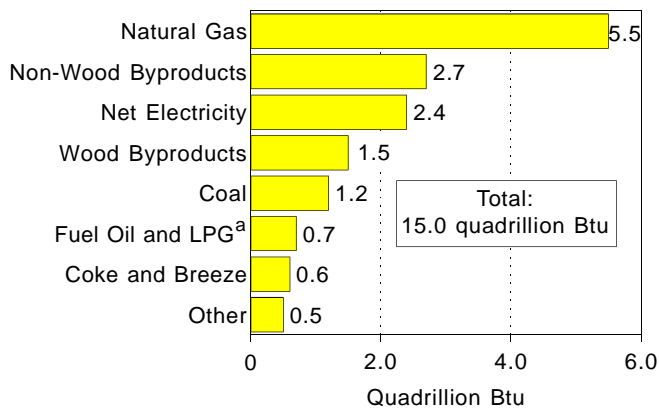
Byproduct energy sources are an important source of manufacturing fuel energy. Non-wood byproducts consist of waste gas (still gas), which is produced in refineries by distillation or other refining processes; petroleum coke, a solid residue left by thermal decomposition in crude oil refining; blast furnace gas and coke oven gas, which are produced during steel making operations; and other waste oils and gases. Wood byproducts consist of chips, bark, other wood wastes, and pulping liquor, the alkaline spent liquor taken from digesters during the chemical pulping of wood.

Specific industries that derived much of their total input energy from byproduct fuels in 1991 included the steel mills and blast furnace industry, which is part of the primary metals industry group (28 percent, mainly from blast furnace gas); petroleum refineries (62 percent, from waste gas and petroleum coke); and the paper and allied products industry (49 percent, mainly from pulping liquor and wood byproducts).

Both the food and kindred products and the paper and allied products industries use little energy as raw material (Figure 4).

⁴The total-input numbers and the primary-energy numbers overlap somewhat. Thus, total primary consumption cannot necessarily be calculated by simply adding the numbers for raw material uses of energy and those for total inputs for heat, power, and electricity generation, although the sums will often be very close. For a more detailed explanation, see Energy Information Administration, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Appendix B.

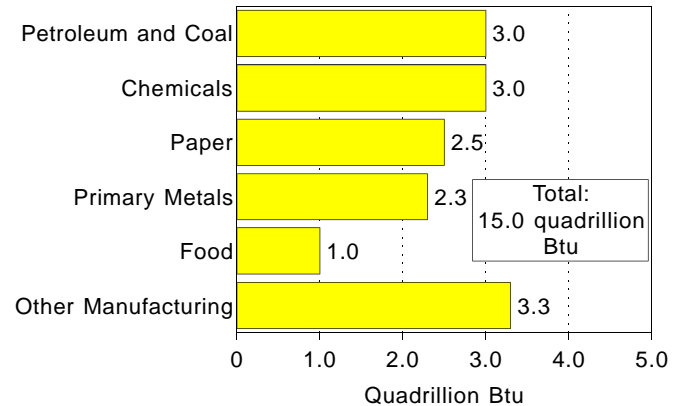
Figure 3. Total Inputs of Energy for Heat, Power, and Electricity Generation by Energy Source, 1991



^aFuel oil includes residual fuel oil and distillate fuel oil. LPG=Liquefied petroleum gases.

Note: Total does not equal sum of components due to independent rounding. Source: EIA, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Tables A4 and A6.

Figure 4. Total Inputs of Energy for Heat, Power, and Electricity Generation by Industry, 1991



Note: Total does not equal sum of components due to independent rounding. Source: EIA, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Table A4.

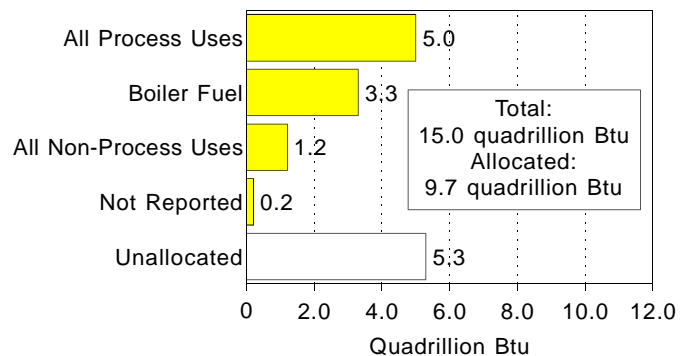
The food industry's total input consumption was 1.0 quadrillion Btu in 1991, most of which was used to process food for distribution. The paper industry consumed 2.5 quadrillion Btu, primarily in the paper pulping process. (Pulping wood, the main raw material for paper, is not counted as an energy source in the MECS because manufacturers consider it a nonenergy input.)

End Uses

U.S. manufacturers reported, by end-use allocation, an energy consumption total of 9.7 quadrillion Btu of energy in 1991 (Figure 5). (Another 5.3 quadrillion Btu were consumed, but could not be allocated to specific uses. See "Unallocated End-Use Consumption," below.) Manufacturing establishments consume energy in three primary ways: direct process uses, including running motors, ovens, strip heaters, and kilns; direct nonprocess uses, including heating, ventilating, and air-conditioning (HVAC) applications and facility lighting; and boiler fuel, which is an indirect use in which energy is transformed from one usable source to another.

Direct process uses. Direct process uses accounted for 5.0 quadrillion Btu, 51 percent of reported total end-use

Figure 5. Consumption of Energy for Heat, Power, and Electricity Generation by Manufacturing End Use, 1991



Source: EIA, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91) (Washington, DC, December 1994), Table A36.

consumption. Of that total, 4.5 quadrillion Btu (90 percent) was used to run motors that drive machines and for process heating, which is used to melt scrap metal and to dry food residual for resale as livestock feed, among many other things. Electrochemical processes, such as that by which aluminum oxide from bauxite ore is split into molten aluminum and oxygen, accounted for the third-heaviest use (0.3 quadrillion Btu). Most electrochemical use of energy occurs in the primary metals and chemical industries.

Direct nonprocess uses. In contrast to the heavy use of energy in manufacturing process applications and the high consumption of nonprocess energy in other sectors, the manufacturing sector uses relatively little energy in direct nonprocess applications. In 1991, 12 percent (1.2 quadrillion Btu) of manufacturing end-use energy for which end-uses were assigned was accounted for by nonprocess uses, such as HVAC, other facility support, onsite transportation, and electricity generation. Facility-related uses accounted for 0.7 quadrillion Btu of that amount. It should be noted that, although this pattern holds for the manufacturing sector in general, some industry groups are exceptions. Where manufacturing takes place in large, environmentally controlled buildings (as in the cases where furniture, automobiles, and computers are manufactured), the fraction of total end-use consumption accounted for by facility non-process uses can be much higher.

Boiler fuel. The use of energy inputs as boiler fuels accounted for 3.3 quadrillion Btu in 1991, making boiler fuel manufacturers' largest specific end use. The most important output from the consumption of energy inputs in boilers is steam, which is used in a variety of ways in manufacturing establishments. The surgical and medical instruments industry uses steam to sterilize medical products. High-pressure steam can be used to generate electricity or to supply heat energy.

Unallocated end-use consumption. As mentioned above, consumption of 5.3 quadrillion Btu (out of a total input energy consumption of 15.0 quadrillion Btu) was reported by manufacturers in 1991 but not formally assigned to specific end uses. Most of that consumption (96 percent) can be attributed to the use of eight byproduct fuels: waste gas (1.6 quadrillion Btu), pulping liquor (0.9 quadrillion Btu), wood byproducts (0.7 quadrillion Btu), coal coke (0.6 quadrillion Btu), petroleum coke (0.6 quadrillion Btu), blast furnace and coke oven gases (0.4 quadrillion Btu), net steam (0.2 quadrillion Btu), and waste oils and other materials (0.1 quadrillion Btu). Although these fuels are not officially allocated, their fates are known in general terms: petroleum refineries use waste gas, for example, for heating processes, while the paper industry uses pulping liquor generated onsite in recovery boilers to generate heat and recover catalysts for use in the pulping process.

Fuel-Switching Capability

A manufacturer's ability to switch from one fuel to another can be a useful means for adapting to changes in economic

conditions or fuel supply interruptions. Fuel-switching capability is defined as the ability to meet requirements for heat, power, and electricity generation by substituting one energy source for another within 30 days while maintaining constant production and without significant modifications to the fuel-using equipment.

Fuel-switching ability varies from one industry or manufacturing establishment to another, depending upon the technologies and the institutional circumstances involved. For example, many boilers may be able to use either natural gas or residual fuel oil, but few can switch between natural gas and electricity. Even if the technical capability exists, a manufacturer's fuel-switching options may be limited by binding agreements to purchase fixed supplies of a particular fuel, regulations that cap allowable emissions of air pollutants, or other constraints. These limitations create a minimum demand quantity for each fuel called the nonswitchable minimum requirement. That quantity defines the lower bound of switchability. It represents the actual consumption of each fuel in 1991, less the amount of each fuel that would not have been required if manufacturers had exercised all identified switching options and thus reduced their use of the fuel.

Since the oil shocks of the mid-1970's, U.S. manufacturers have reduced their dependence on petroleum-based fuels (residual and distillate fuel oils and LPG) from 17 percent of total offsite-produced energy use for heat, power, and electricity generation in 1978 to 5 percent in 1991. Their capability to make further, temporary switches to other fuels is limited. According to the 1991 MECS, manufacturers' consumption of residual fuel oil, distillate fuel oil, and LPG as a fraction of total energy inputs was only 3 percent, 1 percent, and 1 percent, respectively. The switchable portions of that consumption were 45 percent, 20 percent, and 47 percent, respectively.

U.S. manufacturers consumed 5.5 quadrillion Btu of natural gas in 1991; that quantity represented 37 percent of total energy inputs. The nonswitchable minimum requirement for natural gas was 3.6 quadrillion Btu. Manufacturers reported being able to replace 40 percent of switchable natural gas consumption with distillate fuel oil or 34 percent with residual fuel oil in 1991. However, among other disincentives to switching, price differentials between those fuels and natural gas strongly favored the latter.

Finally, the switching potential for electricity is limited, primarily because equipment cannot easily or efficiently be designed to alternate between electricity and a combustible fuel. Only 2 percent of manufacturing electricity consumed in 1991 could have been replaced by alternatives. Of 1991 total coal consumption, 45 percent was switchable. However, coal is cheaper (in terms of heat content) than any competing fuel, so there was little incentive to switch.

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