

## Energy Use in Manufacturing – 1998 to 2002

*Energy Use in Manufacturing* provides information related to energy consumption changes within the U.S. manufacturing sector between 1998 and 2002. This report addresses both manufacturing energy consumption and characteristics of the manufacturing economy related to energy consumption. In addition, special sections on fuel switching capacity and energy-management activities between 1998 and 2002 are also featured in this report. All consumption data in this report comes from the Manufacturing Energy Consumption Surveys (MECS).

This is a follow-up of the [Energy Use in Manufacturing: 1994 to 1998](#) report.

### **Characteristics of the US Manufacturing Economy**

- [Gross Domestic Product \(GDP\)](#)
- [Value of Shipments](#)
- [Capacity Utilization](#)

### **Energy Consumption by the Manufacturing Sector**

- [Cost of Energy](#)
- [First Use Consumption](#)
- [Energy Consumed as Fuel](#)
- [Nonfuel Use of Energy](#)
- [End Uses of Energy](#)
- [Electricity Consumption and Onsite Generation](#)
- [Byproducts Consumed as Fuel](#)
- [Wood Products Consumed as Fuel](#)

### **Special Topics**

- [Fuel Switching Capacity](#)
- [Energy Management Activities](#)

### **Contact Information**

## Characteristics of the Manufacturing Economy, 1998 and 2002

Between 1998 and 2002 the overall manufacturing sector and its major energy-intensive subsectors showed varying amounts and directions of change with regard to major economic indicators.

### Gross Domestic Product

**Table 1. Real Value Added by Industry between 1998 and 2002 (percent increase in chained constant dollars)**

<b>311 -- Food</b>	-6.2
<b>322 -- Paper</b>	-9.5
<b>324 -- Petroleum and Coal</b>	+21.1
<b>325 -- Chemicals</b>	+10.7
<b>331 -- Primary Metals</b>	-6.3
<b>Manufacturing Total</b>	+6.0

**Notes:** Nominal Value Added comes from the 1998 values in the 2001 Annual Survey of Manufacturers (ASM). The 2002 nominal values come from the [2004 ASM](#) (released 12/14/2005). The 3-digit level NAICS value added numbers are deflated using BEA chain-type indices for value added (released 12/15/2005).

**Sources:** U. S. Census Bureau, Annual Survey of Manufacturers. [2001](#) and [2004](#); U. S. Bureau of Economic Analysis, Gross Domestic Product-by-Industry Accounts, [Chain-Type Price Indexes for Value Added by Industry](#).

**Gross Domestic Product (GDP)** is a measure that can be used as an indicator of the economic health of a group of related businesses. It is the sum of the [value added](#) of the members of the group. While GDP alone cannot tell the whole story of the economic prosperity for a group, it is a commonly used indicator. Overall, there was a 6 percent increase in total value added in the manufacturing sector from 1998 to 2002 (see Table 1). However, among the subsectors that consumed the most energy<sup>1</sup>, listed in Table 1, only the chemicals and petroleum and coal groups showed an increase in real value added. The chemicals and petroleum and coal industries, along with other groups that are not among the largest users of energy, drove up real value added to the 6 percent growth between 1998 and 2002.

### Value of Shipments

**Table 2. Real Value of Shipments by industry between 1998 and 2002 (percent increase in constant dollars)**

<b>311 -- Food</b>	+ 4.1
<b>322 -- Paper</b>	- 7.0
<b>324 -- Petroleum and Coal</b>	+ 6.4
<b>325 -- Chemicals</b>	+ 2.8
<b>331 -- Primary Metals</b>	- 12.2
<b>Manufacturing Total</b>	0.0

**Notes:** See sheets "A" (nominal value of shipments) and "C" (price deflators) in the [Industry Shipments by NAICS worksheet](#) on the [Industry Economics Accounts](#) page of the [Bureau of Economic Analysis](#) site. Percent change in real value of shipments is calculated by first computing the constant dollar value of shipments for each manufacturing sub-industry and then aggregating into 3-digit NAICS groups.

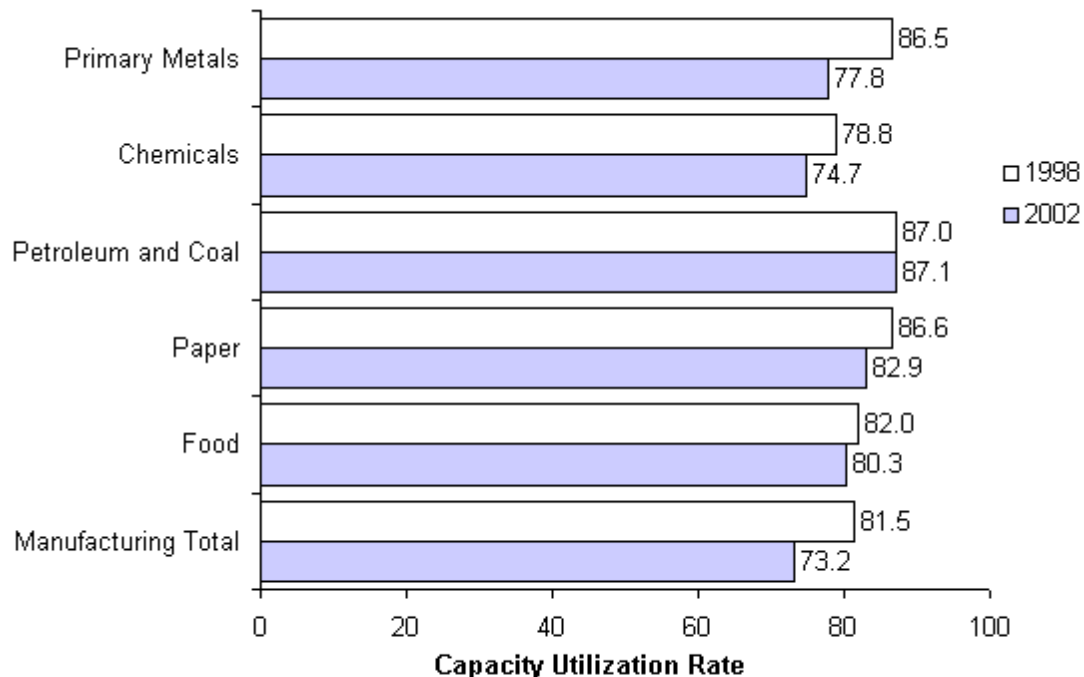
**Source:** U. S. Bureau of Economic Analysis, Gross Domestic Product-by-Industry Accounts, GDPbyInd\_SHIP\_NAICS. Released 12/15/05.

Output measures based on [value of shipments](#) have been shown to be the most useful indicator when comparing manufacturing energy consumption from one year to another.<sup>2</sup> Among the manufacturing industries that have traditionally used the most energy, it has been found that the change in energy consumed from one period to another is positively correlated with the change in real value of shipments between the two periods. If the real value of shipments increases by some percentage between years, it is expected that energy consumption increases by approximately that percentage. A discrepancy indicates that there may have been a change in energy intensity in the industry. One common measure of energy intensity is consumption per dollar value of shipments.

Overall, as can be seen in Table 2, the real value of shipments was flat from 1998 to 2002 for the manufacturing sector. Among manufacturing industry groups that traditionally consume the most energy there were mixed results. Petroleum and coal, food, and chemicals had small increases and paper had a small percentage decrease in real value of shipments. The primary metals industry, however, had a more significant percentage decrease in real value of shipments.

## Capacity Utilization

**Figure 1. Capacity Utilization, 1998 and 2002**



**Source:** U.S. Department of Treasury, Board of Governors of the Federal Reserve System.  
[http://www.federalreserve.gov/releases/G17/tpdisk/utl\\_sa.txt](http://www.federalreserve.gov/releases/G17/tpdisk/utl_sa.txt).

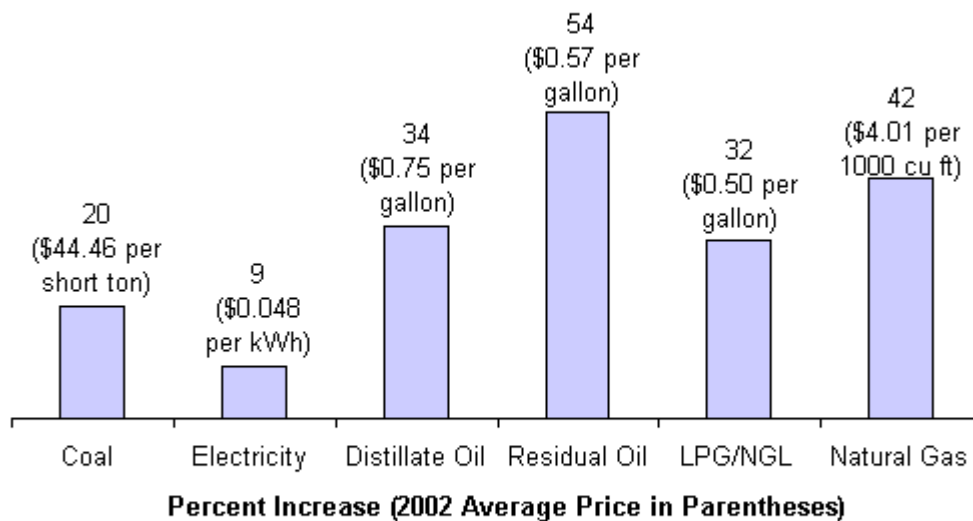
Figure 1 contains the percent of [production capacity utilized](#)<sup>3</sup> in the manufacturing industries which traditionally consume the most energy as well as the sector as a whole for 1998 and 2002. With the exception of the petroleum and coal group, all of the highlighted industries in 2002 operated under the percent capacity levels of 1998. Primary metals was down nearly 10 percent. This, along with the decline in real value of shipments, suggests that the primary metals industry struggled between 1998 and 2002.

## Energy Consumption

### Cost of Energy

It is difficult to isolate the affect the increase in the cost of energy had on the manufacturing economy from 1998 to 2002, but it certainly tightened operating margins. For example, had the sector maintained the same level of natural gas use in 2002 as was used in 1998, the 42 percent increase in cost would have to have been absorbed. However, first use consumption of natural gas fell by 13 percent between 1998 and 2002. Still, the sector-wide expenditures on natural gas increased by nearly 30 percent--over \$5.75 billion (nominal).

**Figure 1. Increase in Average Nominal Price per Unit of Fuel from 1998 to 2002**

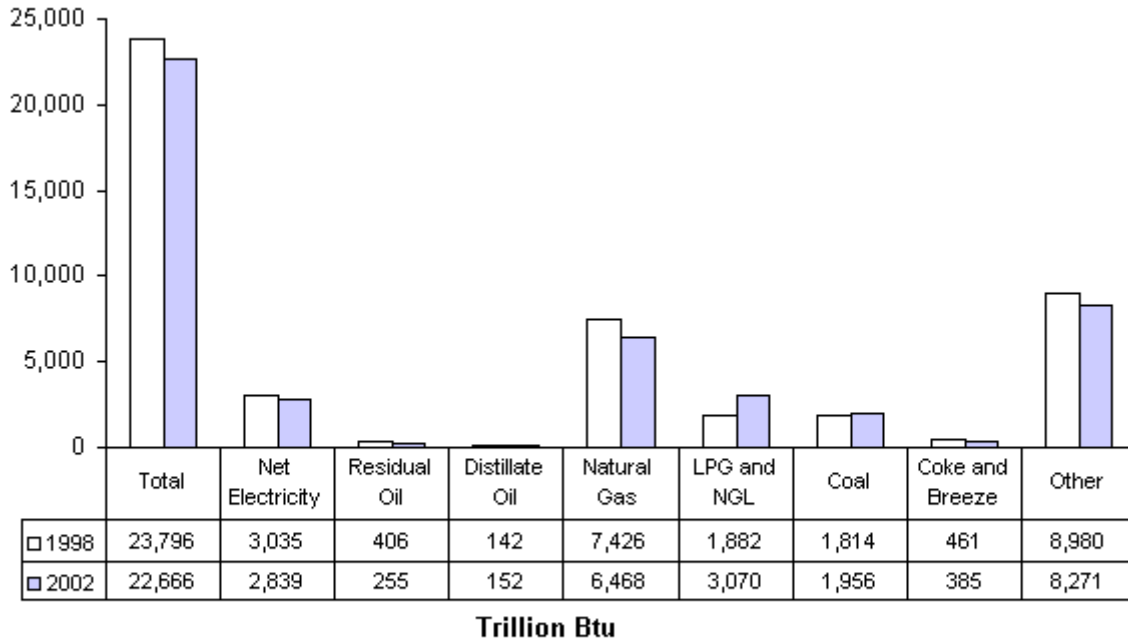


**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 7.2: All Collected Energy Sources by Manufacturing Industry and Region (dollars per million Btu).  
 1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n8\\_2.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n8_2.xls).  
 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table7.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table7.2_02.xls).

## First Use Consumption of Energy

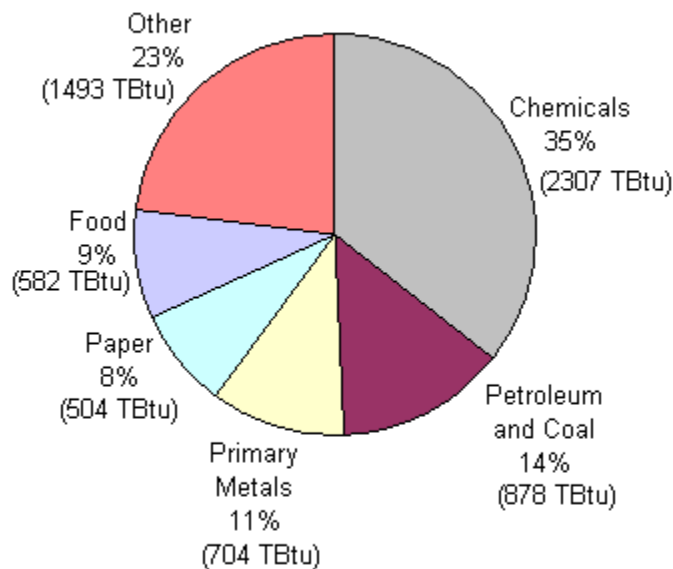
While there was an increase in average cost per unit for all of the major sources of energy used (see Figure 1), it was clearly the increase in the cost of natural gas that hit the sector the hardest. In terms of Btu for first use, natural gas stands out as the energy source used most widely used among manufacturing industries. Natural gas is a relatively low emission fuel and is an irreplaceable feedstock in several major chemical sub-industries.

**Figure 2. First Use of Energy, 1998 and 2002**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 1.2: First Use of Energy for all Purposes (Fuel and Nonfuel). 1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n1\\_2.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n1_2.xls). 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table1.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table1.2_02.xls).

**Figure 3. Manufacturing Sector First Use Consumption of Natural Gas by Industry, 2002**



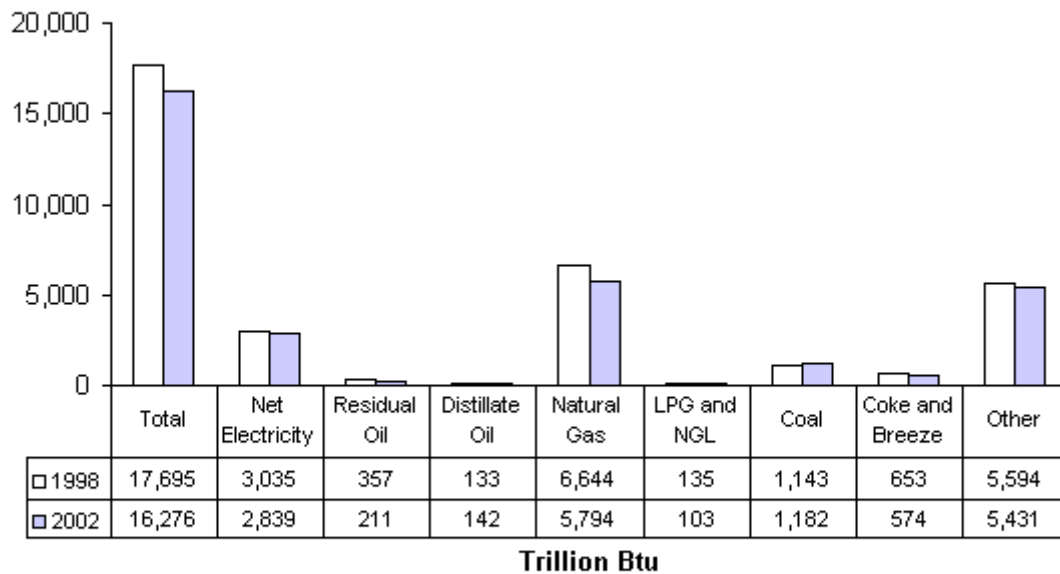
**Source:** Energy Information Administration, Manufacturing Energy Consumption Survey  
-- Table 1.2: First Use of Energy for All Purposes (Fuel and Nonfuel).  
2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table1.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table1.2_02.xls).

The chemical industry is the largest user of natural gas within the manufacturing sector. Chemical manufacturing establishments used over two and a half times as much natural gas as establishments in the second largest user industry, petroleum and coal products. Other industries that consume significant quantities of natural gas include primary metals, paper, food, and nonmetallic minerals. These industries have traditionally been the heaviest users of energy in the manufacturing sector.

### Energy Consumed as Fuel

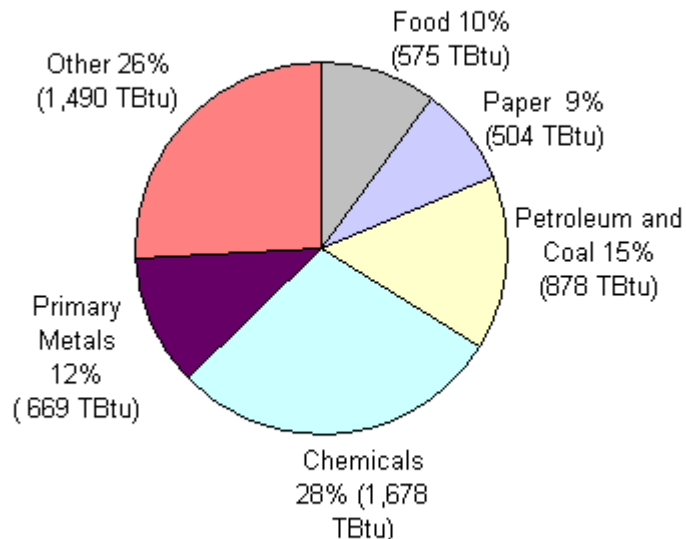
Other than liquefied petroleum gasses and natural gas liquids (LPG/NGL), fuel consumption by energy type for the manufacturing sector in 1998 and 2002 is not substantially different than what is found in Figure 2 above. The chemicals industry makes extensive use of natural gas as a feedstock. Thus, the percent of natural gas utilized by the chemicals industry is higher in Figure 3 (35 percent) than in Figure 5 (28 percent).

**Figure 4. Energy Consumed as Fuel, 1998 and 2002**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 3.2: Fuel Consumption. 1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n3\\_2.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98n3_2.xls). 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table3.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table3.2_02.xls).

**Figure 5. Manufacturing Sector Consumption of Natural Gas as a Fuel by Industry, 2002**

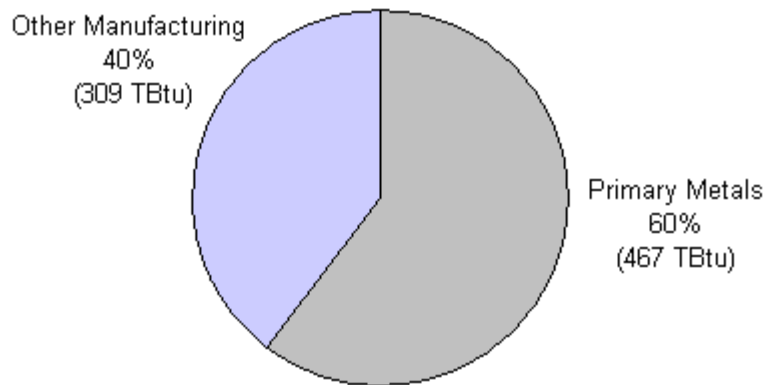


**Source:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 3.2: Fuel Consumption. 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/tables3.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/tables3.2_02.xls).

## Nonfuel Use of Energy

A few manufacturing industries use a large amount of combustible energy sources as a feedstock in their production processes.

**Figure 6. Coal Used as a Feedstock by Industry, 2002**

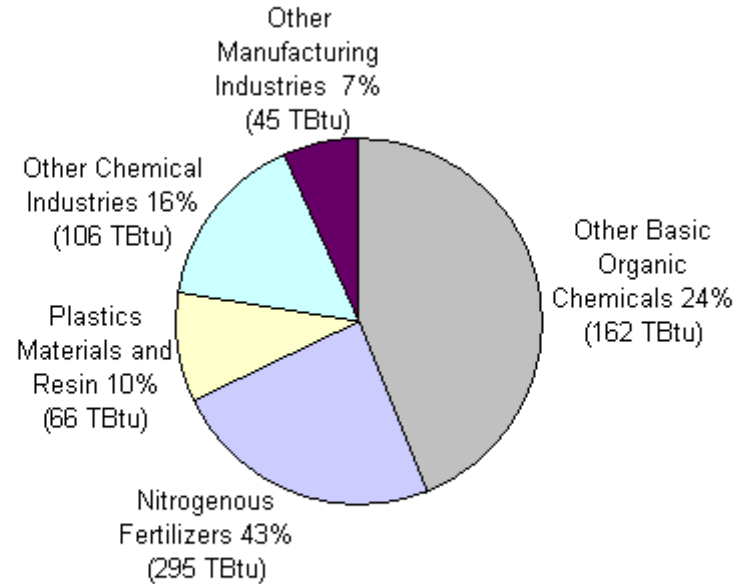


**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- Table 2.2: Nonfuel (Feedstock) Use of Combustible Energy.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table2.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table2.2_02.xls).

Nearly one hundred percent of coal used as a feedstock has traditionally been used in iron and steel mills (NAICS 331111). This industry makes and uses coke (made from coal) in blast furnaces. In 2002, however, 40 percent of the total coal used as a feedstock was used in other industries. This is in part due to the recent emergence of synfuel plants, which are part of the petroleum and coal industry. Synfuel plants apply a chemical treatment to coal and resell it.



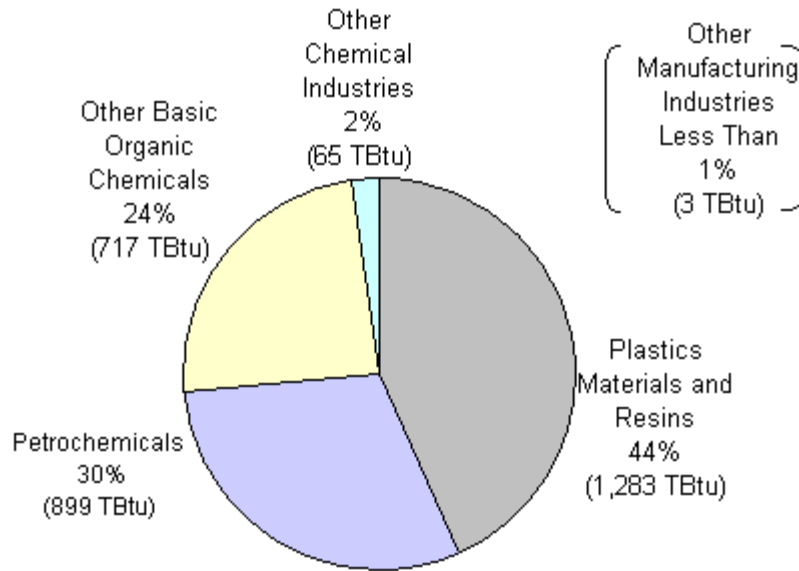
**Figure 7. Natural Gas Used as a Feedstock by Industry, 2002**



**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- Table 2.2: Nonfuel (Feedstock) Use of Combustible Energy.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/exce/table2.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/exce/table2.2_02.xls).

The nitrogenous fertilizer industry (NAICS 32531) uses the most natural gas as a feedstock, followed by other basic organic chemicals (NAICS 325199), plastics materials and resins (NAICS 325211), and iron and steel mills (331111). In 1998 more natural gas was used for nonfuel purposes than in 2002. However, there were no major changes in the percent shares that each of these industries accounted for of the total natural gas for nonfuel purposes.

**Figure 8. LPG/NGL Used as a Feedstock, by Industry, 2002**



**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- Table 2.2: Nonfuel (Feedstock) Use of Combustible Energy.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table2.2\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table2.2_02.xls).

There was a substantial increase from 1998 to 2002 in LPG/NGL use as a feedstock. The total rose over 1.2 quadrillion Btu. Most of the use occurred in the plastics materials and resins group (NAICS 325211). Other big users of LPG/NGL include petrochemicals (NAICS 325110) and other basic organic chemicals (NAICS 325199). Note: It is suspected that instead of this being a completely meaningful increase, LPG/NGL use as a feedstock was underreported in the chemical industry prior to the 2002 MECS.

## End Uses of Energy in Manufacturing

As in previous years, manufacturers allocated their uses of major purchased fuels to end-uses. The end-uses are subsets of boiler fuel, direct process use, and direct nonprocess use. Manufacturers were not asked to estimate end-use of less generally used energy sources such as major byproducts, wood, and waste. The amount of fuel for which end-uses were not allocated has not changed significantly since 1998 (35 percent in 1998 and 37 percent in 2002).

**Table 1. Manufacturing End-Use Breakouts for Commonly Used Energy Sources for 1998 and 2002(Trillion Btu)**

	Fuel Total <sup>1</sup>		Net Electricity		Residual Oil		Distillate (and Diesel) Oil		Natural Gas		LPG		Coal	
	1998	2002	1998	2002	1998	2002	1998	2002	1998	2002	1998	2002	1998	2002
<b>Total Fuel Consumption</b>	11,447	10,267	3,035	2,840	357	208	133	141	6,644	5,794	135	103	1,143	1,182
<b>Indirect Uses-Boiler Fuel</b>	3,635	3,110	19	12	246	127	38	25	2,538	2,162	24	8	770	776
<i>Conventional Boiler Use</i>	--	1,679	--	9	--	76	--	25	--	1,306	--	8	--	255
<i>CHP and/or Cogeneration Process</i>	--	1,443	--	4	--	51	--	10	--	857	--	0	--	521
<b>Direct Uses-Total Process</b>	6,325	5,722	2,408	2,218	103	60	37	43	3,361	2,956	78	64	338	381
<i>Process Heating</i>	4,055	3,595	352	343	97	58	20	24	3,187	2,742	68	60	331	368
<b>Direct Uses-Nonprocess</b>	1,330	1,124	538	514	8	4	52	50	673	513	29	24	30	19
<i>Facility HVAC</i>	692	697	271	262	4	3	6	5	403	417	4	5	4	5
<b>End Use Not Reported</b>	157	300	70	96	1	17	7	12	72	162	4	6	3	6

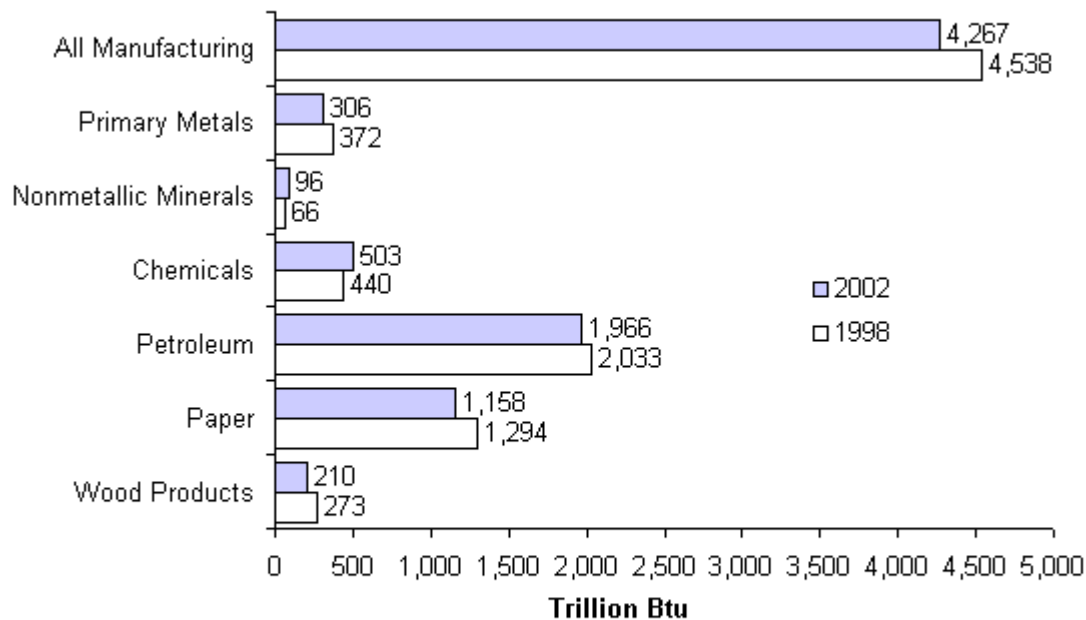
-- = Data not available.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 5.2: Energy Consumed as a Fuel by End Use By Manufacturing Industry with Net Electricity 1998 and 2002.

The pattern of end-uses for the generally used fuels in the table above has remained remarkably stable over the years. In 2002, 30 percent of total fuel for end-use was used in boilers, 56 percent was used directly in the manufacturing process, 11 percent was used in direct nonprocess use, and 3 percent was not reported. Each of the percentages for 1998 is less than 2 percent different from those given for 2002.

## Byproducts in Fuel Consumption

**Figure 9. Byproduct Use as a Fuel by Industry, 1998 and 2002**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 3.5: Byproducts in Fuel Consumption by Manufacturing Industry and Region.  
 1998: [ftp://ftp.ei8a.doe.gov/pub/consumption/industry/d98n5\\_1.xls](ftp://ftp.ei8a.doe.gov/pub/consumption/industry/d98n5_1.xls).  
 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table3.5\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table3.5_02.xls).

The primary metals industry (NAICS 331) declined in its share of byproduct use relative to other industries between 1998 and 2002. Almost all of this byproduct use was coke oven and blast furnace gas in the Iron and steel industry. This decline mirrored an overall decline in production in the steel industry, as well as a continuing shift away from the integrated steel mill into the electric arc furnace.

The chemical industry continued to grow in the use of waste gas for fuel -- 416 trillion Btu in 1998 to 483 trillion Btu in 2002. Waste gas in 2002 accounted for 12.8 percent of the total fuel used in the chemical industry.

**Table 2. Selected Byproducts in Fuel Consumption, 1998 and 2002 (Trillion Btu)**

	1998	2002
<b>Total</b>	4,538	4,267
<b>Blast Furnace/Coke Oven Gases</b>	369	297
<b>Waste Gas, Still Gas</b>	1,837	1,887
<b>Petroleum Coke</b>	703	679
<b>Pulping Liquor/Black Liquor</b>	903	820
<b>Wood Chips/Bark</b>	684	542
<b>Oils, Tars, Waste Material</b>	43	41

**Source:** Energy Information Administration, Manufacturing Energy Consumption Survey --

Table 3.5: Byproducts in Fuel Consumption by Manufacturing Industry and Region, 1998, and 2002.

While fuel consumption declined between 1998 and 2002, the proportion of fuel use that the byproducts listed in Table 2 account for was unchanged from 1998 to 2002. Waste gas, including refinery still gas, was again the most widely used of the selected byproducts. The petroleum and coal group (NAICS 324) was the primary user of waste gas (1,396 trillion Btu) and petroleum coke (565 trillion Btu) in 2002.

## Wood-Related Products in Fuel Consumption

**Table 3. Selected Wood-Related Products in Fuel Consumption in the US (Trillion Btu)**

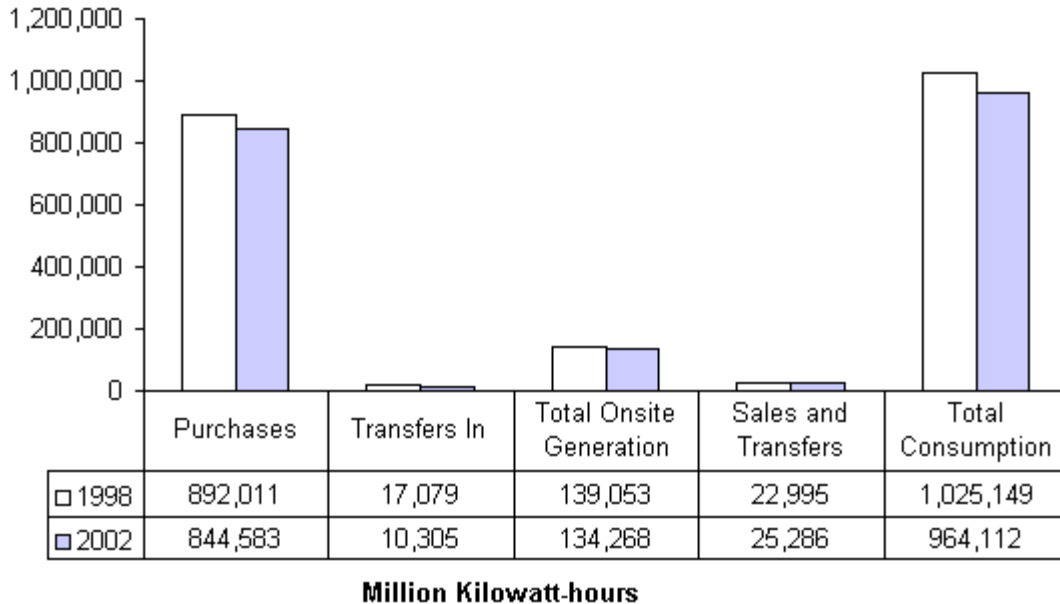
	1998	2002
<b>Pulping or Black Liquor</b>	903	820
<b>Biomass</b>		
<b>Agricultural Waste</b>	43	40
<b>Wood Harvested From Trees</b>	58	35
<b>Wood and Byproducts from Mill Processing</b>	626	507
<b>Wood and Paper-Related Refuse</b>	15	12

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 3.6: Selected Wood and Wood-Related Products in Fuel Consumption, 1994, 1998, and 2002

The use of wood related products dropped between 1998 and 2002, but its percent share in the mix of fuel used in manufacturing remained steady. Pulping or black liquor made up 35 percent of the total fuel used in the paper industry (NAICS 322) in 2002. Biomass made up about 4 percent of the total fuel use in manufacturing in 2002. These percentages were not more than a percent or two different in 1998.

## Total Consumption and Onsite Generation of Electricity

**Figure 10. Components of Electricity Consumption in Manufacturing, 1998 and 2002**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 11.1: Electricity Components of Net Demand. 1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d9813\\_1.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d9813_1.xls). 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table11.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table11.1_02.xls).

Manufacturing as a whole is both a major user and producer of electricity. Although total consumption of electricity did decline approximately 6 percent, there appeared to be little change in the make-up of manufacturing electricity use and production between 1998 and 2002. In fact, the relative shares of electricity consumption among the three component parts, purchases, transfers in, and the net of generation minus sales and transfers out are identical, according to the MECS data (87, 1, and 11 percent in 2002, respectively). Similarly, three industry subsectors, chemicals, primary metals, and paper, accounted for 48 percent of total consumption of electricity, approximately the same share as in 1998.

### Electricity Purchases

Although total electricity consumption has shown stability, restructured energy markets have had an effect on choices made by electricity purchasers. While it is difficult to know whether the changes were due to growth in access to nonutility suppliers or a greater interest in them by manufacturers, clearly more of the electricity purchases were from sources other than the manufacturer's local utility.

Figure 14 shows those changes. The overall amount of electricity purchased from nonutility suppliers<sup>2</sup> increased from 8.7 percent of the total in 1998 to 12.4 percent in 2002. Not only did the share of total purchases change, but the amount of nonutility purchases of electricity by manufacturers actually increased by 27 billion kilowatthours, even though total purchases of electricity declined.

**Table 4. Utility and Nonutility Purchases of Electricity by Manufacturers in 1998 and 2002 (Million Kwh)**

	1998			2002		
	Total Purchases	Utilities	Nonutilities	Total Purchases	Utilities	Nonutilities
<b>Total</b>	892,011	814,622	77,389	844,583	739,921	104,662
<b>Percent of Total</b>	100	91.3	8.7	100	87.6	12.4

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 11.1: Electricity: Components of Net Demand, 1998 and 2002.

Three industry subsectors, chemicals, paper, and petroleum and coal products, accounted for 89 percent of the total onsite generation less sales and transfers out. Of the total onsite generation in manufacturing in 2002 (134,268 million kilowatthours), 93 percent was from a cogeneration or combined heat and power (CHP) process, 2 percent was from a renewable energy source (hydropower, wind, solar, or geothermal), and 6 percent was from other processes including conventional fossil fuel generators, often used as backup. That breakdown is almost identical to what was found in 1998.

Larger establishments are responsible for producing most of the on-site generation. In examining manufacturing establishments by employment size categories, 73 percent of the total generation came from establishments with 500 or more employees. According to the U.S. Census Bureau's Economic Census—Manufacturing<sup>3</sup>, only 2 percent of manufacturing establishments in the MECS population<sup>4</sup> have as many as 500 employees. Approximately 90 percent of the generation is in establishments with 250 or more employees, which account for 5 percent of the MECS population. From these results, it is clear that for the most part only the largest establishments will find it economically feasible to generate electricity.

## Special Topics

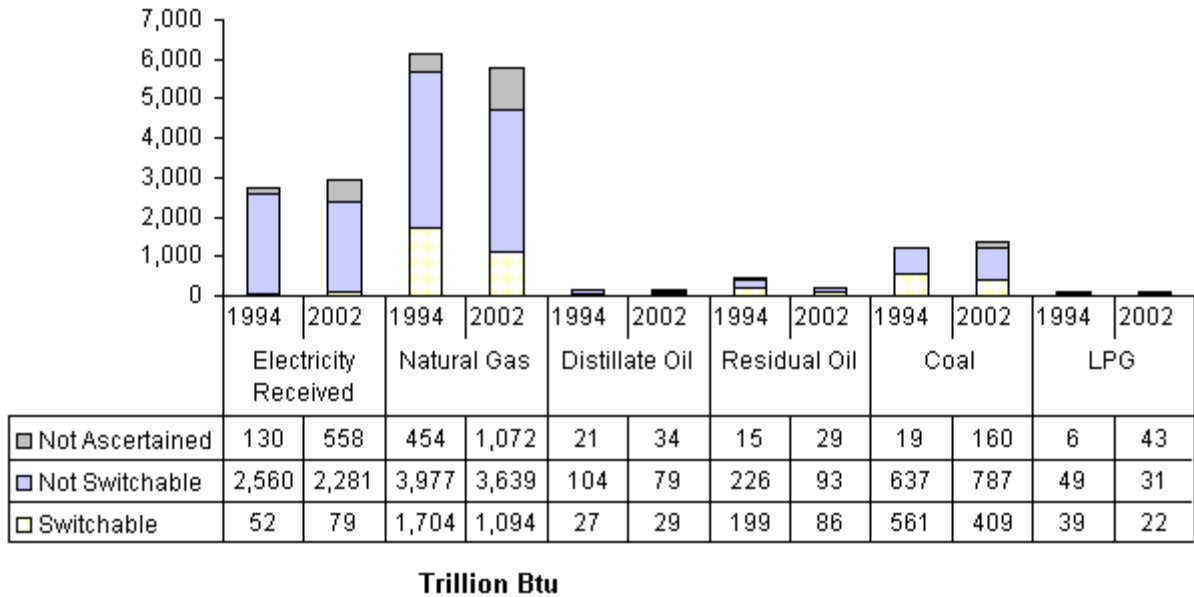
### Manufacturing Fuel-Switching Capability

Many manufacturers have the ability to substitute the consumption of one fuel for that of another when the economic conditions call for making such a change. The ability to switch can be limited not only by the technical considerations of onsite boilers and heaters, but also the practical considerations of

- Federal, state, and local environmental restrictions;
- Available supply and transportation of the fuel;
- Contracts in which the manufacturer is committed to purchasing a certain amount of the fuel, regardless of what has transpired since the contract was agreed upon.

The Manufacturing Energy Consumption Survey (MECS) measures fuel-switching capacity by asking manufacturers to account for both technical and practical considerations simultaneously. Manufacturers were not to consider the relative prices of the fuels when they reported their switching capability. They were instructed to limit their ability to what can be done within a time-period of 30 days and without major modifications to their existing equipment.

**Figure 1. Switchable, Nonswitchable, and Not Ascertained Fuel Consumption, by Fuel, 1994 and 2002**



**Note:** Values in the figure are compiled from fuel switching tables and converted to Btu.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Tables 10.2, 10.4, 10.6, 10.8, 10.10, 10.12, 1994 and 2002. <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>.

A fuel may be completely or partly nonswitchable. In the case of it being completely nonswitchable, it often means that the configuration of the plant's equipment would not allow another fuel to be used in place of the one currently being consumed. Even when an establishment has the ability to switch a portion of its consumption from one fuel to another, it could have a certain amount for which it cannot substitute. The term used to describe both types of situations is, "nonswitchable minimum requirement." For example, a plant may use natural gas in both a boiler and specialty oven used to dry paint. In the boiler, all fuels used may be completely interchangeable. However, in the oven, using something other than natural gas may alter the pigment of the paint. In that case, the natural gas would be nonswitchable. Other reasons a fuel may be partly nonswitchable are the practical considerations such as in-place take-or-pay contracts with a supplier or environmental restrictions that limit the amount the establishment can consume during a specified time.

The MECS measured fuel-switching capability of a selection of the most common purchased energy sources (Figure 1). The total fuel consumption accounted for by those energy sources was 10,512 trillion Btu, approximately 65 percent of all fuel use in manufacturing. Most of the fuels for which the MECS did not measure fuel-switching were byproducts, waste products, and otherwise rarer substances. The interest in measuring an establishment's ability to switch out of those substances is minimal as many of those fuels are produced on-site or acquired through means other than open-market purchases.

Because of the relatively higher amount of not-ascertained switching in 2002 compared to 1994 (18 percent to 6 percent), comparisons are problematic. However, the ratio of total switchable fuel consumption to the sum of all ascertained switchable and nonswitchable fuel of all measured fuels allows a useful comparison without the not-ascertained amount. In 1994, that ratio was 25 percent while in 2002, the ratio apparently dropped to 20 percent. While not entirely conclusive, this result indicates that there may have been some decline in fuel-switching capability between 1994 and 2002.<sup>1</sup>



**Table 1. Fuel Switching Percentages Based on Total Consumption and Sum of Switchable and Nonswitchable Amounts, 1994 and 2002**

	Year Consumed	Total	Not	Not	Switchable	Not Switchable	
		(Trillion Btu)	Switchable	Switchable			Ascertainable
			Percentages Based on Total Consumption)			Percentages Based on Sum of Switchable and Nonswitchable Amounts)	
<b>Electricity Received</b>	2002	2,918	2.7	78.2	19.1	3.4	96.6
	1994	2,742	1.9	93.4	4.7	2.0	98.0
<b>Natural Gas</b>	2002	5,805	18.8	62.7	18.5	23.1	76.9
	1994	6,135	27.8	64.8	7.4	30.0	70.0
<b>Distillate Oil</b>	2002	142	20.1	55.7	24.2	26.5	73.5
	1994	152	18.0	68.2	13.8	20.9	79.1
<b>Residual Oil</b>	2002	208	41.4	44.6	14.0	48.1	51.9
	1994	441	45.2	51.3	3.4	46.9	53.1
<b>Coal</b>	2002	1,356	30.2	58.0	11.8	34.2	65.8
	1994	1,218	46.1	52.3	1.6	46.8	53.2
<b>LPG</b>	2002	96	22.8	32.6	44.5	41.2	58.8
	1994	94	41.8	52.1	6.1	44.5	55.5
<b>Total</b>	2002	10,525	16.3	65.7	18.0	19.9	80.1
	1994	10,781	24.0	70.1	6.0	25.5	74.5

**Note:** Values in the table are compiled from fuel switching tables 10.2-10.12 (<http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>) and converted to Btu.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Tables 10.2, 1994 and 2002; 10.4, 1994 and 2002; 10.6, 1994 and 2002; 10.8, 1994 and 2002; 10.10, 1994 and 2002; 10.12, 1994 and 2002.

Referring to both Figure 1 and Table 1, natural gas, as the fuel with the most total consumption, accounts for most of the switchable consumption on a Btu basis in 2002. However, all but one of the energy sources measured (electricity) has higher rates of switchability on a percentage basis. Electricity and natural gas have the highest non-switchable percentages and also account for the greatest share of the nonswitchable total among all fuels.

### **Nonswitchable Minimum Requirements, Maximum Possible, and Discretionary Fuel Use**

The MECS measured the nonswitchable minimum requirements of a fuel and the maximum possible if all possible switching into that fuel took place. By comparing those limits with actual consumption, one can compute a measure of discretionary fuel use. The discretionary-use rate is a measure, in percent, of the extent to which manufacturers elected to consume discretionary quantities of a given energy source. That is, manufacturers will consume certain fuels above the absolute minimum nonswitchable consumption. A measure of discretionary fuel use can be defined as:

$$USE = \frac{ACT - MIN}{MAX - MIN}$$

where

USE is the discretionary-use rate of a given energy source;

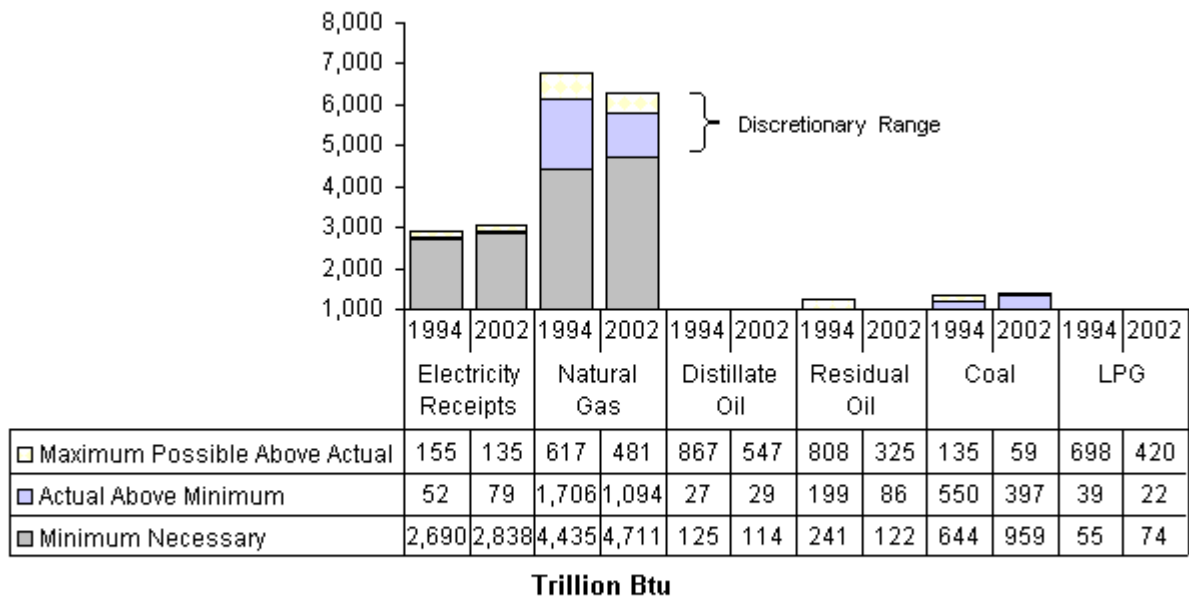
ACT is the actual consumption of that energy source;

MIN is the minimum consumption, which would have been achieved if all ascertained switching from that type of energy had occurred, and

MAX is the maximum consumption, which would have been achieved if all ascertained switching into that type of energy had occurred.

The higher the ratio USE is, the closer the actual consumption was to the maximum possible consumption of that fuel, given all possible fuel-switching *into* the fuel and the same level of operations. Thus discretionary fuel consumption is a measure of preference for one fuel over another.

**Figure 2. Actual, Minimum, and Maximum Fuel Consumption, 1994 and 2002**



**Note:** Values in the figure are compiled from fuel switching tables and converted to Btu.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Tables 10.2, 10.4, 10.6, 10.8, 10.10, 10.12, 1994 and 2002. <http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>.

**Table 2. Discretionary Fuel Use Rates and Ratios of Minimum to Maximum Consumption, by fuel, 2002 and 1994**

Energy Source	Discretionary Fuel Use Rate (Percent)		Minimum/Maximum (Percent)	
	1994	2002	1994	2002
Electricity Receipts	25.2	37.1	92.8	93.0
Natural Gas	73.4	69.5	65.6	75.0
Distillate Fuel Oil	3.1	5.0	12.2	16.5
Residual Fuel Oil	19.8	20.9	19.3	22.9
Coal	80.3	87.0	48.5	67.7
LPG	5.3	5.0	6.9	14.4

**Note:** Values in the table are compiled from fuel switching tables 10.2-10.12 (<http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>) and converted to Btu.

**Sources:** EIA, Manufacturing Energy Consumption Survey -- Tables 10.2, 1994 and 2002; 10.4, 1994 and 2002; 10.6, 1994 and 2002; 10.8, 1994 and 2002; 10.10, 1994 and 2002;

10.12, 1994 and 2002.

As can be seen in Figure 2 and Table 2, the discretionary fuel rate for coal and natural gas are quite high, indicating strong preferences for those fuels. Conversely, Table 2 shows a strong reluctance to use distillate fuel oil and LPG. The pattern of discretionary fuel use rates among the fuels in 2002 is markedly similar to the pattern found in 1994. However, it does appear that preferences for electricity receipts and coal have increased since 1994. In the case of electricity receipts, the increase in the discretionary fuel use rate mirrors the decrease in ratios of electricity generated onsite to electricity receipts (15.7 percent in 2002, down from 17.7 percent in 1994)<sup>2</sup>. The increase in preference for coal may be a direct result of the rise in prices of other energy sources.

Although the discretionary fuel rates have not changed substantially in most cases, it appears that the discretionary ranges themselves have decreased (Table 1). This finding is verified by the fact that the ratios of the switchable amounts to the nonswitchable have decreased for the total and all the fuels, except distillate and residual fuel oil (See data table below Figure 1).

### **Fuel-Switching Flexibility**

Another measure that is useful in evaluating fuel-switching capacity is *flexibility*. Flexibility in fuel-switching is a measure of redundancy in the alternatives available to a manufacturer to switch out of a fuel. Flexibility will always be measured as percentage greater than 100 as it is defined as the sum of the quantities of alternative fuels, divided by the total amount of switchable fuel. For example, an establishment reports that it consumes 15,000 thousand cubic feet (MCF) of natural gas, and that the equivalent of 10,000 MCF of which could have instead been consumed as other fuels. The establishment also reports that 7,500 MCF could have been switched into residual fuel oil, and 5,000 MCF could have been switched into LPG. If no other alternatives were reported, then the establishment's flexibility in switching to natural gas was 125 percent (computed as  $(7,500 + 5,000) \div 10,000$ ). The establishment essentially has flexibility in choosing how it would use residual fuel oil and LPG to substitute for natural gas over the year if it chose to do so.

Table 3 shows the measures of flexibility of energy sources over all manufacturing in 2002 and 1994.

<b>Table 3. Fuel Switching Flexibility by Fuel Type, 1994 and 2002</b>		
<b>Energy Source</b>	<b>Flexibility (Percent) by Year</b>	
	<b>1994</b>	<b>2002</b>
<b>Natural Gas</b>	126.27	116.37
<b>Electricity Receipts</b>	145.17	136.48
<b>Coal</b>	152.13	127.81
<b>Residual Fuel Oil</b>	152.90	129.23
<b>Distillate Fuel Oil</b>	138.74	143.33
<b>LPG</b>	N/A <sup>3</sup>	N/A <sup>3</sup>

**Note:** Values in the table are compiled from fuel switching tables 10.2-10.12 (<http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html>) and converted to Btu.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Tables 10.2, 1994 and 2002; 10.4, 1994 and 2002; 10.6, 1994 and 2002; 10.8, 1994 and 2002; 10.10, 1994 and 2002; 10.12, 1994 and 2002.

As can be seen in Table 3, flexibility has decreased for all fuels since 1994, except distillate fuel oil. Put together with the decrease in the overall ability to switch fuels and the smaller discretionary ranges, it does appear that manufactures have reduced their capacity to switch fuels from 1994 to 2002.

Possible reasons for the observed decrease in switchability since 1994 are:

- The use of long-term contracts in natural gas purchasing;
- Continuing concerns about complying with environmental laws, both in storage of fuel oil and LPG and in emissions, have continued to favor the use of natural gas over other combustible fuels;
- An overall decline in the use of fuel oils for fuel, while relatively unswitchable electricity receipts account for a greater share;
- The relative inexpensiveness of natural gas for most of the period between 1994 and 2002, coupled with its more desirable environmental characteristics.

As energy prices have risen dramatically since 2002, it will be interesting to see whether manufacturers have increased their ability to switch fuels in response.

### **Other Observations**

- Examination of fuel-switching capability of natural gas in 2002 by value of shipments categories and employment size show that the ability to switch increases on average from smaller to larger establishments until the final category when there is a sharp drop off. Thus, fuel switching capability out of natural gas seems to correlate with size, regardless of industry.
- The relative inability of chemical companies to switch<sup>4</sup> may be due indirectly to their heavy use of natural gas as a feedstock. It might not be worthwhile for them to invest in capacity to switch out of gas since their operations are so dependent on it. Further, those manufacturers usually get lower-than-average prices due to their large usage.

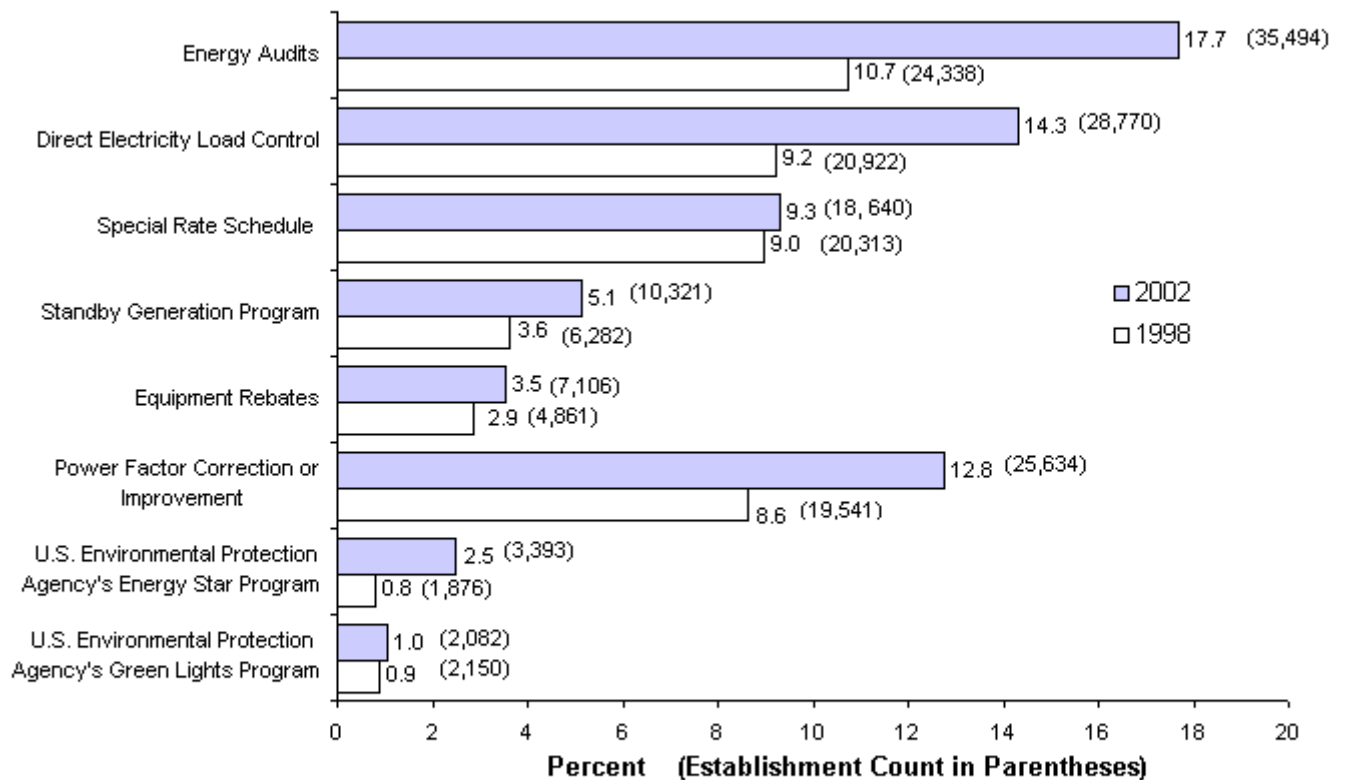
- example, there is a fairly wide distribution of alternatives available for natural gas: 38 percent can be switched to distillate fuel oil, 34 percent to LPG, and 22 percent to residual fuel oil. Yet, for residual fuel oil, 81 percent was switchable to natural gas, distillate fuel oil could replace 24 percent, and no other alternative could replace more than 10 percent of the total.

## Energy Management Activity, 1998 and 2002

### Manufacturing Establishment Participation in Energy Management Activities by Program Type

Associated with the [increased cost of energy](#) between 1998 and 2002 is a general increase in participation in [energy management activities](#) by manufacturing establishments.

**Figure 1. Manufacturing Establishments Participating in Energy Management Programs, 1998 and 2002**

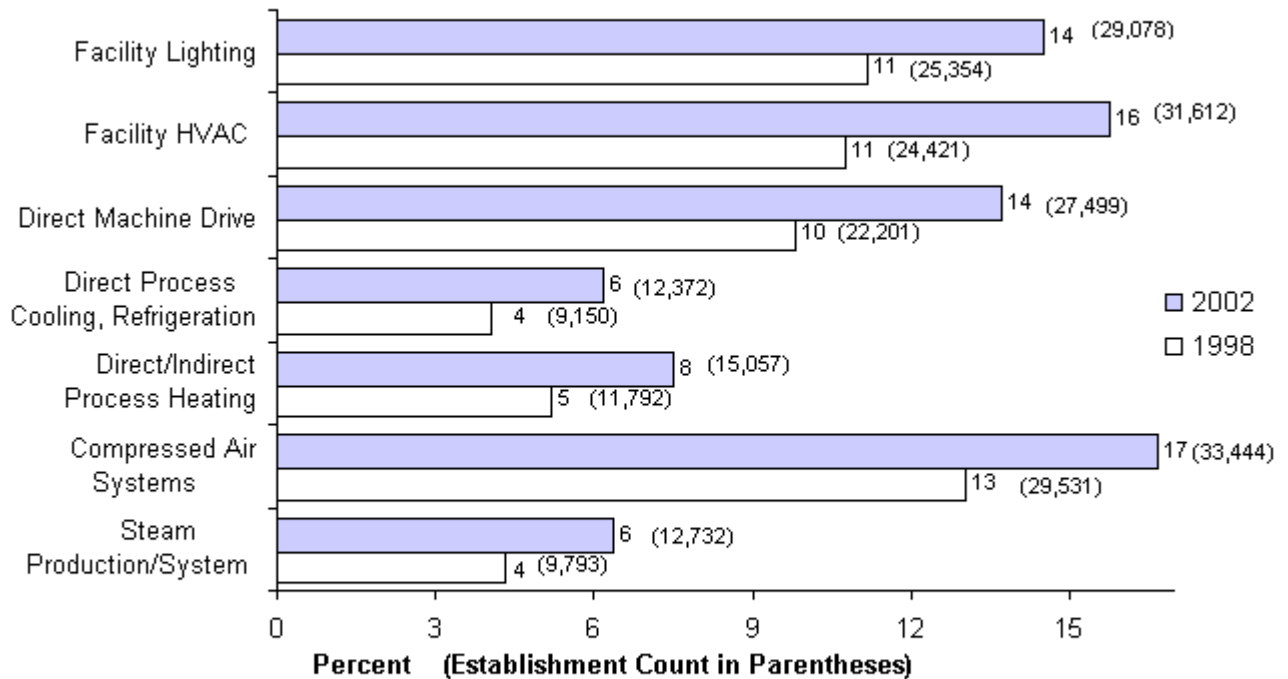


**Note:** U.S. Environmental Protection Agency's Green Lights Program was no longer in existence at the release date of this report.

**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey, Table 8.1: Number of Establishments Participating in Energy Management Activities. 1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9\\_1.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9_1.xls). 2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).

Figure 1 shows that for virtually all of the programs listed, there has been an increase in participation from 1998 to 2002 by manufacturing establishments. When the cost of inputs to production processes, such as energy sources, undergo percentage increases greater than that of the price of the manufactured product, profit margins are squeezed. Responses to this condition can include initiating an effort to improve energy management.

**Figure 2. Manufacturing Establishments Installing or Retrofitting Equipment with Primary Purpose to Improve Energy Efficiency, 1998 and 2002**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 8.1: Number of Establishments Participating in Energy Management Activities.

1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9\\_1.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9_1.xls).

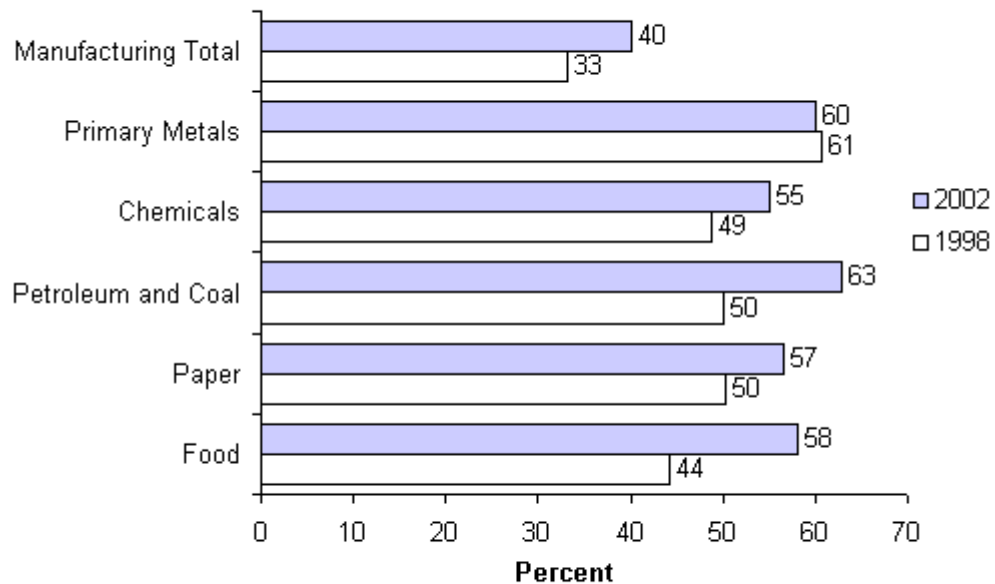
2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).

More manufacturing establishments, in an effort to improve energy efficiency, installed new or retrofit equipment in 2002 than in 1998. In Figure 2, as in Figure 1, the increase is in both percentage and establishment count.

Forty percent of manufacturing establishments participated in an energy efficiency program<sup>1</sup> or equipment upgrade to improve energy efficiency in 2002. This was up 7 percent from 1998.

## Manufacturing Establishment Participation in Energy Management Activities by Industry

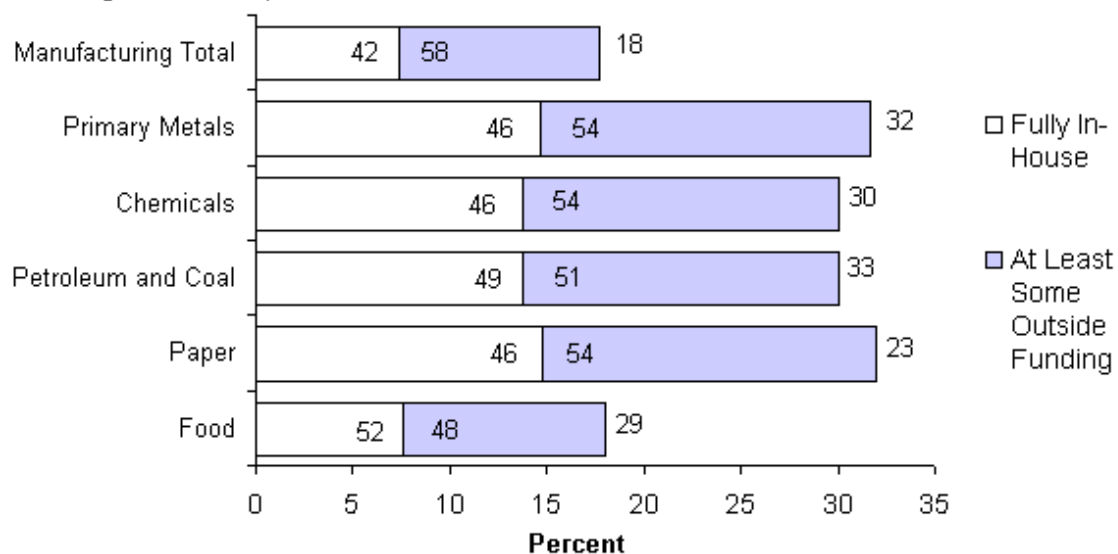
**Figure 3. Participation in Energy Management Activities Among Establishments in Energy Intensive Industries**



**Sources:** Energy Information Administration, Manufacturing Energy Consumption Survey -- Table 8.1: Number of Establishments Participating in Energy Management Activities.  
1998: [ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9\\_1.xls](ftp://ftp.eia.doe.gov/pub/consumption/industry/d98c9_1.xls).  
2002: [http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).

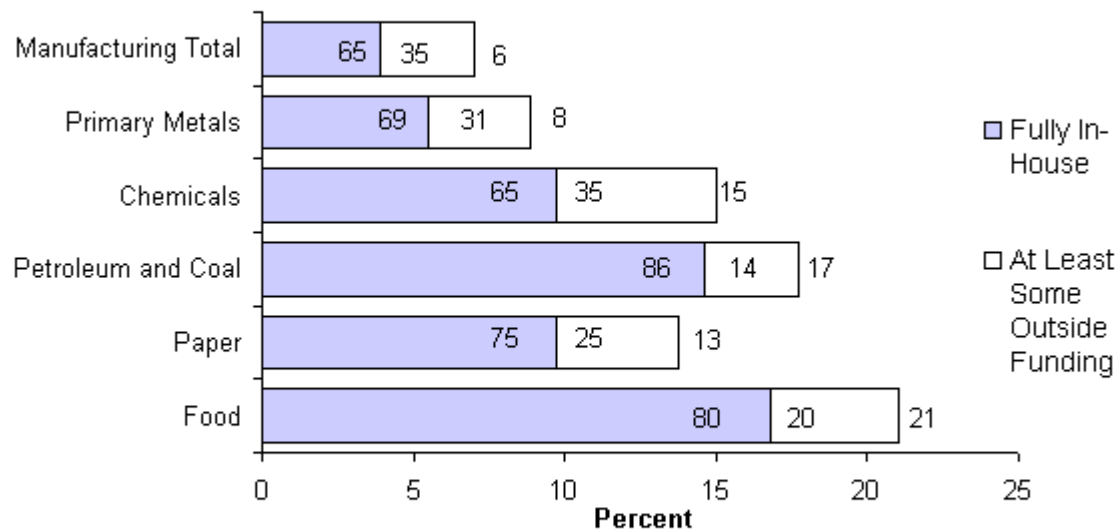
Industry groups that traditionally consume the most energy<sup>2</sup> participated in some kind<sup>1</sup> of energy management activity at a higher percentage than the sector overall. Each of the subindustries listed in figure 2 participated well above the sector-wide levels for both 1998 and 2002 (33 and 40 percent, respectively). In each of these groups, except for primary metals, the participation percentage increased from 1998 to 2002.

**Figure 4. Participation in Energy Audits by Industry and Funding Source, 2002 (Percent of Establishment Participants Fully Funded In-House vs At Least Some Outside Funding Within Bars)**



**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- Table 8.1: Number of Establishments Participating in Energy Management Activities.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).

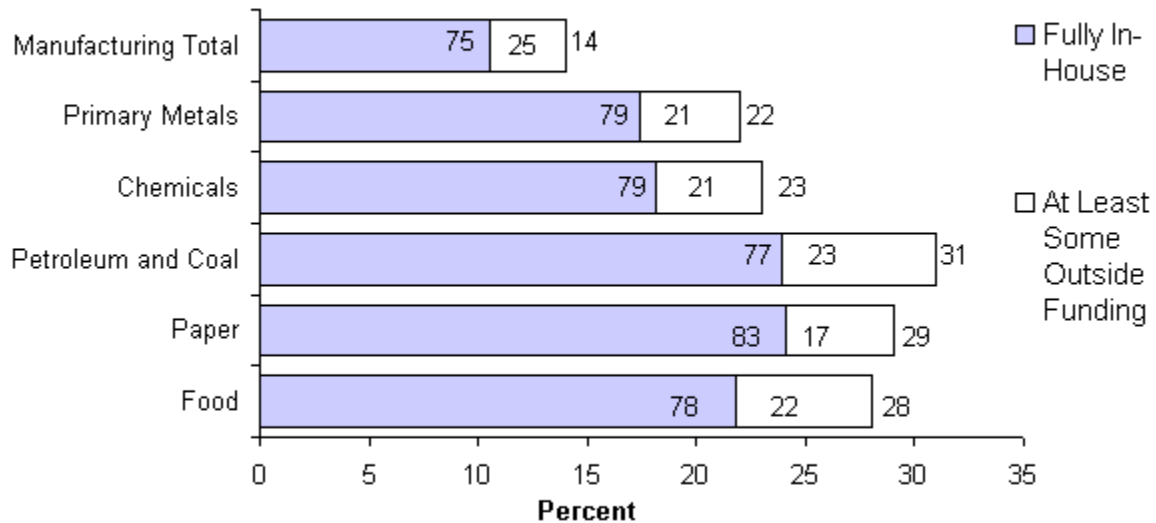
**Figure 5. Establishment Participation in Steam Production System Upgrade by Industry and Funding Source, 2002 (Percent of Establishment Participants Fully Funded In-House vs At Least Some Outside Funding Within Bars)**



**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- Table 8.1: Number of Establishments Participating in Energy Management Activities.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).



**Figure 6. Establishment Participation in Machine Drive Efficiency Upgrade by Industry and Funding Source, 2002 (Percent of Establishment Participants Fully Funded In-House vs. At Least Some Outside Funding Within Bars)**



**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey --Table 8.1: Number of Establishments Participating in Energy Management Activities.  
[http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1\\_02.xls](http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/excel/table8.1_02.xls).

In terms of percentage of establishments, energy-intensive industries<sup>2</sup> participated in energy audits, steam production system upgrades, and machine drive efficiency upgrades more than the manufacturing sector overall. Figures 4, 5, and 6 contain the percentage of establishments participating in the respective program by industry. For each industry, it also gives the percent of establishments participating in the program type that were funded completely in-house and the percent that used at least some funds from other sources (such as government or an energy-supplier program).

Each of the subsectors listed in the three figures above had significantly more participation, led by the petroleum and coal industry, in each of the three program types, than the overall sector. Each of these five industries also had a higher percentage of the programs completely funded by the establishments themselves than was the case in the sector overall. It should be noted that the "other" category includes instances where some in-house funding was used. Total dollars spent on energy management is not available.

While the relationships in Figures 4, 5, and 6 are similar in terms of energy-intensive industry participation relative to the manufacturing sector overall, there are some notable differences in other regards. The percentage of establishments fully funding energy audits is significantly lower than the percentage of establishments fully funding efficiency upgrades in machine drive and steam production systems. The percent participation also varies between the three programs in these figures. A much lower percentage of establishments made efficiency improvements to their steam production systems than they did for machine drive systems, and for most industries the percent participation in machine drive efficiency upgrade programs was lower than the percentage of establishments conducting an energy audit.

**Table 1. Manufacturing Industries with 80 Percent or More Establishments Participating in One or More Energy Management Activity, 2002**

NAICS	Industry	Number of Establishments	Percent Participation in One or More Energy Management Activity <sup>3</sup>
<b>311-339</b>	<b>Manufacturing - Total</b>	<b>200,710</b>	<b>40</b>
311221	Wet Corn Milling	49	86
322110	Pulp Mills	34	91
322121	Paper Mills, Except Newsprint	323	93
322130	Paperboard Mills	210	83
324110	Petroleum Refineries	215	85
325110	Petrochemicals	37	87
325193	Ethyl Alcohol	48	83
327211	Flat Glass	38	92
327213	Glass Containers	61	80
331112	Electrometallurgical Ferroalloy Products	15	80
336112	Light Trucks and Utility Vehicles	42	88

**Notes:** "One or More Energy Management Activity " refers to the programs in MECS Table 8.1 and not the programs listed in Figure 1 and Figure 2, which are subsets of the energy management programs that can be found in table 8.1. There are programs in the 1998 table that are not in the 2002 table and vice versa. These were excluded from the figures in this report.

**Source:** Energy Information Administration, 2002 Manufacturing Energy Consumption Survey -- [Table 8.1: Number of Establishments Participating in Energy Management Activities.](#)

Several manufacturing industries in 2002 had very high percent participation in one or more energy management activity. The industries listed in Table 1 all had 80 percent participation or more, which was more than twice the percentage of the manufacturing sector overall. Most of these industries come from industry groups listed in figures 4, 5, and 6 above, which are the most energy-intensive industries in the sector.

These figures imply that participation in energy management activities has been on the rise and that industries that use the most energy lead the sector overall in participation. This is not surprising as establishments in these industries have the most to gain from energy management.

## Endnotes

### [Characteristics of the Manufacturing Economy](#)

<sup>1</sup> In terms of first use of energy sources (energy used for all purposes), the subsectors in Table 1 accounted for 83 percent of the total Btu's used in the manufacturing sector in 2002.

<sup>2</sup> See "Measures of Output" section of [MECS Survey Design, Implementation, and Estimates, 1994](#) . Publication DOE/EIA-0552 discusses how value of shipments mirrors physical output more closely than value added when value added is variable relative to value of shipments for an industry between comparison years.

<sup>3</sup> Industrial Production Capacity is an index released currently on a monthly basis by the [Federal Reserve Board](#).

## **Energy Consumption**

<sup>1</sup> "Total" includes only energy sources listed in the column headings. It excludes fuel use of unallocated energy sources (6,248 trillion Btu in 1998 and 6,006 trillion Btu in 2002).

<sup>2</sup> These are brokers, marketers, independent power producers, cogenerators from other companies, marketing subsidiaries of other utilities, and any other entities that are not local utilities for a given establishment.

<sup>3</sup> U.S. Department of Commerce, U.S Census Bureau, [2002 Economic Census-Manufacturing, General Summary 2002](#), Washington, DC, October 2005, page 54

<sup>4</sup> The MECS population are those establishments that cover at least 97 percent of the total energy use in U.S. manufacturing. Only the smallest establishments are excluded. See U.S. Energy Information Administration, [2002 Manufacturing Energy Consumption Survey Methodology and Data Quality: Survey Design, Implementation, and Estimates](#) (internet report), "Methodology" subsection

## **Fuel Switching**

<sup>1</sup> The assumption used here is that the not-ascertained amount would breakout in the same proportions as the fuel consumption that was actually measured as switchable or nonswitchable. As the not-ascertained amount increases, so does the potential for bias and the uncertainty of that assumption.

<sup>2</sup> MECS Tables, Electricity: Components of Net Demand, [2002](#) and [1994](#).

<sup>3</sup> Some of the necessary data was unpublished because of large sampling error.

<sup>4</sup> [MECS Table 10.2 Capability to Switch Natural Gas to Alternative Energy Sources, 2002](#)

## **Energy Management Activities**

<sup>1</sup> "Any Program" refers to the programs in MECS table 8.1 and not the programs listed in Figure 1 and Figure 2. This set of programs is a subset of the energy management programs that can be found in table 8.1. There are programs in the 1998 table that are not in the 2002 table and vice versa. These were excluded from the figures in this report.

<sup>2</sup> In terms of first use of energy sources (energy used for all purposes), the subsectors in Figure 3 accounted for 83 percent of the total Btu's used in the manufacturing sector in 2002.

<sup>3</sup> Refers to the set of activities in MECS table 8.1

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