

Manufacturing Energy
Consumption Survey:

Changes in Energy Intensity in the Manufacturing Sector 1980 - 1988



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Changes in Energy Intensity in the Manufacturing Sector 1980-1988

December 1991

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The data from the Manufacturing Energy Consumption Survey (MECS) are included in the Longitudinal Manufacturing Energy Data System (LMEDS) maintained by the Bureau of the Census. The LMEDS file includes yearly data beginning in 1972 for individual establishments that responded to the 1985 and 1988 MECS. In addition to energy data, the file also includes economic data collected by the Annual Survey and Census of Manufactures. A researcher interested in using LMEDS should send a research proposal to EIA for consideration. The EIA, in consultation with the Bureau of the Census, will examine the proposal and review with the researcher how the use of the file may benefit the proposed research. If the use of LMEDS is deemed appropriate, the Bureau of the Census will perform the work on a cost-reimbursable basis.

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Executive Summary

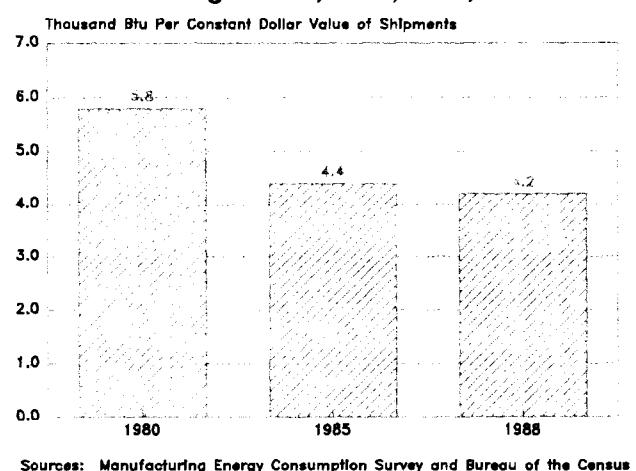
Numerous recent events—the turmoil in the Soviet Union, Iraq's invasion of Kuwait, the 1990 amendments to the Clean Air Act, the December 1989 crisis in heating oil markets, the 20th anniversary of Earth Day, concerns about global climate change, the development of the National Energy Strategy—have refocused America's attention on energy use. Questions are being asked about the quantities and types of energy consumed by various sectors, the purposes for which energy is consumed, and the potential for improved energy efficiency. The Manufacturing Energy Consumption Survey (MECS), conducted by the Energy Information Administration (EIA), provides background information for addressing many of these questions for the manufacturing sector. The purpose of this report is to begin to examine the changes in energy efficiency from 1980 to 1988.

In this report, energy intensity is defined as the ratio of offsite-produced energy consumption per unit of output. Energy consumption is measured in British thermal units (Btu) and output is measured as the constant dollar value of shipments and receipts. A *decrease* in energy intensity from one period to another corresponds to an *increase* in energy efficiency, and vice versa.

The findings of this report suggest that the mid-1980's mark the start of a period of generally diminished energy efficiency gains in manufacturing.

- In 1980, manufacturers needed 5.8 thousand Btu of offsite-produced energy for every constant dollar of value of shipments. (See Figure ES1.) By 1985, this requirement had dropped to 4.4 thousand Btu per constant dollar of value of shipments, and by 1988 it had decreased further, to 4.2 thousand Btu per constant dollar value of shipments. The 1988 level of intensity represented a 3.8 percent per year improvement in energy efficiency from 1980. However, the 1980-1985 period accounted for an average improvement of 5.2 percent per year. Whereas, between 1985 and 1988, energy efficiency improved by only 1.5 percent per year. Thus, improvements in energy efficiency continued between 1985 and 1988, although at a substantially decreased rate.
- Prior to 1985, many industry groups maintained or increased real output while reducing their aggregate consumption of purchased energy. After 1985, real output continued to grow in most industries, but consumption often began to increase in conjunction with increased production. These conditions indicate that the economic environment and production needs between 1985 and 1988 did not result in energy efficiency improvement being an economic priority. Moreover, substantial efficiency gains did not materialize as a result of manufacturing changes put in place for other purposes.
- The paper and allied products industry group, one of the extremely energy-intensive process-dominated industries, was one industry that maintained its 1980-1985 pace of improvement in energy efficiency through 1988. Their improvement in energy efficiency from 1980 to 1985 was an average of 2.6 percent per year. From 1985 to 1988, the average energy efficiency for this industry group improved an additional 2.7 percent per year.
- Manufacturers of chemicals and allied products are another energy-intensive industry group that continued to exhibit substantial efficiency improvement throughout the 8-year period. Their energy efficiency improved by an average rate of 3.6 percent per year. Between 1985 and 1988, the average energy efficiency improvement was 2.9 percent per year.

Figure ES1. Energy Intensity in the Manufacturing Sector, 1980, 1985, and 1988



Sources: Manufacturing Energy Consumption Survey and Bureau of the Census

- Other major energy-consuming industry groups—food and kindred products; petroleum and coal products; and stone, clay, and glass products—at best maintained their efficiency gains of 1980-1985 in the 1985-1988 period, or lost some ground. It is likely that this performance is a reflection of structural and production changes in these industries, rather than efficiency losses in existing processes.
- The remaining industries for which statistics are shown present a mixed picture for 1985-1988, with efficiency change ranging from moderate gains to moderate losses. Once again, it is likely that this is a reflection of structural and production changes, rather than efficiency losses.

An upcoming EIA report will describe the methodological development of the 1991 Manufacturing Energy Consumption Survey. Among other topics, this report will present the results of a series of industrial roundtables EIA held with energy experts from seven of the most energy-intensive industries: fertilizer, petroleum refining, steel, motor vehicles, pulp and paper, chlor-alkali, and olefins. The goals of these roundtables were (1) to examine the types of information available about energy use; (2) to enhance EIA's understanding of how energy is used, how facilities keep track of energy use, and how energy-related decisions are made; (3) to understand the sources of past improvements in energy efficiency; and (4) to develop an understanding of the forces that will drive energy consumption and affect energy efficiency in the future.

The efficiency changes presented in this report are comprehensive benchmark measures for major industrial groups. As with any single global type of efficiency measure, they embody certain structural changes in the manufacturing sector as well as efficiency changes, and present a concept of efficiency that reflects the assumptions inherent in the measurement process. Other measures can provide alternative insight into efficiency patterns. Another upcoming EIA report will be a major analytic effort that will provide insight into the effects of structural and production changes on manufacturing energy efficiency. Among the issues it will examine are:

- The effect of shifts in production shares among major industry groups and more specific industries;
- The differences in energy intensity trends based on total energy use (including byproduct and waste product energy) as opposed to offsite-produced energy use;
- The effect of considering electricity generation and transmission losses as embodied energy in manufacturing when evaluating efficiency;
- The potential effects on efficiency measures of changes in industry definitions due to revisions to the Standard Industrial Classification system.

1. Introduction

This report—*Changes in Energy Intensity in the Manufacturing Sector 1980-1988*—continues the data series on energy intensity change that followed the results of the 1985 Manufacturing Energy Consumption Survey (MECS).¹ That publication presented changes in energy intensities from 1980 to 1985. This publication extends that analysis to 1988.

Section 310(a) of the 1986 Omnibus Budget Reconciliation Act (Public Law 99-509, as amended) mandated the MECS. The MECS was first conducted in 1986 to collect 1985 data. That first survey was conducted prior to the passage of Public Law 99-509, and was, therefore, conducted under the authority of the Federal Energy Administration Act of 1974, Public Law 93-275, as amended. The 1988 MECS was conducted three years later under the authority of Section 310(a) of Public Law 99-509. Current plans call for the MECS to be conducted in three-year cycles. The MECS is designed and published by the Energy Information Administration (EIA). The data are collected and compiled by the Industry Division of the U.S. Bureau of the Census (Census Bureau) for the EIA. All MECS responses submitted to the Census Bureau are confidential under the provisions of Section 9, Title 13 of the U.S. Code.

The primary purposes of the MECS are to provide estimates of energy consumption and fuel-switching capability for the manufacturing sector. However, by supplementing the MECS data with data collected by the Bureau of the Census in the corresponding years of the Annual Survey of Manufactures (ASM), it is also possible to develop estimates of energy intensity change.

The purpose of this report is to present the MECS/ASM estimates of the changes in energy intensity by manufacturing industry groups between 1980 and 1988. This report is the third of a series based on the results of the 1988 MECS. The data in this report are published to provide objective, accurate energy information for a wide audience including Congress, Federal and State agencies, industry, and the public. The MECS is the first survey conducted by the EIA to collect detailed data on energy use by the manufacturing sector. The MECS does not include energy data for mining, agriculture, construction, fishing, forestry activities, or electric utilities. Other publications in the MECS series include reports on energy consumption² and fuel-switching capability.³

The EIA gratefully acknowledges the cooperation of respondents in supplying information for the MECS.

¹Energy Information Administration, *Manufacturing Energy Consumption Survey: Changes in Energy Efficiency, 1980-1985*, DOE/EIA-0516(85), (Washington, DC, 1990).

²Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, DOE/EIA-0512(88), (Washington, DC, May 1991).

³Energy Information Administration, *Manufacturing Fuel-Switching Capability 1988*, DOE/EIA-0515(88), (Washington, DC, September 1991).

2. Surveying the Manufacturing Sector

Manufacturing Sector Consists of Business Establishments that Produce Goods

The manufacturing sector consists of establishments that use mechanical or chemical processes to transform materials or substances into new products. These products may be final products that consumers will purchase, such as an automobile or a chair. Manufacturers also produce goods for use by other manufacturers such as parts for automobile engines or rolls of upholstery fabric.

An establishment is usually at a single physical location and is often called a plant, factory, or mill. It ordinarily uses power-driven machines and equipment for handling materials. A manufacturing establishment may also assemble parts or perform blending operations.

The Office of Management and Budget developed procedures for classifying manufacturing and non-manufacturing establishments into industry classes. Those procedures are known as the Standard Industrial Classification (SIC) system.⁴ Each industry class consists of establishments that produce similar types of goods or services.

The SIC system divides the manufacturing sector into 20 broad groups, and assigns a numerical code to each of those groups. For the manufacturing sector, the codes range from 20 through 39. For example, SIC 26 consists of establishments that manufacture paper and allied products. The SIC system subdivides each of the broad industry groups into several specific industries and assigns each a four-digit code. For example, the paper and allied products industry group (SIC 26) contains 17 specific industries. SIC 2621 includes establishments classified as paper mills, and SIC 2631 includes paperboard mills.

If an establishment produces more than one good or service, it is classified into a four-digit industry based upon its primary production (see Glossary). For example, an establishment that primarily engages in manufacturing paper from wood pulp, and also manufactures some paperboard, is classified in the paper mill industry (SIC 2621). It is not classified in the paperboard mill industry (SIC 2631).

MECS Samples Establishments in All the Major Industry Groups

The estimates of energy intensity change presented in this report are based on 1985 and 1988 data collected by the MECS, and on 1980, 1985, and 1988 data collected by the ASM. The EIA included several important considerations in the criteria for the design of the MECS sample. Specifically, the sampling procedures assure that the MECS

Energy-Intensity Ratios Based on 1972 Definitions of Industry

The Standard Industrial Classification system underwent a major revision in 1987, resulting in several industry groups being redefined. The MECS estimates of energy consumption and ASM estimates of value of shipments for 1988 conform to the revised industry classifications. The corresponding estimates for 1980 and 1985 were based on the 1972 classification system.

Calculating the changes in energy intensity for industry groups requires comparability between the base and target year estimates. Accordingly, the 1988 estimates of energy consumption and the corresponding estimates of value of shipments, were re-estimated using the 1972 classification. These re-estimates were used only to calculate the energy intensity ratios. All other estimates appearing in this report are based on the 1972 or revised 1987 classification system, as appropriate, in order to be consistent with previously published information.

⁴Office of Management and Budget, *Standard Industrial Classification Manual, 1987* (Washington, DC, 1987).

sample is representative of the population of establishments from which it was drawn. Also, the size of the sample in each industry class was controlled so that error levels of the survey estimates would be similar for each class.

The MECS sample is a subset of the mail sample used by the Census Bureau to collect data for the ASM. The ASM sample includes 56,000 manufacturing establishments. The ASM sample is, in turn, a subset of the mail file of 225,000 manufacturing establishments used by the Census Bureau to conduct the Census of Manufactures. The Census of Manufactures is conducted every five years, while the ASM is conducted annually. The Census Bureau selected about 12,000 manufacturing establishments from the ASM sample to serve as the MECS sample. The sample for the 1988 MECS retained those establishments from the 1985 sample that were still in operation when the 1988 MECS was conducted. This holdover sample was then supplemented by a sample of manufacturing establishments that came into existence between 1985 and 1988.

Further, 1988 MECS estimates were adjusted to cover the entire manufacturing population. The 1985 MECS did not cover the smallest establishments that were estimated to account for 2 to 3 percent of energy consumption in manufacturing. However, as a result of performing the same population adjustment on both the consumption and the economic measures, the adjustment would not influence the current 1988 intensity measures differently from the 1985 measures. See Appendix A for a comprehensive discussion of the sampling and estimation procedures for the MECS.

The MECS sample was stratified to provide controlled representation from each of the 20 major manufacturing industry groups (two-digit SIC codes) that make up the manufacturing sector. In addition, representation was controlled in the 10 specific industries (four-digit SIC codes) that historically have consumed the most energy. Thus, the MECS sample not only represented all major manufacturing industry groups, it also had a high probability of including the major energy-consuming establishments in the universe of manufacturing establishments. (See Appendix D for descriptions of the 20 major industry groups.)

Measuring Energy Intensity in the Manufacturing Sector

Both "intensity" and "efficiency" can be defined as the ratio of useful output to the total input in any system. Fuel efficiency in automobiles, for example, is measured as the ratio of miles (output) per gallon of gasoline (input). Such output-input measures are, basically, measures of productivity because they measure the consumption of a fixed amount of input to produce a variable amount of output. The basic concept of motor fuel-efficiency is to produce as many miles as possible with a gallon of fuel.

The basic concept of energy efficiency, however, is to consume the minimum amount of energy while producing a fixed amount of output. In other words, the demand for the output is to be fulfilled as efficiently as possible with respect to energy consumption. Therefore, in this report, energy *intensity* is an input-output measure defined as the ratio of energy consumption (input) to production (output). More specifically, energy consumption is defined as the

Expanded Coverage For 1988 MECS Results in Higher Energy Consumption and Fuel-Switching Estimates, but Unchanged Intensity Estimates.

The 1988 MECS was designed to produce estimates of energy consumption, fuel-switching capabilities, and other energy-related activities for the *entire* population of manufacturing establishments. It is important to note that the coverage of the 1988 MECS is more comprehensive than the coverage of the 1985 MECS. The 1985 MECS omitted the energy consumption of very small manufacturing establishments. That change in coverage resulted in 1988 energy consumption and fuel-switching estimates that are *two to three percent higher* over all industries than they would have been if the procedures of the 1985 MECS had been similarly followed for the 1988 MECS. The coverage differential is larger for industries dominated by small businesses (such as printing and publishing) than for industries dominated by relatively few large corporations (such as primary aluminum smelting). However, the adjustment methodology used to expand the coverage of the 1988 MECS has no effect on the SIC-specific intensity change estimates in this report. The adjustment factors are applied to numerator and denominator of the 1988 intensity measures, and cancel each other out. Thus, the coverage-adjusted 1988 intensities, and the corresponding 1980-1988 intensity are no different than they would have been had the coverage adjustment not been done. See Appendix A for additional details.

total consumption of offsite-produced energy to produce heat and power and to generate electricity. Output is defined as the value of shipments expressed in constant dollars. This report presents changes in energy intensity from 1980 to 1985, from 1985 to 1988, and from 1980 to 1988. A *decrease* in energy intensity between two years indicates an *increase* in energy efficiency, and visa versa.

There are several alternative measures of energy consumption and output that could have been used to measure energy intensity. The following sections describe some of these alternatives and present the reasons for selecting offsite-produced energy and constant dollar value of shipments as the components of the energy-intensity ratios.

Offsite-Produced Energy Is the Consumption Measure for Computing Intensity

The total consumption of offsite-produced energy is the total amount of energy purchased or transferred from offsite sources that is consumed onsite to produce heat and power and to generate electricity. The primary reason for selecting offsite-produced energy as the measure of energy consumption for calculating energy intensity is that it is the only measure for which comparable estimates are available for the three years, 1980, 1985, and 1988. A second reason is that offsite-produced fuel is the best measure for ascertaining the dependence of establishments on outside sources to meet their energy requirements. The 1985 and 1988 estimates of offsite-produced energy consumption by manufacturers come directly from the MECS.⁵ Comparable energy consumption estimates for the base year of 1980 were taken from the 1980 ASM.⁶ The 1980 ASM and the 1988 MECS cover identical universes. The 1985 MECS excluded those manufacturing establishments with fewer than five employees. That slight difference does not affect the changes in energy intensity, however. (See box on previous page and Appendix A for more details.)

The use of energy by establishments in the manufacturing sector, however, is much more complex than simply purchasing or transferring energy from offsite sources and consuming it to produce heat and power and to generate electricity. Some manufacturers transform energy into other products (including other fuels), and some produce useful energy as a byproduct of their manufacturing process. The MECS deals with this complexity by using two additional methods for measuring energy consumption. The total primary consumption of energy consists of the total energy requirements (including raw material uses of energy forms) of manufacturing industries to produce goods. Total inputs of energy represent the total amount of energy used to produce heat and power and to generate electricity. Total inputs of energy differs from total primary consumption because total inputs does not include energy forms consumed as raw material (feedstock). Total inputs of energy differs from total consumption of offsite-produced energy in that it includes fuels that are byproducts of the manufacturing process, are produced onsite from renewable resources or captive mines and wells, or are reclaimed from waste materials. Byproduct fuels are excluded from offsite-produced energy consumption.

The interrelationships among the consumption measures are complex, especially when comparing estimates between two years. Using offsite-produced energy in the calculation of energy intensity ratios does have its limitations because the resulting ratios do not include the effect of switching from offsite-produced energy to byproduct and other energy produced onsite. Such switches are energy-efficient in their own right and should be reflected in the energy intensity ratios. Certain onsite-produced energy sources are obtained as a function of the manufacturing process or the production of waste products. These energy sources are often not conserved in the same way as offsite-produced energy. As offsite-produced fuel consumption estimates are the only ones available for the year 1980, only comparisons using this measure will be used in this report.

⁵Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1985*, Table 7 and *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, Table 4.

⁶U.S. Department of Commerce, Bureau of the Census, *1980 Annual Survey of Manufactures*, "Fuels and Electric Energy Consumed," M80(AS)-4.1 (Washington, DC, August 1982).

Manufacturing Output Is Measured by Value of Shipments

The estimates of changes in energy intensity presented in this report are based on energy-intensity ratios calculated from constant dollar value of shipments as the measure of output. The value of shipments is collected as a part of the ASM. The Census Bureau defines the value of shipments as including the receipts for products manufactured, services rendered, and resales of products bought and resold without further manufacture.⁷ Changes in the output of an establishment result in corresponding changes in its value of shipments and receipts. Physical output and the value of shipments are, therefore, correlated.

A change in the value of shipments from one period to another reflects more than just changes in output, however. A change may also reflect an increase (or decrease) in price resulting from inflation (or deflation). Such price changes do not represent a change in output. Therefore, before using estimates of the value of shipments as an output measure, they were adjusted for the effect of changes in price using "price indices."

The U.S. Bureau of Labor Statistics (BLS) publishes many price indices. Government agencies and the private sector use these indices to adjust for inflation and deflation. The best known of these indices is the Consumer Price Index (CPI). The BLS describes the CPI as "... a measure of the average change in prices paid by urban consumers for a fixed market basket of goods and services."⁸ The CPI is commonly used to convert average net family income to purchasing power.

The BLS also publishes a series known as the "industry price index." This index, as described by the BLS, is a price series that follows "... the general economic pattern of a particular industry."⁹ The industry price index can be used to convert the value of shipments and receipts to a constant dollar measure that excludes the effect of price changes. As a result, changes in the adjusted value of shipments from one period to another closely correspond to changes in physical output.¹⁰

An alternative measure of output for the manufacturing sector is the physical quantity of the good produced. For example, the output of a broadwoven cotton fabric mill (SIC 2211) might be measured in linear yards of fabric. A major difficulty with that approach, however, is that physical quantities are product-specific. Few establishments and no four-digit industry produce a single product line. A broadwoven fabric mill may produce woven fabrics measured in linear yards and sheets and pillow cases measured in dozens. Because they have no common basis, physical quantity measures are inappropriate for measuring the total output of a multiproduct establishment.

Using product-specific physical quantities for the development of energy-intensity ratios would not be a serious problem if energy consumption estimates also were available for each product line. However, manufacturing establishments usually monitor total energy consumption only. When necessary, they estimate energy consumption for each product line. In the interest of reducing respondent burden, the MECS did not try to collect energy consumption for specific products.

Value added by manufacturers, published by the Census Bureau, was considered as the measure of output for developing the estimates of energy-intensity change that appear in this report. Value added was rejected in favor of the value of shipments and receipts. A complete discussion of the reasons for selecting the value of shipments over value added appears in Appendix A of this report.

⁷U.S. Department of Commerce, Bureau of the Census, *1985 Annual Survey of Manufactures*, "Statistics for Industry Groups and Industries," M85(AS)1 (Washington, DC, January 1987), p. A-2.

⁸U.S. Department of Labor, Bureau of Labor Statistics, *BLS Handbook of Methods, Volume II, Bulletin 2134-2* (Washington, DC, April 1984), p. 3.

⁹U.S. Department of Labor, Bureau of Labor Statistics, *BLS Handbook of Methods, Volume I, Bulletin 2134-1* (Washington, DC, December 1983), p. 49.

¹⁰The actual price deflators used in this report were obtained from the Bureau of Economic Analysis (BEA). However, BEA bases its aggregated deflators for manufacturing industries on the product-specific price indices from BLS. The deflators used in this report represent a revision from the deflators used in 1985. Hence, some of the intensity change measures shown in this report are changed from the 1985 report. For more information on the price index revision see "Gross Product by Industry, 1977-1988: A Progress Report on Improving the Estimates," *Survey of Current Business*, Vol 71, (January 1991), 23-32.

Measuring Energy-Intensity Changes

The purpose of this report is to present the percent changes in energy intensity from 1980 to 1988 for the two-digit industry groups of the manufacturing sector. The first step in determining these estimates consisted of deriving constant dollar value of shipments for use as an output measure. The Census Bureau provided estimates of value of shipments and receipts for individual establishments from the ASM. These values were attached to the MECS data records, and used to derive MECS-based estimates of value of shipments and receipts for each of the 20 manufacturing industry groups for the 1985 and 1988. For 1980, the Census Bureau provided estimates of value of shipments and receipts computed from the ASM. Industry price indices for the same years and industry groups were obtained from the Bureau of Economic Analysis (BEA). The EIA expressed the value of shipments in constant 1982 dollars to remove the effect of price changes. Energy consumption estimates (offsite-produced energy) for 1985 and 1988 were available for each of the 20 manufacturing industry groups from the MECS. Comparable energy consumption estimates for 1980 were available from the ASM.

Energy-intensity ratios (offsite-produced energy consumption per constant dollar of value of shipments) were prepared for each two-digit manufacturing industry group for 1980, 1985, and 1988. That calculation consisted of dividing the energy consumption for each two-digit SIC industry group by its corresponding constant dollar value of shipments (output). Measures of the change in energy intensity were developed for each of the 20 manufacturing industry groups by calculating the percent change from the 1980 ratio to the 1985 and 1988 ratios. The results for 18 of the 20 manufacturing industry groups are published in this report. The results for two industry groups were withheld because, in one case, the relative standard errors (RSE) of both energy intensity change estimates exceeded 50 percent, and, in the other case, the estimates of energy consumption were not comparable. (A complete discussion of RSE's appears in Appendix B of this report.)

Understanding the Causes of Change in Energy Efficiency

The MECS did not collect information on the causes of the changes in energy efficiency. However, in late 1990 and early 1991, the EIA conducted a series of industrial roundtables¹¹ to discuss MECS-related issues. These roundtables included a major segment on energy efficiency. According to the roundtable participants, there are a variety of factors that could influence energy efficiency. Among the factors noted that increase or facilitate energy efficiency improvements are:

- **Improved energy management** consists of better equipment maintenance, improved insulation, lowering thermostats, routine energy audits, and conservation goals.
- **Computer controls and instrumentation** allow companies to track energy use and keep processes running at optimal efficiency.
- **Heat recovery and heat exchange** involves lowering stack temperatures, the installation of waste-heat recovery boilers, and condensate recovery.
- **Improvements in electricity cogeneration**, including switching to gas turbines, have been an important factor in improving energy efficiency.
- **Increases, renovations, and turnover in production capacity**, commonly incorporate technological advances and improved operational techniques that have allowed many industries to increase energy efficiency.

¹¹Industrial roundtables were held with seven of the most energy-intensive manufacturing industries: fertilizer, petroleum refining, steel, motor vehicles, pulp and paper, chlor-alkali, and olefins. The goals of these roundtables were (1) to examine the types of information available about energy use; (2) to enhance EIA's understanding of how energy is used and how energy-related decisions are made; (3) to understand past improvements in energy efficiency; and (4) to develop an understanding of the forces that will drive energy consumption and energy efficiency in the future. The complete results of these roundtables will be summarized in an upcoming report.

The participants also cited several factors that directly increase energy consumption per unit of product and, therefore, decrease energy efficiency. Among these factors are:

- **Environmental regulations**, which often involve a direct energy cost with no increase in output, may have a negative impact on energy efficiency. The implementation of these regulations often absorbs financial resources that might otherwise be used for projects to improve energy efficiency.
- **Improvements in product quality** frequently result in increased energy consumption per unit of product produced. Such improvements frequently result in a higher value of the product so that total energy cost as a percentage of the price of the product decreases. However, energy consumption per unit of product increases, resulting in decreased energy efficiency.
- **Overutilization of capacity** frequently results in decreased energy efficiency because previously idle or underused equipment and processes, which frequently are less energy efficient, are used in order to get extra production. Despite this inefficiency, such activities are profitable because extra output is obtained with no capital investment, and because energy costs are often a small proportion of total costs.
- **Weather conditions** affect the energy consumption of building conditioning systems. This factor is more important in those industries not dominated by process energy use but have large floorspace areas. Examples of such industries include the motor vehicles industry and electrical and electronic equipment manufacturers.
- **Economic conditions** may adversely affect energy efficiency in a number of ways. Energy prices and availability determine the incentives for investing in projects that conserve energy. Expanding markets require the expansion of capacity, which improves energy efficiency by bringing in new technologies. Conversely, economic stagnation is typically coupled with a slower rate of energy-efficiency improvement. In general, interest rates and the availability of capital also affect corporate investment decisions, including investments in energy conservation.
- **Energy-efficiency potential** continually decreases as a process approaches its theoretical limit of efficiency. Most of the "easy" efficiency gains were implemented in the late 1970's and the early 1980's.

Thus, according to the roundtable participants, energy efficiency in the manufacturing sector is a function of technological advancements, economic conditions, and a variety of production factors. Most manufacturers view energy from a purely economic perspective. Accordingly, energy investments are subject to return-on-investment calculations and must compete with other projects for scarce capital. Energy investments are also subject to risk analysis because of the volatility of energy prices. Ultimately, what motivates manufacturers' actions with regard to energy is energy cost, rather than efficiency or consumption. Improvements in energy efficiency often result from projects whose primary purpose is to increase production, to improve quality, or to replace worn-out equipment. Few major capital expenditures are justified solely on the basis of improving energy efficiency.

3. Energy Intensity Changes In the Manufacturing Sector

Table 1 shows the energy intensities for 1980, 1985, and 1988 for each of the two digit industry groups. Additionally, each of the energy intensity change estimates for 1980 to 1985, 1985 to 1988, and 1980 to 1988 are shown. It is important to realize that a 1980 to 1985 intensity change estimate added to the corresponding intensity change estimate for 1985 to 1988 does not yield the intensity change estimate for 1980 to 1988. That is because of the different bases used to compute the intensity change estimates: 1980 intensities were used as the base year for the 1980 to 1985 and the 1980 to 1988 intensity changes while the 1985 intensities were used for the 1985 to 1988 intensity change measures.

Table 1. Energy Intensity in Manufacturing Industry Groups, 1980, 1985, and 1988

SIC Code ^a	Industry Group	Energy Intensity Ratios ^b			Percent Change in Energy Intensity		
		1980	1985	1988	1980-1985	1985-1988	1980-1988
20	Food and Kindred Products	3.52	2.72	2.98	22.8	-9.4	15.5
21	Tobacco Products	NA	NA	NA	NA	NA	NA
22	Textile Mill Products	5.69	4.80	4.85	15.6	-0.9	14.8
23	Apparel and Other Textile Mill Products	NA	NA	NA	NA	NA	NA
24	Lumber and Wood Products	NA	NA	NA	NA	NA	28.2
25	Furniture and Fixtures	1.87	1.55	1.72	16.5	-10.1	8.0
26	Paper and Allied Products	15.92	13.96	12.86	12.3	7.9	19.2
27	Printing and Publishing	NA	NA	NA	NA	NA	NA
28	Chemicals and Allied Products	14.91	12.40	11.34	16.8	8.6	24.0
29	Petroleum and Coal Products	5.32	4.87	5.67	8.3	-16.3	-6.6
30	Rubber and Misc. Plastic Products	4.29	3.10	3.22	27.7	-3.8	25.0
31	Leather and Leather Products	NA	NA	NA	NA	NA	NA
32	Stone, Clay, and Glass Products	21.53	16.74	16.74	22.3	0	22.2
33	Primary Metal Industries	16.30	14.64	14.37	10.2	1.8	11.8
34	Fabricated Metal Products	2.74	2.33	2.42	15.2	-4.0	11.8
35	Machinery, Except Electrical	1.66	0.95	0.77	43.2	18.7	53.8
36	Electrical and Electronic Equipment	1.67	1.25	1.18	24.9	5.4	29.0
37	Transportation Equipment	1.51	1.15	1.06	23.6	8.0	29.7
38	Instruments and Related Products	1.60	1.19	1.16	26.0	2.5	27.9
39	Misc. Manufacturing Industries	1.71	1.36	1.35	20.3	1.1	21.1
--	All Manufacturing	5.78	4.43	4.23	23.4	4.3	26.7

^aFor comparability, all data in this table are based on the 1972 Standard Industrial Classification System.

^bThousand British thermal units per constant (1982) dollar value of shipments.

NA=Withheld because the MECS sampling process did not sufficiently represent the diverse size or economic diversity of the industry group to produce viable estimates of changes in energy intensity.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

The remainder of this report presents estimates of changes in energy intensity from 1980 to 1988 for 15 of the 20 major manufacturing industry groups (two-digit SIC). Five manufacturing industry groups are excluded from the analysis. The MECS sampling process did not sufficiently represent their diverse sizes and economic activities to produce viable estimates of energy efficiency change. These groups are tobacco products (SIC 21), apparel and other textile products (SIC 23), lumber and wood products (SIC 24), printing and publishing (SIC 27), and leather and leather products (SIC 31). The presentations for each of the 15 industry groups includes three graphs and a brief discussion.

How to Interpret the SIC-Specific Graphs and Discussions

The first graph presents a historical overview of the relationship of energy consumption and output from 1974 through 1988. It provides indices of energy consumption and output. Both indices have a base year of 1974 (that is, 1974 = 100). The output indices were calculated using estimates of the value of shipments as published by the ASM. Those estimates were converted to constant (1982) dollars using the industry price indices provided by the BEA. The energy consumption indices were calculated from estimates of purchased fuels and electricity from the ASM for 1974 through 1981. The MECS estimates of offsite-produced energy consumption were used for 1985 and 1988. Estimates of energy consumption for 1982 through 1984 and 1986 through 1987 are not available. All index values prior to 1987 are based on the 1972 SIC definitions. Index values for 1987 and 1988 are based on the revised 1987 SIC definitions.¹²

The second graph presents estimates of the percent change in energy intensity using data from both the MECS and the ASM. The estimates are the percent change in energy consumption per unit of output from 1980 to 1985,¹³ from 1985 to 1988 and from 1980 to 1988. The output values used in the calculation of the intensity ratios were specially-prepared estimates of the value of shipments using the MECS weights. It was necessary to use the MECS-weighted estimates of value of shipments so that the resulting values would be fully comparable to the MECS estimates of offsite-produced energy consumption. The difference between the estimates of value of shipments is small for most industry groups. There are a few industry groups, however, for which the MECS-weighted and ASM-weighted estimates differ substantially.¹⁴ In addition, the energy intensity ratios are based on the 1972 SIC system to assure definitional comparability for the period 1980 through 1988. As a result, the reported percent change in energy intensity may differ from what might be expected by examining the historical trends in the first graph. Estimates are shown for both the industry group being considered and the overall manufacturing intensity change for purposes of comparison. As stated previously, 1980 intensities were used as the base year for the 1980 to 1985 and the 1980 to 1988 intensity changes while the 1985 intensities were used for the 1985 to 1988 intensity change measures. Thus, the addition of the 1980 to 1985 and 1985 to 1988 intensity change estimates will *not* result in the 1980 to 1988 intensity change.

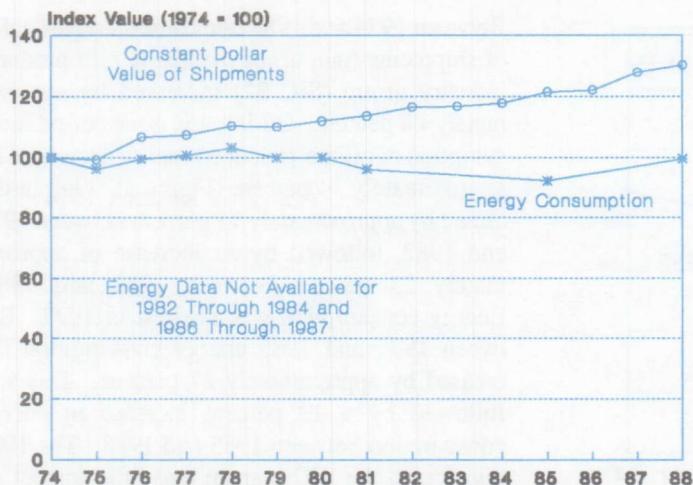
¹²Only a few industries were affected by the revisions of the SIC definitions. The most significant change occurred in shifts of selected industries from electronic and other electric equipment, SIC 36, to instruments and related products, SIC 38. A complete description of the revisions appears in Office of Management and Budget, *Standard Industrial Classification Manual, 1987* (Washington, DC, 1987), Appendix A, Section III. In addition to the revisions in the SIC classifications, the Census Bureau reclassified certain products from petroleum and coal products, SIC 29, to chemical and allied products, SIC 28. See U.S. Department of Commerce, Bureau of the Census, *1987 Census of Manufactures and Census of Mineral Industries*, "Numerical List of Manufactured and Mineral Products," MC87-R-1 (Washington, DC, February 1989) for details.

¹³The estimates of changes in energy efficiency from 1980 to 1985 have been revised. These revisions are due to revisions in the price deflators. These revisions were negligible in most cases. The 1980-1985 efficiency change estimate for the petroleum and coal products industry group (SIC 29) was substantially revised, however. The revision for this industry group resulted from the re-estimation of the consumption of offsite-produced energy sources. See Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, page 143 for details.

¹⁴The industry groups for which the 1988 ASM-weighted and MECS-weighted estimates of value of shipments differed by more than plus or minus 5 percent were: paper and allied products, SIC 26; chemicals and allied products, SIC 28; rubber and miscellaneous plastics products, SIC 30; instruments and related products, SIC 38; and miscellaneous manufacturing, SIC 39.

Food and Kindred Products Industry Group, SIC 20

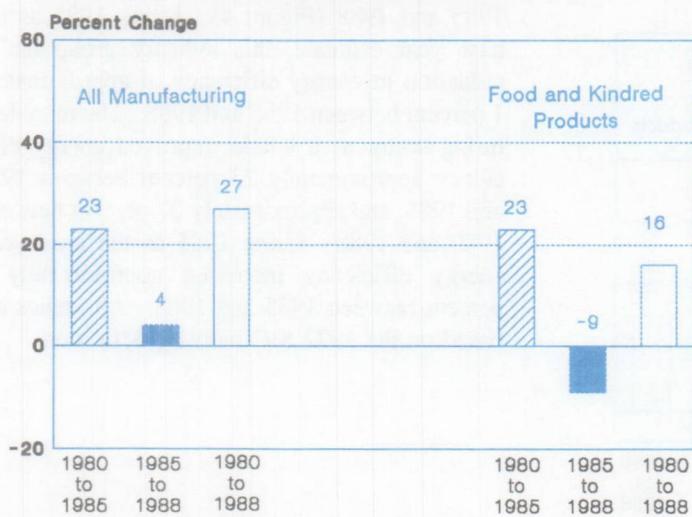
Figure 1. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 2. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

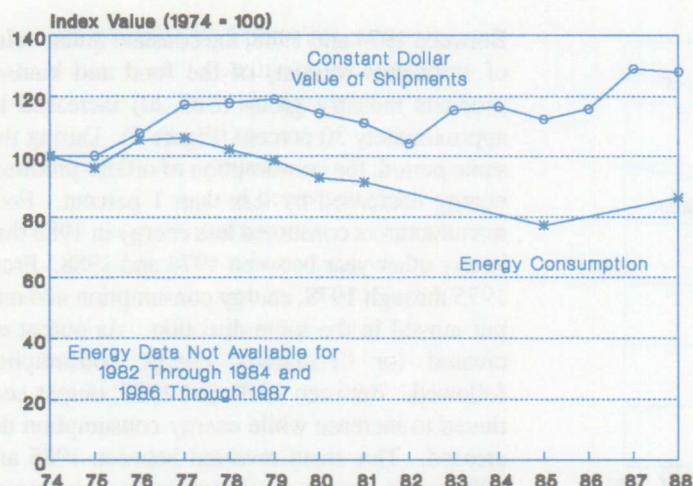
Between 1974 and 1988, the constant dollar value of shipments (output) of the food and kindred products industry group (SIC 20) increased by approximately 30 percent (Figure 1). During this same period, the consumption of offsite-produced energy decreased by less than 1 percent. Food manufacturers consumed less energy in 1985 than in any other year between 1974 and 1988. From 1975 through 1978, energy consumption and output moved in the same direction. As output increased (or decreased), energy consumption followed. Between 1979 and 1985, output continued to increase while energy consumption decreased. This trend reversed between 1985 and 1988 when energy consumption again increased along with increased output. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, food manufacturers improved their energy efficiency approximately 23 percent between 1980 and 1985, and 16 percent between 1980 and 1988 (Figure 2). Using 1985 as the base year estimate, this group had a reduction in energy efficiency between 1985 and 1988 of approximately 9 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Textile Mill Products Industry Group, SIC 22

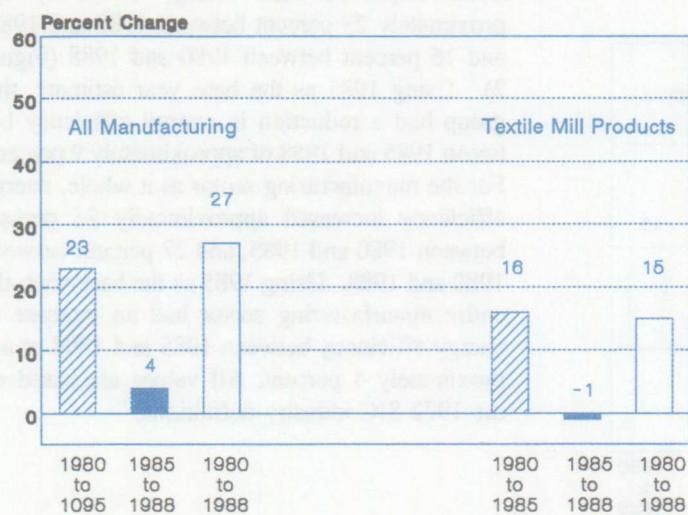
Figure 3. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 4. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

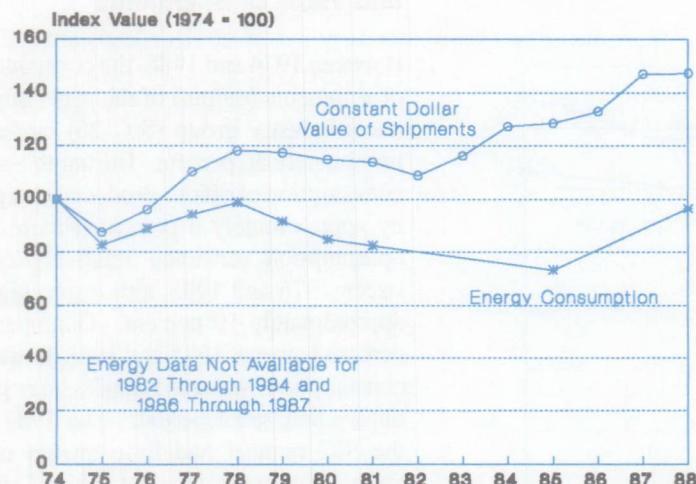
Between 1974 and 1988, the constant dollar value of shipments (output) of the textile mill products industry group (SIC 22) increased by approximately 28 percent. During this same period, consumption of offsite-produced energy decreased by approximately 14 percent (Figure 3). Output declined by approximately 11 percent between 1977 and 1982, followed by an increase of approximately 23 percent between 1982 and 1988. Energy consumption was greatest in 1977. Between 1977 and 1985 energy consumption decreased by approximately 27 percent. This was followed by a 12 percent increase in energy consumption between 1985 and 1988. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, the energy efficiency improvement of textile mill manufacturers was approximately 16 percent between 1980 and 1985, and approximately 15 percent between 1985 and 1988 (Figure 4). Using 1985 as the base year estimate, this industry group had a reduction in energy efficiency of approximately 1 percent between 1985 and 1988. The manufacturing sector as a whole improved energy efficiency approximately 23 percent between 1980 and 1985, and approximately 27 percent between 1980 and 1988. Using 1985 as the base year, energy efficiency increased approximately 4 percent between 1985 and 1988. All values are based on the 1972 SIC industry definitions.

Furniture and Fixtures Industry Group, SIC 25

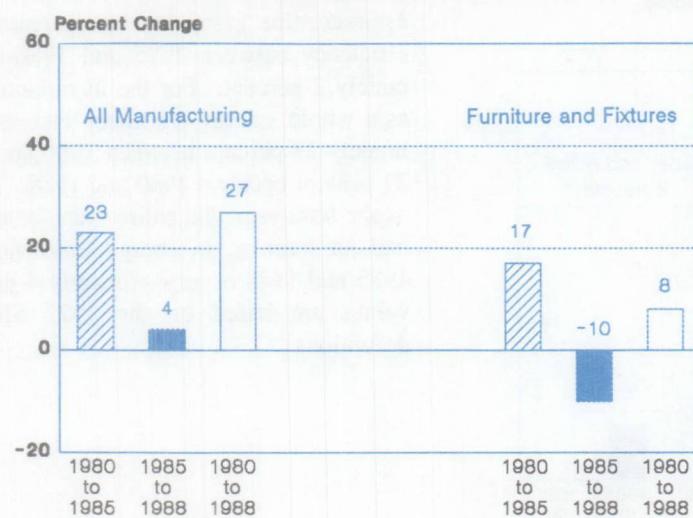
Figure 5. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 6. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

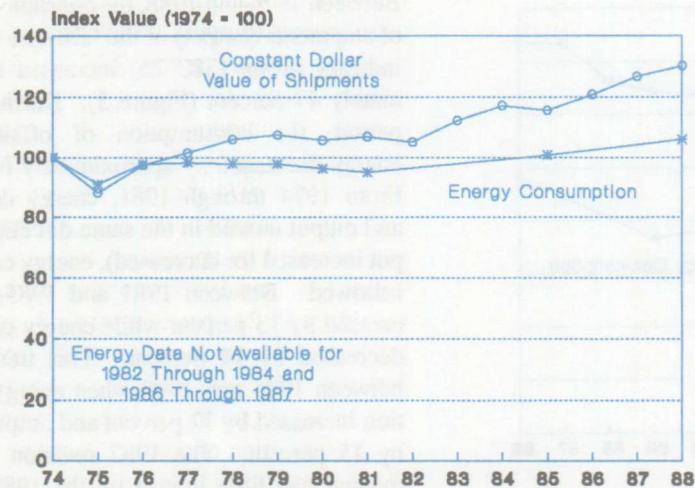
Between 1974 and 1988, the constant dollar value of shipments (output) of the furniture and fixtures industry group (SIC 25) increased by approximately 47 percent (Figure 5). During this same period, the consumption of offsite-produced energy decreased by approximately four percent. From 1974 through 1981, energy consumption and output moved in the same direction. As output increased (or decreased), energy consumption followed. Between 1981 and 1985, output increased by 13 percent while energy consumption decreased by 11 percent. This trend reversed between 1985 and 1988 when energy consumption increased by 32 percent and output increased by 15 percent. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, furniture and fixture manufacturers improved their energy efficiency by approximately 17 percent between 1980 and 1985, and approximately 8 percent between 1980 and 1988 (Figure 6). Using 1985 as the base year estimate, this industry group had a reduction in energy efficiency of approximately 10 percent between 1985 and 1988. The manufacturing sector as a whole improved energy efficiency approximately 23 percent between 1980 and 1985, and approximately 27 percent between 1980 and 1988. Using 1985 as the base year, energy efficiency increased approximately 4 percent between 1985 and 1988. All values are based on the 1972 SIC industry definitions.

Paper and Allied Products Industry Group, SIC 26

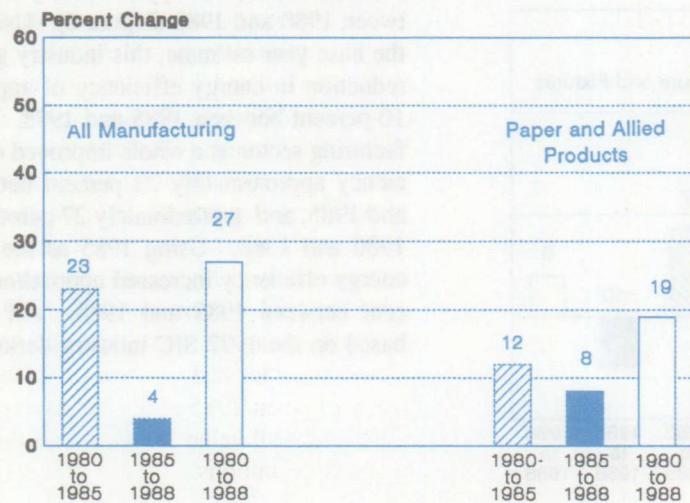
Figure 7. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 8. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

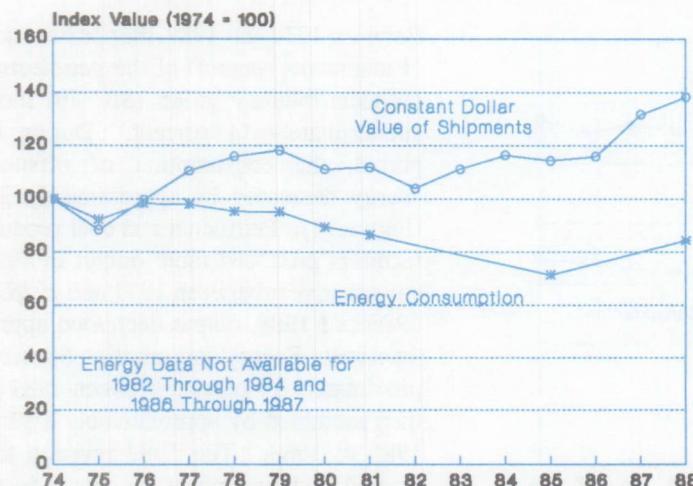
Between 1974 and 1988, the constant dollar value of shipments (output) of the paper and allied products industry group (SIC 26) increased by approximately 30 percent. During this same period, consumption of offsite-produced energy increased by approximately 6 percent (Figure 7). Energy consumption remained relatively constant between 1976 and 1985, although output increased approximately 19 percent. Output increased 13 percent between 1985 and 1988, however, energy consumption increased approximately 5 percent during that same period. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, paper and allied products manufacturers improved their energy efficiency approximately 12 percent between 1980 and 1985, and 19 percent between 1980 and 1988 (Figure 8). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 8 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Chemicals and Allied Products Industry Group, SIC 28

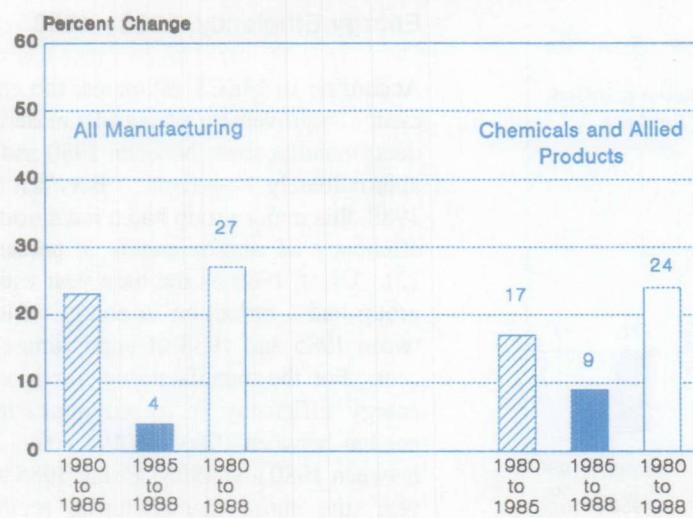
Figure 9. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 10. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

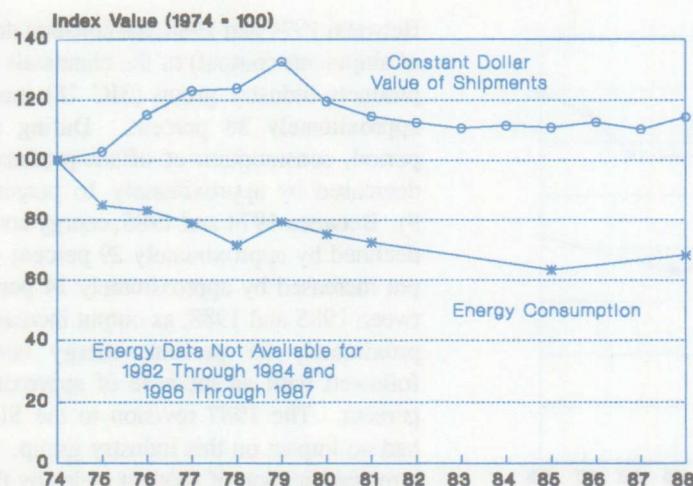
Between 1974 and 1988, the constant dollar value of shipments (output) of the chemicals and allied products industry group (SIC 28) increased by approximately 38 percent. During this same period, consumption of offsite-produced energy decreased by approximately 16 percent (Figure 9). Between 1974 and 1985, energy consumption declined by approximately 29 percent while output increased by approximately 14 percent. Between 1985 and 1988, as output increased by approximately 21 percent, energy consumption followed with an increase of approximately 18 percent. The 1987 revision to the SIC manual had no impact on this industry group. However, a reclassification of product codes by the Census Bureau did result in the transfer of establishments between this industry group and the petroleum and coal products industry group (SIC 29). This reclassification did have a substantial impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, chemicals and allied products manufacturers improved their energy efficiency approximately 17 percent between 1980 and 1985, and 24 percent between 1980 and 1988 (Figure 10). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 9 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Petroleum and Coal Products Industry Group, SIC 29

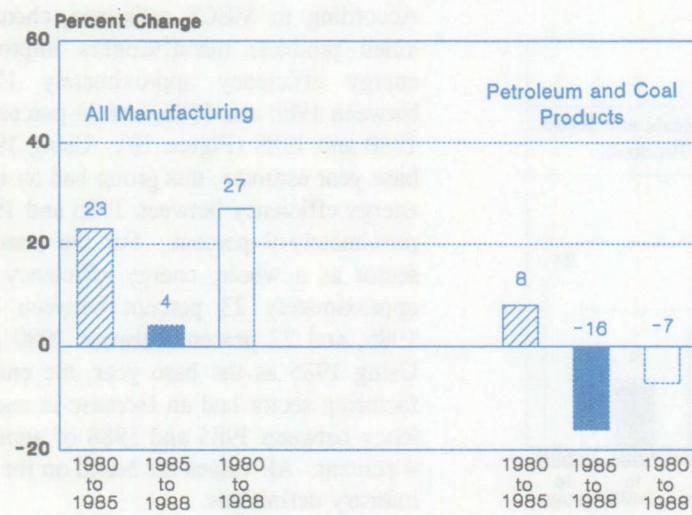
Figure 11. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 12. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

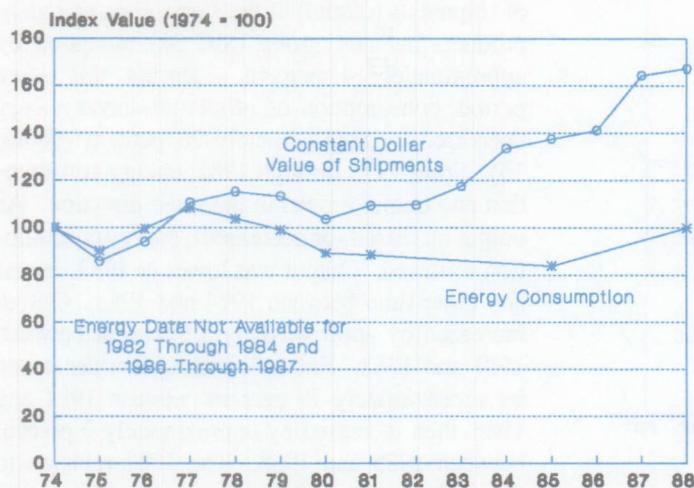
Between 1974 and 1988, the constant dollar value of shipments (output) of the petroleum and coal products industry group (SIC 29) increased by approximately 14 percent. During this same period, the consumption of offsite-produced energy decreased by approximately 32 percent (Figure 11). Petroleum and coal products manufacturers produced more output in 1979 than in any other year between 1974 and 1988. Between 1980 and 1988, output decreased approximately 4 percent. Energy consumption decreased by approximately 13 percent between 1981 and 1985, then increased by approximately 8 percent from 1985 to 1988. The 1987 revision to the SIC manual had no impact on this industry group. However, a reclassification of product codes by the Census Bureau did result in the transfer of establishments between this industry group and the chemicals and allied products industry group (SIC 28). This reclassification did have a substantial impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, the energy efficiency improvement of petroleum and coal products manufacturers between 1980 and 1985 was approximately 8 percent. Between 1980 and 1988, this major group had a reduction in energy efficiency of approximately 7 percent (Figure 12). Using 1985 as the base year estimate, this group had a reduction in energy efficiency between 1985 and 1988 of approximately 16 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Rubber and Miscellaneous Plastics Products Industry Group, SIC 30

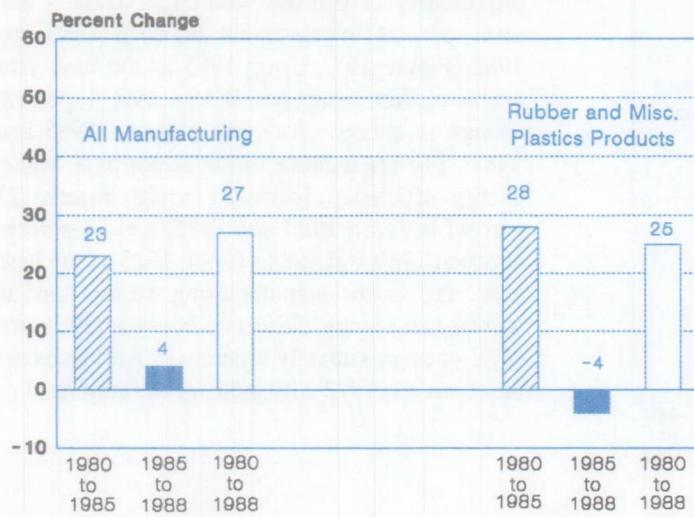
Figure 13. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 14. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

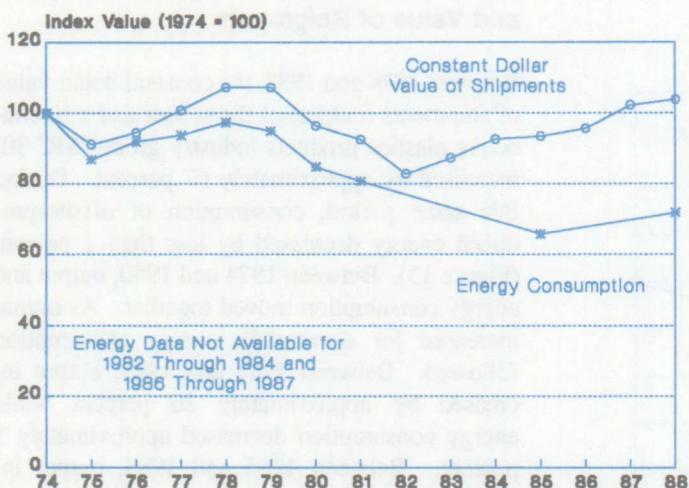
Between 1974 and 1988, the constant dollar value of shipments (output) of the rubber and miscellaneous plastics products industry group (SIC 30) increased by approximately 67 percent. During this same period, consumption of offsite-produced energy decreased by less than 1 percent (Figure 13). Between 1974 and 1980, output and energy consumption moved together. As output increased (or decreased), energy consumption followed. Between 1981 and 1985, output increased by approximately 26 percent while energy consumption decreased approximately 5 percent. Between 1985 and 1988, output increased by approximately 22 percent, but energy consumption increased by 19 percent. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, rubber and miscellaneous plastic products manufacturers improved their energy efficiency by approximately 28 percent between 1980 and 1985, and 25 percent between 1980 and 1988 (Figure 14). Using 1985 as the base year estimate, this group had a reduction in energy efficiency between 1985 and 1988 of approximately 4 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Stone, Clay, and Glass Products Industry Group, SIC 32

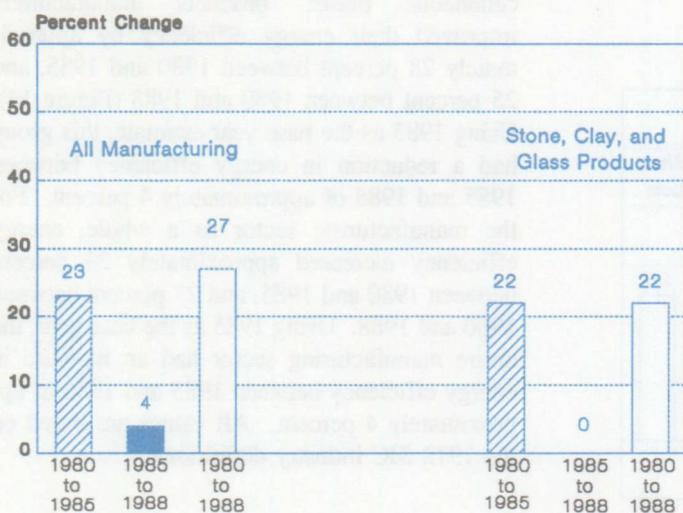
Figure 15. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 16. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

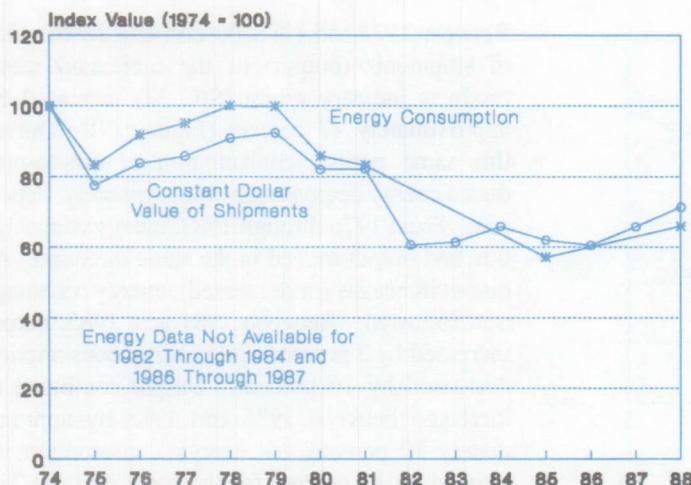
Between 1974 and 1988, the constant dollar value of shipments (output) of the stone, clay, and glass products industry group (SIC 32) increased by approximately 4 percent. During this same period, consumption of offsite-produced energy decreased by approximately 28 percent (Figure 15). From 1975 through 1981, energy consumption and output moved in the same direction. As output increased (or decreased), energy consumption followed. Output was lower in 1982 than at any other time between 1974 and 1988. Output increased by approximately 12 percent between 1981 and 1988. Energy consumption decreased by approximately 19 percent between 1981 and 1985, then increased by approximately 9 percent between 1985 and 1988. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, the energy efficiency improvement of stone, clay, and glass manufacturers between 1980 and 1985 was approximately 22 percent, with approximately the same percent improvement between 1980 and 1988 (Figure 16). Using 1985 as the base year estimate, this group had a less than 1 percent change in energy efficiency between 1985 and 1988. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Primary Metals Industry Group, SIC 33

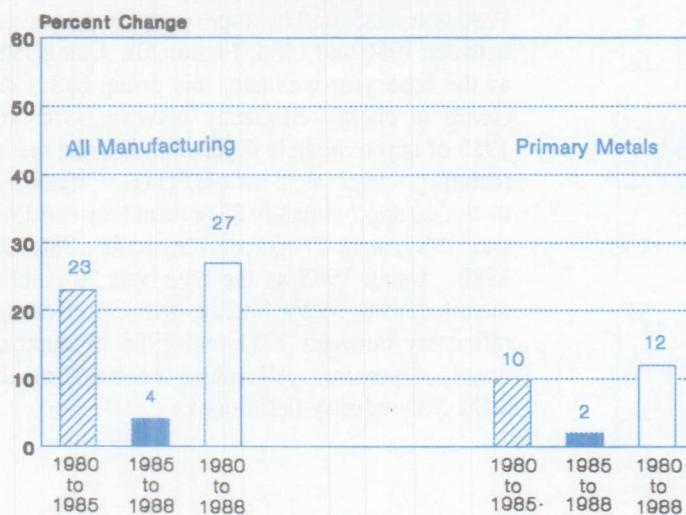
Figure 17. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 18. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

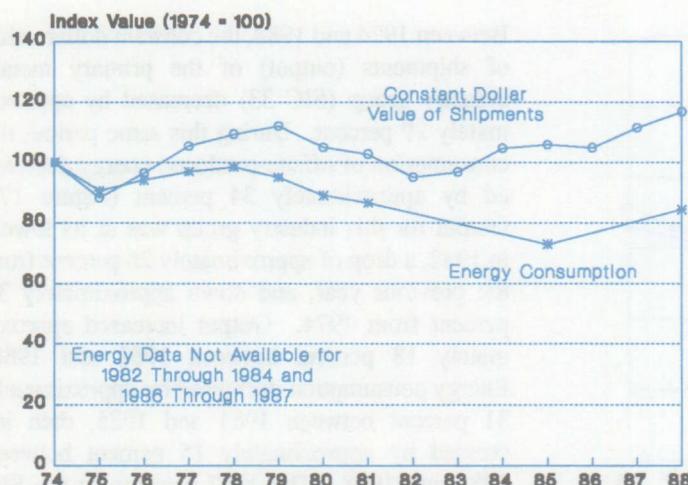
Between 1974 and 1988, the constant dollar value of shipments (output) of the primary metals industry group (SIC 33) decreased by approximately 29 percent. During this same period, the consumption of offsite-produced energy decreased by approximately 34 percent (Figure 17). Output for this industry group was at its lowest in 1982, a drop of approximately 26 percent from the previous year, and down approximately 39 percent from 1974. Output increased approximately 18 percent between 1982 and 1988. Energy consumption decreased by approximately 31 percent between 1981 and 1985, then increased by approximately 15 percent between 1985 and 1988. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, primary metals manufacturers improved their energy efficiency by approximately 10 percent between 1980 and 1985, and by approximately 12 percent between 1980 and 1988 (Figure 18). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 2 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Fabricated Metal Products Industry Group, SIC 34

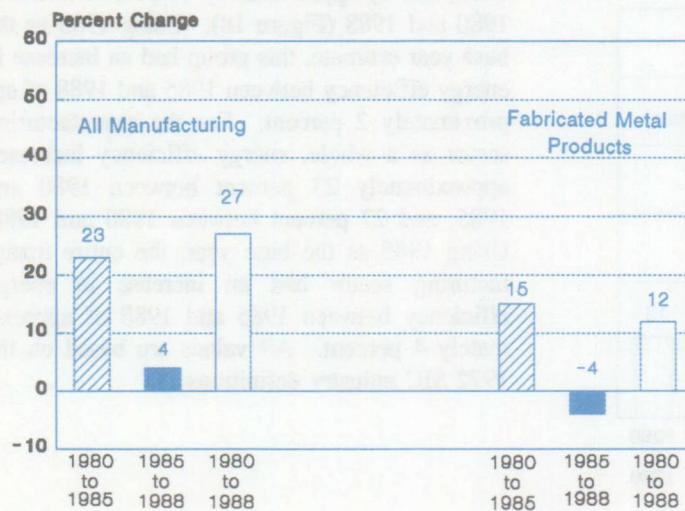
Figure 19. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 20. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

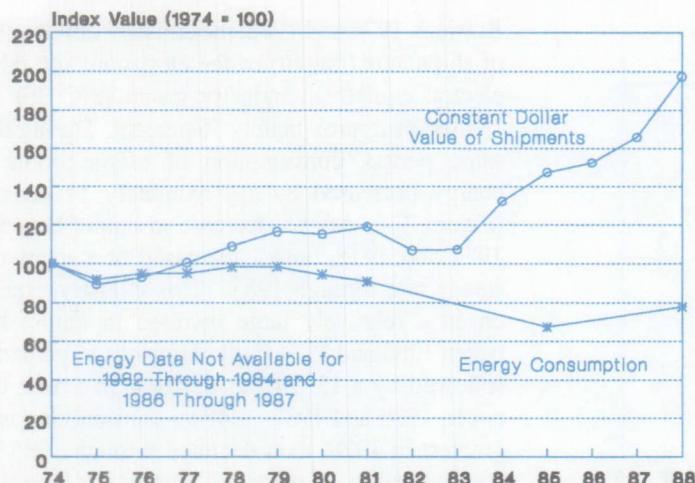
Between 1974 and 1988, the constant dollar value of shipments (output) of the fabricated metal products industry group (SIC 34) increased by approximately 17 percent (Figure 19). During this same period, consumption of offsite-produced energy decreased by approximately 16 percent. From 1976 through 1981, energy consumption and output moved in the same direction. As output increased (or decreased), energy consumption followed. Between 1981 and 1985, output increased by 3 percent while energy consumption decreased by 16 percent. Output continued to increase between 1985 and 1988 by approximately 10 percent, but energy consumption increased by 15 percent for the same period. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, fabricated metal products manufacturers improved their energy efficiency by approximately 14 percent between 1980 and 1985, and by approximately 12 percent between 1980 and 1988 (Figure 20). Using 1985 as the base year estimate, this group had a decrease in energy efficiency between 1985 and 1988 of approximately 4 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Industrial Machinery and Equipment Industry Group, SIC 35

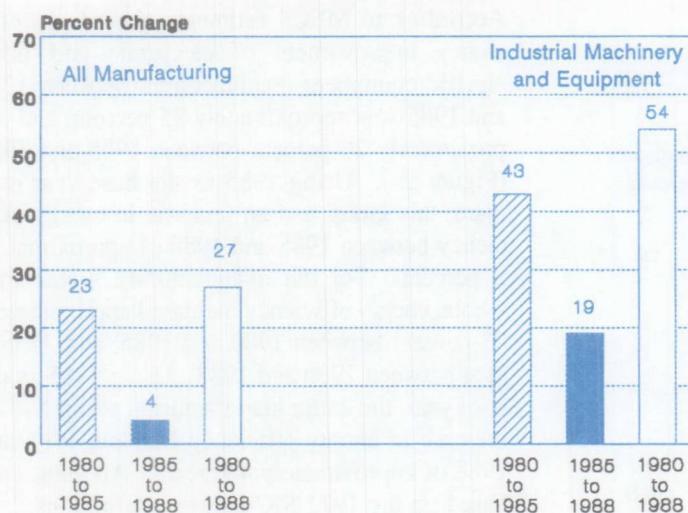
Figure 21. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 22. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

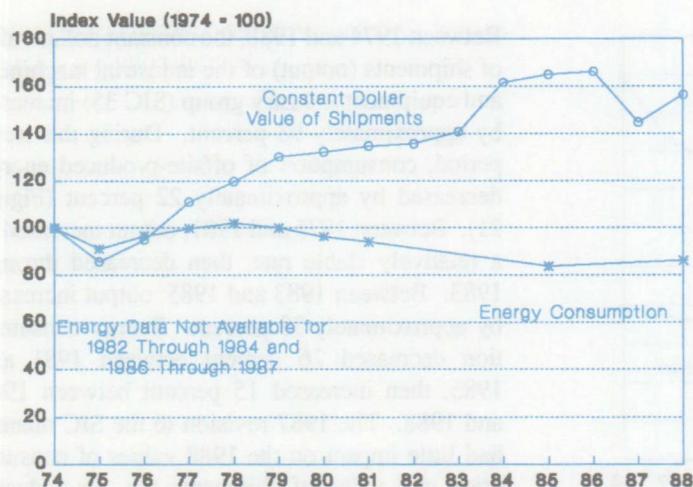
Between 1974 and 1988, the constant dollar value of shipments (output) of the industrial machinery and equipment industry group (SIC 35) increased by approximately 98 percent. During this same period, consumption of offsite-produced energy decreased by approximately 22 percent (Figure 21). Between 1975 and 1981, output increased at a relatively stable rate, then decreased through 1983. Between 1983 and 1985, output increased by approximately 38 percent. Energy consumption decreased 26 percent between 1981 and 1985, then increased 15 percent between 1985 and 1988. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, industrial machinery and equipment manufacturers improved their energy efficiency by approximately 43 percent between 1980 and 1985, and 54 percent between 1980 and 1988 (Figure 22). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 19 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Electronic and Other Electric Equipment Industry Group, SIC 36

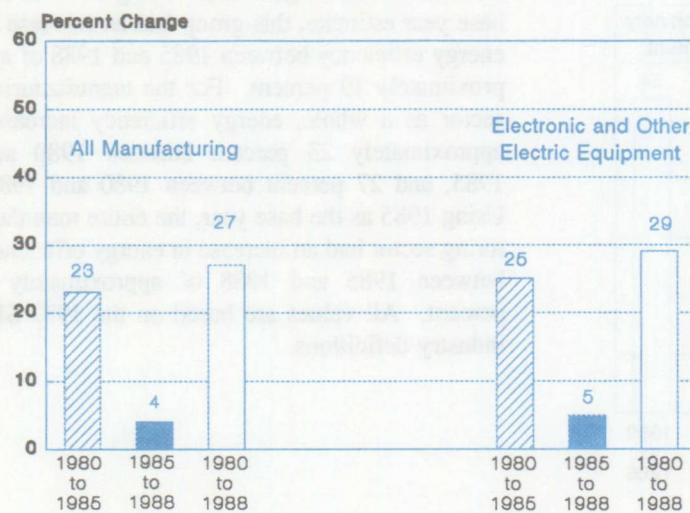
Figure 23. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 24. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

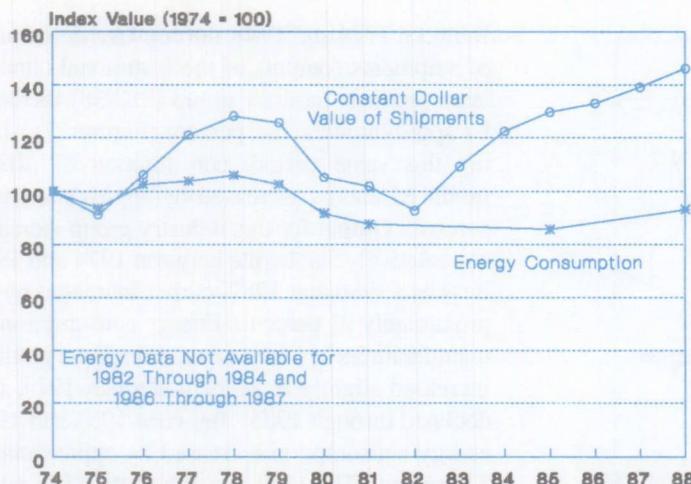
Between 1974 and 1988, the constant dollar value of shipments (output) of the electronic and other electric equipment industry group (SIC 36) increased by approximately 56 percent. During this same period, consumption of offsite-produced energy decreased by approximately 14 percent (Figure 23). After a decrease in output between 1974 and 1975, output increased at a relatively steady rate through 1983. This industry experienced a relatively large increase in output between 1983 and 1984 (approximately 15 percent), followed by a 13 percent decrease in output between 1986 and 1987. Energy consumption was greatest in 1978, then declined through 1985 by approximately 18 percent. Energy consumption was slightly higher in 1988 than it was in 1985. The 1987 revision to the SIC manual had a substantial impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, the energy efficiency improvement of electronic and other electric equipment manufacturers between 1980 and 1985 was approximately 25 percent, and approximately 29 percent between 1985 and 1988 (Figure 24). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 5 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Transportation Equipment Industry Group, SIC 37

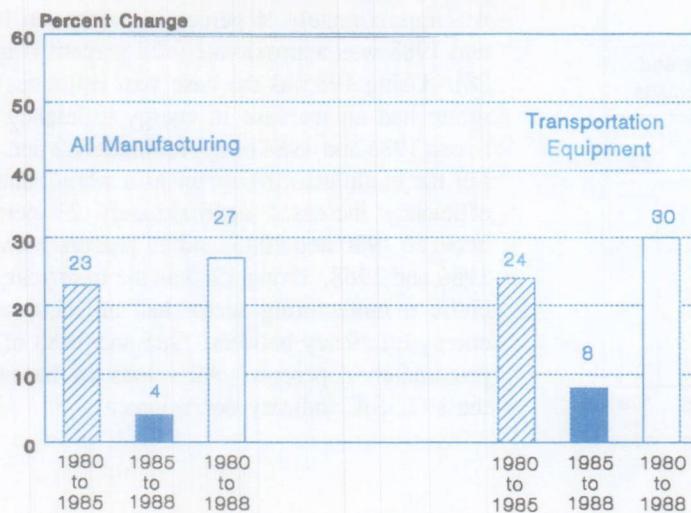
Figure 25. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 26. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

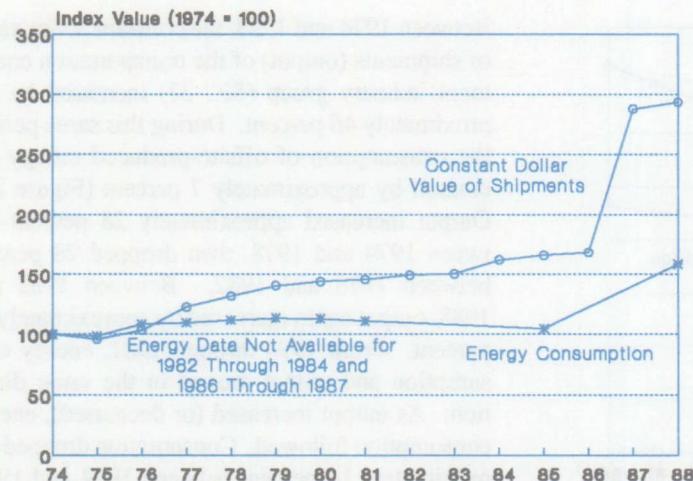
Between 1974 and 1988, the constant dollar value of shipments (output) of the transportation equipment industry group (SIC 37) increased by approximately 46 percent. During this same period, the consumption of offsite-produced energy decreased by approximately 7 percent (Figure 25). Output increased approximately 28 percent between 1974 and 1978, then dropped 28 percent between 1978 and 1982. Between 1982 and 1988, output again increased by approximately 57 percent. From 1974 through 1981, energy consumption and output moved in the same direction. As output increased (or decreased), energy consumption followed. Consumption dropped approximately 14 percent between 1974 and 1985, then increased 9 percent between 1985 and 1988. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, transportation equipment manufacturers improved their energy efficiency by approximately 24 percent between 1980 and 1985, and by approximately 30 percent between 1980 and 1988 (Figure 26). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 8 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

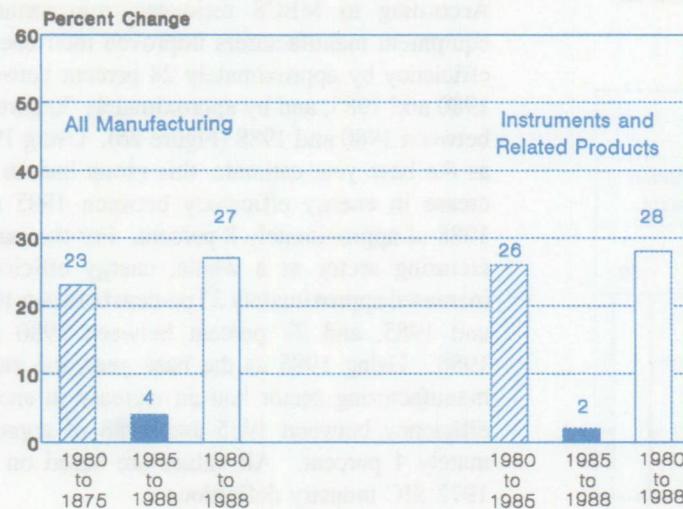
Instruments and Related Products Industry Group, SIC 38

Figure 27. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group.
 Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 28. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.
 Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

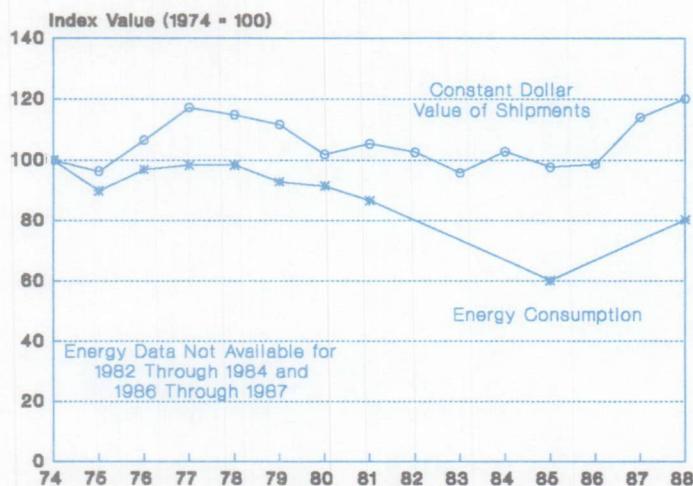
Between 1974 and 1988, the constant dollar value of shipments (output) of the instruments and related products industry group (SIC 38) increased by approximately 194 percent (Figure 27). During this same period, consumption of offsite-produced energy increased by approximately 59 percent. Output for this industry group increased at a relatively stable rate between 1974 and 1986. Between 1986 and 1987, output increased by approximately 71 percent. Energy consumption for manufacturers of instruments and related products increased slightly from 1974 through 1979, then declined through 1985. Between 1985 and 1988, energy consumption increased by approximately 51 percent. The 1987 revision to the SIC manual had a substantial impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, the energy efficiency improvement of instruments and related products manufacturers between 1980 and 1985 was approximately 26 percent and between 1980 and 1988 was approximately 28 percent (Figure 28). Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 2 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Miscellaneous Manufacturing Industry Group, SIC 39

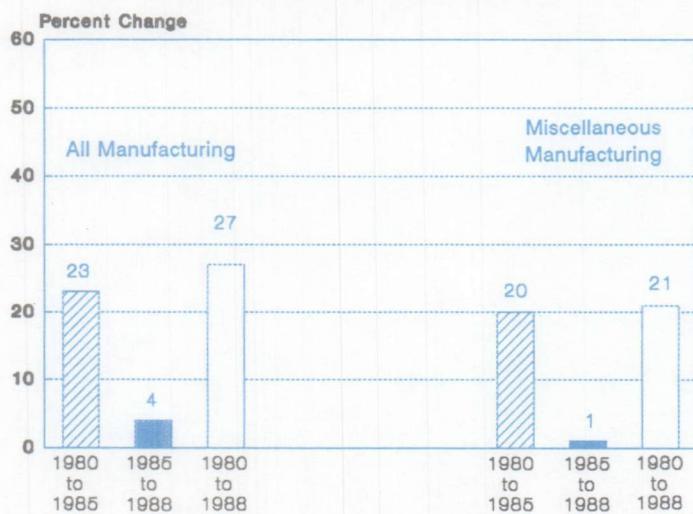
Figure 29. Output and Energy Consumption Indices, 1974 to 1988



Note: Values through 1985 are based on the 1972 SIC definitions of this industry group, while the 1988 values are based on the 1987 definitions.

Sources: Manufacturing Energy Consumption Survey, Bureau of the Census, and Bureau of Economic Analysis.

Figure 30. Percent Change in Energy Efficiency, 1980 to 1985, 1985 to 1988, and 1980 to 1988



Note: All values are based on the 1972 SIC definitions of this industry group.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census.

Historical Trends of Energy Consumption and Value of Shipments

Between 1974 and 1988, the constant dollar value of shipments (output) of the miscellaneous manufacturing industry group (SIC 39) increased by approximately 20 percent (Figure 29). During this same period, the consumption of offsite-produced energy decreased by 20 percent. Output peaked in 1977, then decreased to its lowest point in 1983. Between 1986 and 1988, output increased 22 percent. Energy consumption for this industry group declined steadily between 1978 and 1985, a decrease of 39 percent. Energy consumption increased by 33 percent between 1985 and 1988; however, it was still below the 1978 amount. The 1987 revision to the SIC manual had little impact on the 1988 values of consumption and value of shipments for this industry group.

Energy Efficiency, 1980 - 1988

According to MECS estimates, miscellaneous manufacturing establishments improved their energy efficiency by approximately 20 percent between 1980 and 1985, and approximately 21 percent between 1980 and 1988. Using 1985 as the base year estimate, this group had an increase in energy efficiency between 1985 and 1988 of approximately 1 percent. For the manufacturing sector as a whole, energy efficiency increased approximately 23 percent between 1980 and 1985, and 27 percent between 1980 and 1988. Using 1985 as the base year, the entire manufacturing sector had an increase in energy efficiency between 1985 and 1988 of approximately 4 percent. All values are based on the 1972 SIC industry definitions.

Appendix A

**Survey Design,
Implementation,
and Estimates**

Appendix A

Survey Design, Implementation, and Estimates

Introduction

The 1988 Manufacturing Energy Consumption Survey (MECS) has been designed by the Energy Information Administration (EIA) to provide information related to energy consumption and related issues for the U.S. manufacturing sector. It is the second such survey to be completed. The first survey covered the year 1985. The MECS is an ongoing survey that is conducted every three years.

This report on changes in energy intensity is the third report based on the 1988 MECS. Other reports in this series include reports on the consumption of energy¹⁵ and fuel-switching capabilities.¹⁶ A future analytic report will examine the underlying causes of changes in total energy intensities from 1985 to 1988.

This report presents estimates of changes in the intensity of the use of offsite-produced energy¹⁷ from 1980 to 1988 along with previously published estimates of changes for 1980 to 1985.¹⁸ The base year (1980) estimates of offsite-produced energy intensities were prepared using energy consumption and value of shipments data provided by the Bureau of the Census from the Annual Survey of Manufactures (ASM). Estimates for 1985 and 1988 were prepared using MECS energy consumption data and ASM value of shipments data. The Bureau of Labor Statistics (BLS) provided industry price indices, which were used to express value of shipments in constant dollars as a proxy measure of output.

There were a few methodological and statistical refinements in the 1988 MECS. Most importantly, the 1988 data represent the entire manufacturing sector. This coverage is more complete than that of the 1985 MECS, which did not represent the smallest manufacturing establishments.

The basic unit of data collection for the MECS is the manufacturing establishment. A nationally representative sample of these establishments supplied the information through mailed questionnaires. The Industry Division of the Bureau of the Census selected the MECS sample according to EIA design specifications; conducted the fieldwork; and handled data processing, again with EIA's input.

This appendix presents a summary of the design and implementation procedures for the survey. A methodological report published for the 1985 survey presented details relating to the background of the survey, forms design, sample design, and estimation procedures.¹⁹ This appendix also presents a brief overview of these topics and describes the changes made for the 1988 survey.

¹⁵Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, DOE/EIA-0512(88) (Washington, DC, May 28, 1991).

¹⁶Energy Information Administration, *Manufacturing Energy Consumption Survey: Manufacturing Fuel-Switching Capability 1988*, DOE/EIA-0515(88) (Washington, DC, September 1991).

¹⁷Offsite-produced energy consists of purchased and transferred energy available onsite for consumption. See Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, Table 4.

¹⁸Energy Information Administration, *Changes in Energy Efficiency 1980-1985*, DOE/EIA-0516(85) (Washington, DC, January 17, 1990).

¹⁹Energy Information Administration, *Manufacturing Energy Consumption Survey: Methodological Report*, DOE/EIA-0514 (Washington, DC, 1988).

Description of the Manufacturing Sector

The manufacturing sector consists of 350,000 manufacturing establishments in the 50 States and the District of Columbia. The working definition of a manufacturing establishment is the definition stated in the Office of Management and Budget's Standard Industrial Classification (SIC) Manual:

[Manufacturing establishments are] ... engaged in the mechanical or chemical transformation of materials or substances into new products. These establishments are usually described as plants, factories, or mills and characteristically use power driven machines and materials handling equipment. Establishments engaged in assembling component parts of manufactured products are also considered manufacturing if the new product is neither a structure nor other fixed improvement. Also included is the blending of materials such as lubricating oil, plastics, resins, or liquors.²⁰

The SIC Manual contains a hierachial classification system that groups establishments according to their primary economic activities. This system divides the manufacturing sector into 20 major industrial groups that are relatively homogeneous with respect to primary output. Each of these major industrial groups is assigned a two-digit code. The two-digit codes for the manufacturing division range from SIC 20, Food and Kindred Products, through SIC 39, Miscellaneous Manufacturing Industries. Each major group is subdivided into three-digit groups, which are further divided into four-digit industries. For example, SIC 20 includes SIC 201, Meat Products, which, in turn, is subdivided into SIC 2011, Meat Packing Plants; SIC 2012, Sausages and Other Prepared Meat Products; SIC 2016, Poultry Dressing Plants; and SIC 2017, Poultry and Egg Processing.

The SIC category is the single most important classification variable in the MECS data system, both for selecting the MECS sample and analyzing the MECS data. The categories of primary interest for the MECS are the 20 major industrial groups (SIC 20 through 39) and the 10 most energy-conservative four-digit industries within these industry groups. The estimates of changes in the intensity of the use of offsite-produced energy are presented only for the 20 major industrial groups. Descriptions of these 20 groups appears in Appendix D.

The 1988 MECS uses the SIC classification scheme presented in the 1987 edition of SIC manual. The 1985 MECS was based on the 1972 SIC Manual. The revisions have a substantial effect on consumption measures in SIC 36 (Electronic and Other Electric Equipment) and in SIC 38 (Instruments and Related Products), and minor or no effect on consumption in the other major industrial groups. In addition, there was one significant internal revision in the way certain petrochemical plants were classified for the 1988 MECS, as opposed to the 1985 MECS. If the primary product of a petrochemical plant in 1985 was a liquefied petroleum gas (LPG), it was classified in SIC 2911, Petroleum Refining, regardless of how the LPG was produced. For the 1988 MECS, the establishment was classified in SIC 2911 only if the LPG was produced by a refinery process. If the LPG was produced by a chemical process, the establishment was classified in organic chemicals (SIC 2865 or 2869).

The MECS Sampling Frame and Sample Design

As mentioned in the Introduction to this appendix, the Industry Division of the Census Bureau serves as the collecting and compiling agent for the MECS. A major benefit of this arrangement is that the Census Bureau's sample for the ASM can serve as the sampling frame for the MECS sample. Therefore, prior to discussing the MECS sample design, the frame from which it was selected will be described in some detail.

The Sample for the Annual Survey of Manufactures

A major responsibility of the Industry Division of the Bureau of the Census is to conduct the Census of Manufactures (CM) and the ASM. The CM is conducted for years ending in "2" or "7" (for example, 1982), and obtains economic

²⁰Office of Management and Budget, *Standard Industrial Classification Manual*, 1987 (Washington, DC, 1987), p. 67.

data for the complete universe of approximately 350,000 manufacturing establishments in the United States. For the purposes of data collection, the CM universe is divided into two major subsets as follows.

1. **Small Single-Establishment Companies Not Sent a Report Form.** These companies are excused from filing a CM report. Generally, those with less than 5 employees are excused while all with more than 20 are mailed report forms. Those with 5 through 20 employees are excused or sent a report form based on the magnitude of their annual payroll and shipments data. Approximately 125,000 establishments are excused due to this criterion.
2. **Establishments Sent a Report Form.** The remaining manufacturing establishments in the universe are sent a report form.

The ASM is conducted during non-CM years to provide estimates of economic characteristics for the universe of manufacturing establishments. As with the CM, the ASM contains two components. The first component is the mail portion, a probability sample of manufacturing establishments selected from the list of establishments that are sent the CM report form (see above). Those establishments are weighted so that they represent the mail portion of the CM universe. The second component of the ASM is the nonmail portion of the CM. These small establishments are not sent an ASM questionnaire, but their contribution to economic statistics published in the ASM and the CM is estimated based on selected information obtained annually from other Federal agencies.

Sample Design

A major design objective for the 1988 MECS sample was that it should facilitate analyses of changes in energy consumption and related issues between 1985 and 1988. This was accomplished by including many of the 1985 establishments in the 1988 sample. Therefore, some discussion of the design of the 1985 MECS sample is in order.

For the 1985 survey, the overall desired size of the MECS sample was set at 12,000 establishments based upon available resources and preliminary estimates of expected and desired sampling error. The desired sample size was allocated among 30 industry-based strata consisting of the 10 most energy-consumptive four-digit SIC industries and the remaining portions of the 20 two-digit SIC industry groups. (See Appendix D for descriptions of industry groups and industries.) Due to random variability in the sample selection process, the actual sample contained 12,065 establishments.

For the 10 most energy-consumptive industries, all the establishments in the 1984 ASM sample were included in the 1985 MECS sample with certainty. The remaining establishments were sampled from the 20 two-digit groups in a pattern designed to keep sampling errors within pre-established bounds for estimates of total energy consumption and consumption of four major types of energy: electricity, natural gas, residual oil, and coal. The procedures for subselecting ASM sample establishments into the MECS sample were such that their overall probabilities of selection for the MECS were proportional to an estimated energy measure of size. The overall probabilities for selection of the MECS sample establishments ranged from 0.002 to 1.000.

The selection of the MECS sample for 1985 was, therefore, a two-stage selection process, with the first stage being the selection of the ASM mail sample, and the second, being the subselection of the MECS sample from the ASM sample. Thus, a MECS sample establishment was selected conditionally upon it having been selected into the ASM mail sample, which means that its probability of selection from the ASM sample is a conditional probability. Therefore, the overall probability of selection into the MECS sample was represented by the product of this conditional probability and its ASM selection probability.

Of the initial 1988 sample of 12,400 establishments, approximately 200 were determined to be out of business or out of scope based on updating procedures used by the Census Bureau. Thus, a final sample of 12,200 establishments were mailed a questionnaire. Of these, usable responses were received from 10,650 or 87 percent of those establishments. However, these respondents represented 96 percent of the total unweighted value of shipments and receipts of the final sample.

Fieldwork, Editing, and Quality Control

The 1988 MECS used customized questionnaires for specific industries, with similar energy consumption characteristics. The three questionnaires were:

- **Form EIA-846(A).**—This questionnaire was sent to the majority of the sample and collected the basic consumption, expenditure, and fuel-switching information.
- **Form EIA-846(B).**—This questionnaire was sent exclusively to establishments in the Petroleum Refining Industry (SIC 2911). The design of the questionnaire took advantage of the fact that other EIA surveys collect certain consumption and expenditure data from the refinery population. Thus, the EIA-846(B) did not require respondents to report on particular data items. The questionnaire also collects data on nonfuel use and shipments of energy sources from adjoining petrochemical plants.
- **Form EIA-846(C).**—This questionnaire was sent to establishments in the Steel Works, Blast Furnaces, and Rolling Mills Industry (SIC 3312), producers of Chemicals and Allied Products (SIC 28), and producers of Petroleum and Coal Products other than Petroleum Refining (SIC 29 excluding SIC 2911). It is identical to the EIA-846(A) except that it collects additional information on shipments of energy sources produced onsite.²¹

The questionnaires were mailed to the in-scope MECS sample establishments on June 15, 1989. Returned questionnaires were subjected to initial screening procedures for completeness, and incomplete forms or responses with obvious inconsistencies were set aside for review by industry specialists. Valid returned questionnaires were forwarded directly to check-in and then to data entry.

All forms that were incomplete or failed the initial screening procedures were carefully reviewed by the industry specialists from the Census Bureau and EIA. The Census Bureau specialists retrieved missing data and verified questionable items by telephone contact with the individual who completed the questionnaire. Once the forms were completed and verified, they were forwarded to check-in and to data entry.

The resulting MECS data file was then subjected to a series of computer edits. These edits included consistency checks against data items from other parts of the MECS and the 1988 ASM, as well as checks for outliers in the distribution of individual variables. Records with failed edits were reviewed and followed up by industry specialists.

The Estimation Process

The 1988 energy consumption estimates used to prepare the estimates of energy intensity in this report represent the entire population of manufacturers. Full representation is accomplished by weighting the data from the establishment records in the consumption data file. Weighting is the process of multiplying the reported or derived values by a case-specific constant designed to inflate the data from each sample case to that portion of the population that it represents. The first, basic component in the MECS weights is the sampling weight. The sampling weight for a MECS sample case is the reciprocal of its overall probability of selection into the ASM and subsequent selection for the MECS.

The second component of the MECS weights is an adjustment for nonresponse. Adjustment factors to account for nonresponse were calculated by using the known energy measures of size of the respondents and the total sample. Because an establishment is selected into the MECS sample with a probability proportional to the establishment's energy measure of size, that measure can be viewed as an establishment's estimated contribution to energy

²¹Establishments in these industries routinely produce energy sources from the input of other energy sources, which are, in turn, sold or transferred to other establishments. The additional information collected on Form EIA-846(C) was to permit the necessary adjustments to avoid double counting. Response to these items was incomplete, however, and the adjustments were not made.

consumption in 1987. A separate adjustment factor was computed for each of the 30 sampling strata²² and took the form:

$$a_s = \frac{\sum_{j \in s}^{\text{Sample}} MOS_{s,j}}{\sum_{i \in s}^{\text{Resp.}} MOS_{s,i}}, \quad (1)$$

where $MOS_{s,j}$ is the measure of size for MECS sample establishment j in stratum s , and $MOS_{s,i}$ is the measure of size for MECS respondent i in stratum s .

The final adjustment to the weights took advantage of the fact that a recent enumeration of the population, the 1987 CM, was performed prior to the compilation of the MECS data. It is difficult to maintain the accuracy and currency of a sample over a number of years even employing the established updating methods used by the Bureau of the Census. Time restrictions and the desire to have a longitudinal component in the MECS precluded drawing a completely new sample. Therefore, the MECS sample data were further adjusted by using known CM totals.

The adjustment that was used is analogous to the one that is routinely employed for ASM data. In the ASM case, cell totals have high correlations from year to year as a result of including many of the same establishments for each ASM within a CM cycle. By taking advantage of those correlations, cell totals can be made more reliable. The adjustment the Census Bureau chose maximizes those benefits.²³ In that adjustment, CM data are substituted into the ASM sample establishments and a difference between that estimate and the actual Census total for any particular variable is computed. That difference is then added to the ASM data for the current year. The adjustment is shown in Equation (2):

$$Y'' = Y' - X' + X, \quad (2)$$

where Y'' is the adjusted ASM value, Y' is the ASM sample estimate for the current year, X' is the ASM sample estimate for the Census year, and X is the total Census for the Census year.

As all ASM quantities are also collected by the CM, the adjustment described can be done for the ASM variables individually. In order to have the MECS sample represent the 1988 MECS population as closely as possible, the MECS data should be adjusted in a way similar to the ASM. However, most data items collected by the MECS are not included on the CM. Data items included in the MECS are related to energy consumption and fuel switching, while ASM and CM data items are economic in nature. Therefore, a simple difference for corresponding items cannot be used to adjust MECS data as was done for the ASM data. Rather a measure that can be found on both the CM and the MECS must be used to ratio adjust all the MECS data items. The measure chosen was cost of fuels as it has shown a high correlation with energy consumption in the past.²⁴

Essentially, each MECS nonresponse-adjusted weight was further adjusted by multiplying the weight by the ratio of cost of fuels measured by the 1987 CM to the 1987 cost of fuels estimate by the MECS sample establishments. This ratio was computed for each of the 30 MECS sampling strata (20 two-digit industry groups and 10 four-digit industries). For highly disaggregated estimates, the ratio adjustment is not as advantageous as for others. Indeed,

²²For the 1985 MECS there was a separate adjustment for employment size category as well as for sampling stratum. That added separation proved not to be worthwhile.

²³For a more detailed discussion, see U.S. Department of Commerce, Bureau of the Census, *The Annual Survey of Manufactures: A Report on Methodology*, Technical Paper No. 24, U.S. Government Printing Office (Washington, DC, February 1971).

²⁴Correlation coefficients between 1981 ASM establishment values of total purchased fuels and electric energy and the cost of fuels and electric energy ranged from .78 to .98 within two-digit SIC categories. (Unpublished document, U.S. Department of Commerce, Bureau of the Census.)

as the same adjustment is used for all estimates within a stratum, it is possible that the adjustment could affect some estimates in an adverse way. The ratio adjustment to the MECS weights takes the following form:

$$R_s = \frac{\sum_{j \in s}^{CM} (CF_{s,j})}{\sum_{i \in s}^{MECS} (W_{s,i} CF_{s,i})}, \quad (3)$$

where R_s is the adjustment to the MECS nonresponse-adjusted weight for all MECS respondents in stratum s , $CF_{s,j}$ is the 1987 cost of fuels value for establishment j from the 1987 CM, $W_{s,i}$ is the 1988 MECS sampling weight for establishment i in stratum s , a_s is the nonresponse adjustment just described, and $CF_{s,i}$ is the 1987 cost of fuels value for 1988 MECS sample establishment i in stratum s .

The adjustment of the sampling weights according to Equation (3) extends the MECS sample coverage to the entire manufacturing division. This was not the case in for the 1985 when no CM-based ratio adjustment was performed.²⁵ The CM totals for cost of fuels include estimated values for cases in the nonmail file as well as the mail file totals. Hence, by using the adjustment described in Equation (3), non-mail cases are also covered by the MECS.

The difference in weighting methodology, while it is important for interpreting aggregate estimates such as consumption and fuel-switching capability, has no effect on energy intensity and intensity change measures within SICs, as shown in the next section.

The Concept of Energy Intensity

Energy intensity is one specialized concept that can be measured using the MECS data base and estimation process. Energy intensity is the ratio of energy consumption to output for any given year. In this report, energy consumption is defined as the consumption of offsite-produced energy, and output is defined as the value of shipments and receipts expressed in constant (1980) dollars. Thus, the energy-intensity ratio is expressed as:

$$I_{s,t} = \frac{E_{s,t}}{Q_{s,t}}, \quad (4)$$

where I represents the energy-intensity ratio for industry group s in year t , E is offsite-produced energy consumption, and Q is the constant dollar value of shipments and receipts. Because consumption and value of shipments are MECS-based estimators, the intensity ratio can be written in expanded form as:

$$I_{s,t} = \frac{E_{s,t}}{Q_{s,t}} = \frac{\sum_{i \in s}^{MECS} R_{s,t} a_{s,t} W_{s,t,i} e_{s,t,i}}{\sum_{i \in s}^{MECS} R_{s,t} a_{s,t} W_{s,t,i} q_{s,t,i}}, \quad (5)$$

²⁵The 1985 and 1988 MECS samples were both based on the 1982 CM file, augmented with updates to represent subsequent population changes as well as possible. Because the elapsed time between the 1985 MECS and the 1982 CM was shorter, there was less coverage degradation in the first cycle. As the 1987 CM and the 1988 MECS covered the same population, the adjustment described in Equation (3) is a natural one. However, there were no corresponding Census data available to adjust the 1985 MECS.

where $e_{s,t,i}$ and $q_{s,t,i}$ are the offsite-produced energy consumption and value of shipments, respectively, for respondent i in SIC s at time t . Since $R_{s,t}$ and $a_{s,t}$ are constants with respect to the summation operator, Equation (5) can be rewritten as:

$$I_{s,t} = \frac{R_{s,t} a_{s,t} \sum_{i \in s}^{MECS} W_{s,t,i} e_{s,t,i}}{R_{s,t} a_{s,t} \sum_{i \in s}^{MECS} W_{s,t,i} q_{s,t,i}}, \quad (6)$$

which, in turn, reduces to:

$$I_{s,t} = \frac{\sum_{i \in s}^{MECS} W_{s,t,i} e_{s,t,i}}{\sum_{i \in s}^{MECS} W_{s,t,i} q_{s,t,i}}. \quad (7)$$

Thus, neither the nonresponse adjustment nor the coverage adjustment have any effect on the intensity ratio within an industry group.

Changes in energy intensity are represented as the percent change in the intensities from one year to another. In this report, the changes in energy intensity reflect the change from the base year of 1980 to the MECS survey years of 1985 and 1988. The energy intensity changes are given as:

$$\Delta I_{s,b:t} \% = 100 \left(\frac{I_{s,b} - I_{s,t}}{I_{s,b}} \right) = 100 \left(1 - \frac{I_{s,t}}{I_{s,b}} \right), \quad (8)$$

where $\Delta I\%$ is the percent change²⁶ in energy intensity for industry s from the base year b ($b = 1980$ or 1985) to time period t ($t = 1985$ or 1988).

There are alternative measures of energy consumption and output that could be used in place of constant dollar value of shipments and receipts and the consumption of offsite-produced energy. The reasons for selecting these two measures are presented in the two following sections.

Measures of Energy Consumption

The MECS was conducted for the first time in 1986 to collect 1985 data. Prior to the MECS, the Bureau of the Census collected energy consumption data for 1974 through 1981 as a part of the ASM or CM. The 1985 and 1988 MECS produced three separate estimates of energy consumption. These are the consumption of offsite-produced energy, total inputs of energy, and primary consumption of energy.²⁷

²⁶It should be noted that the numerator in Equation (8) is reversed from what would be normally expected in calculating a percent change. This reversal is to account for the fact that a *decrease* in the energy intensity ratios from one period to another results in an *increase* in energy efficiency, while an *increase* in the ratios results in a *decrease* in efficiency.

²⁷Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1985*, DOE/EIA-0512(85) (Washington, DC, 1988) and *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, DOE/EIA-0512(88) (Washington, DC, 1991).

Offsite-produced energy consumption is defined as the total amount of energy purchased or transferred from offsite sources that is consumed onsite to produce heat and power and to generate electricity. The definition of energy used by the Bureau of the Census is comparable to the MECS' definition of offsite-produced energy used in the MECS.

The estimates of offsite-produced energy consumption were used to develop the energy-intensity ratios because two years of data are required to examine changes in energy intensity. The estimates of offsite-produced energy consumption is the only one of the three energy consumption measures resulting from the MECS for which definitionally comparable estimates are available for earlier years. The 1980 estimates of energy consumption prepared by the Census Bureau were used for the base year in constructing the estimates of changes in energy intensity. The 1985 and 1988 estimates of offsite-produced energy were taken from the MECS.

Measures of Output

Ideally, the output measure used to calculate the change in energy intensity would be a measure of physical output. Physical output measures were not collected by the MECS, however, and it was necessary to use a proxy measure of output. Two economic measures of manufacturing activity were considered for this purpose: value of shipments and value added by manufacture. Both of these economic measures were available from the Bureau of the Census for the establishments in the MECS sample.

Value of shipments consists of the total receipts for products manufactured, services rendered, and the resales of products bought and sold without further manufacture. Value added, on the other hand, represents the unique contribution of a manufacturer to the production of finished goods. It is derived by subtracting the cost of all materials from the value of shipments and adding the net change in finished goods and work in progress inventory. Basically, value added consists of wages and employee supplements, net interest, indirect business taxes and adjustments, and income or corporate profits.²⁸

The value of shipments for any given industry group contains a large amount of duplication because the product outputs of some industries are used as raw material inputs by others. For example, a manufacturer of copper wire may sell wire to another manufacturer that builds electric motors. The electric motor manufacturer may, in turn, sell electric motors to a manufacturer that assembles refrigerators. Thus, the cost of the copper wire, which originated with the first manufacturer, appears in the value of shipments for all three manufacturers. If the values of shipments are summed for these three manufacturers, the result will contain duplication of the cost of the copper wire. Because of this duplication, the value of shipments of the individual industry groups should never be summed to calculate the total output of the manufacturing sector. Enormous duplication would result. Value added by manufacture is the output measure appropriate for that purpose because it includes only the unique contribution of each industry group toward the production of final products.

The duplication inherent in the value of shipments is *not* an important consideration in the estimation of energy intensity ratios, because the purpose is not to compare the ratios between industries. Rather, the purpose is to compare energy consumption per unit of output at two different points in time within an industry group. In most cases, whatever duplication existed in the base year will also be present in the comparison year (that is, value added as a percent of the value of shipments is approximately equal for the base and comparison years). Accordingly, for industry groups with perfectly stable proportions of value added to value of shipments, the same estimate of energy intensity change will result regardless of whether the base is the value of shipments or value added.

For a few industry groups, however, value added as a percent of the value of shipments is not stable from year to year. This was especially true in SIC 29, petroleum and coal products between 1980 and 1985. During this period, constant dollar value added as a percent of constant dollar value of shipments declined from 12.5 to 4.3 percent. The energy intensity change calculated using the value of shipments as a base was 8.3 percent. Energy intensity change calculated using value added as a base was -160.0 percent. The basic question is, then, which economic

²⁸For more details on the value of shipments and value added, see U.S. Department of Commerce, Bureau of the Census, *1985 Annual Survey of Manufactures*, "Statistics for Industry Groups and Industries," M85(AS)1 (Washington, DC, January 1987), Appendix A.

measure, value added or value of shipments, best mirrors physical output when value added is variable relative to the value of shipments?

The petroleum and coal products industry group is the one group for which some physical output measures are available. In 1980 and 1985, petroleum refineries supplied 6,225.4 and 5,740.0 million barrels, respectively, of refined petroleum products.²⁹ (Note that these values represent the output of the petroleum refineries only, and not the entire industry group. Since petroleum refineries account for 91 percent of the value of shipments of the entire sector, however, the values are a reasonable proxy.) The estimated consumption of offsite-produced energy for these two years was 1,180.5 and 917.0 trillion Btu. Using physical output as the base yields an estimated energy intensity change of 15.7 percent.

Clearly, for the petroleum and coal products industry group, an estimate of energy intensity change between 1980 and 1985 based on the value of shipments more closely corresponds to the estimate based on physical production than does the estimate based on value added. Thus, when value added as a proportion of value of shipments differs between the base and comparison years, it would appear that constant dollar value of shipments more closely approximates physical production than does constant dollar value added. Therefore, constant dollar value of shipments were used as the proxy measure of output for calculating the energy intensity ratios used in this report.

Finally, it should be noted that using constant dollar value of shipments as a surrogate for physical output is fully consistent with the procedures adopted by other Federal agencies for estimating output. The Bureau of Labor Statistics (BLS), for example, publishes a productivity measure known as "output per employee hour." Basically, this index is produced by dividing an output index by an index of aggregate employee hours for a given industry. According to the BLS,

... industry output indexes are based on quantifiable units of products or services of the industry Whenever possible, physical quantities are used as the unit of measurement. For those industries lacking quantity data, constant-dollar value of shipments, sales, or revenue data are used to develop the output series.³⁰

²⁹Energy Information Administration, *Monthly Energy Review*, November 1988 (February 1989), Table 3.1a. Published values converted to annual production.

³⁰U.S. Department of Labor, Bureau of Labor Statistics, *BLS Handbook of Methods*, Volume I, Bulletin 2134-1 (Washington DC, December 1983), p. 103.

Appendix B

Quality of the Data

Appendix B

Quality of the Data

Introduction

All data collection activities and the estimates produced from them are subject to a variety of errors. These errors may be broadly classified under two general types, sampling error and nonsampling error.

Sampling error is defined as the variability in a survey estimator that arises because data are collected from a sample of units rather than the entire population. Each possible sample produces different estimates of population parameters, depending on the set of respondents that are selected. Nonsampling errors are attributable to all aspects of the total survey design other than the sampling process, and can include both random and systematic (biasing) errors. Commonly recognized sources of nonsampling error include undercoverage, random and systematic response errors, nonresponse, data processing errors, and tabulation errors. This appendix describes the effect of both sampling and nonsampling on the estimates of energy intensity change using data from the MECS and the ASM.

Sampling Error

The estimates of energy intensity change appearing in this report were developed from one of a very large number of samples of manufacturing establishments that could have been selected under the same sampling specifications. As a result, survey estimates differ from true population values that would be obtained from a complete enumeration of all manufacturing establishments. Each possible sample yields its own estimates of the true population values, with the differences attributable to the particular set of establishments selected into each sample.

One measure of the variability due to sampling is the average squared differences between the estimates that would be produced by all possible samples and the mean value of those estimates. This type of measure is commonly known as sampling error. Estimates of the magnitude of these sampling errors based on data from a single sample are provided by a statistic known as the standard error of an estimate.

Estimates of standard error have been computed for the estimated energy efficiency changes appearing in this report, and are presented in Table B1 of this appendix. The estimates were derived in the form of relative standard errors (RSE's) using pre-existing data, and converted to standard errors.

Computation of Relative Standard Errors

The RSE's for the estimates of energy efficiency change, defined as 100 times the standard error, divided by the estimate to which it refers, were computed using a specially-derived formula that yields an approximate RSE. The primary inputs for the computation are the relative variances and covariances of energy consumption, the constant dollar value of shipments, and the estimated change in energy efficiency. The following paragraphs describe the derivation of the formula.

In Equation (8) of Appendix A, the change in energy efficiency for an industry group is given as:

$$\Delta I_{s,b:t} = \left(1 - \frac{I_{s,t}}{I_{s,b}} \right), \quad (9)$$

where the multiplier of 100 in Equation (8) is ignored.

The object is to derive an approximate RSE for the change in energy intensity. The derivation proceeds as follows:

$$RSE(\Delta I_{s,b:t}) = RSE\left(1 - \frac{I_{s,t}}{I_{s,b}}\right) = \sqrt{RSE^2\left(1 - \frac{I_{s,t}}{I_{s,b}}\right)}, \quad (10)$$

where RSE^2 is the relative variance, or rel-variance. By definition of the rel-variance,

$$RSE(\Delta I_{s,b:t}) = 100 \sqrt{\frac{VAR\left(1 - \frac{I_{s,t}}{I_{s,b}}\right)}{\Delta I_{s,b:t}^2}}. \quad (11)$$

Equation (11) can be restated as:

$$RSE(\Delta I_{s,b:t}) = 100 \sqrt{\frac{VAR(1) + VAR\left(\frac{I_{s,t}}{I_{s,b}}\right) - 2COV\left(1, \frac{I_{s,t}}{I_{s,b}}\right)}{\Delta I_{s,b:t}^2}}. \quad (12)$$

Since the variance of a constant and the covariance of a constant and a variable are equal to zero, Equation (16) reduces to:

$$RSE(\Delta I_{s,b:t}) = 100 \sqrt{\frac{VAR\left(\frac{I_{s,t}}{I_{s,b}}\right)}{\Delta I_{s,b:t}^2}}. \quad (13)$$

Expressing Equation (13) in terms of the rel-variance,

$$RSE(\Delta I_{s,b:t}) = 100 \sqrt{\frac{RSE^2\left(\frac{I_{s,t}}{I_{s,b}}\right) \times \left(\frac{I_{s,t}}{I_{s,b}}\right)^2}{\Delta I_{s,b:t}^2}}. \quad (14)$$

By Hansen, Hurwitz, and Madow,³¹ the rel-variance of a ratio can be approximated using the rel-variances and the rel-covariance of the components. Applying the approximation of Hansen et al., Equation (14) becomes:

$$RSE(\Delta I_{s,b:t}) \doteq 100 \sqrt{\frac{\left[RSE^2(I_{s,t}) + RSE^2(I_{s,b}) - 2RELCOV(I_{s,t}, I_{s,b})\right] \times \left[\frac{I_{s,t}}{I_{s,b}}\right]^2}{\Delta I_{s,b:t}^2}}. \quad (15)$$

³¹M. Hansen, W. Hurwitz, and W. Madow, *Sample and Survey Methods and Theory*, Volume 1 (New York: John Wiley & Sons, Inc., 1953), p. 166.

The relative covariance in Equation (15) between the two ratios can be assumed to be zero because sample selection for the 1988 and 1985 MECS is independent of sample selection for the 1980 ASM. Thus, Equation (15) reduces to:

$$RSE(\Delta I_{s,b:t}) \doteq 100 \sqrt{\frac{[RSE^2(I_{s,t}) + RSE^2(I_{s,b})] \times \left[\frac{I_{s,t}}{I_{s,b}}\right]^2}{\Delta I_{s,b:t}^2}} \quad . \quad (16)$$

Since the two rel-variances in Equation (16) are the rel-variances of the energy intensity ratios for industry group s in time periods t and b (b may equal 80 or 85), the approximation of Hansen et al. may be used again. Thus, the rel-variances in Equation (16) may be approximated as:

$$RSE^2(I_{s,t}) \doteq RSE^2(E_{s,t}) + RSE^2(Q_{s,t}) - 2RELCOV(E_{s,t}, Q_{s,t}), \quad (17)$$

and,

$$RSE^2(I_{s,b}) \doteq RSE^2(E_{s,b}) + RSE^2(Q_{s,b}) - 2RELCOV(E_{s,b}, Q_{s,b}). \quad (18)$$

The components of these rel-variances were available from the 1988 and 1985 MECS, and the 1980 ASM, and in information provided by the Bureau of the Census. The rel-variances were estimated and substituted into Equation (16) to derive the RSE's of the estimated changes in energy intensity. These RSE's were converted to standard errors for Table B1 by dividing by 100 and multiplying by the corresponding estimate of intensity change.

Unlike the derivation of an approximate RSE for the change in energy intensity from 1980 to 1985 and 1988, the derivation of the change in energy intensity from 1985 to 1988 is complicated because the two MECS samples were not independently drawn (See Appendix A for a detailed description of the MECS sample designs). The derivation process is similar to the methodology used for approximating an RSE of changes from 1980 to 1985 and 1988, with the singular exception that the rel-covariance of the random variables, $I_{s,85}$ and $I_{s,88}$, is obviously not zero. Again, a conservative approach would be to assume the covariance between the two random variables to be zero.

However, by Cochran,³² the rel-covariance term can be approximated when the ratios, $I_{s,85}$ and $I_{s,88}$, may be correlated. For changes between the time periods 1985 and 1988, this sample estimate enables the RSE expression given in Equation (15) to represent the correlation between the overlapping MECS samples and can be written as:

$$RELCOV(I_{s,85}, I_{s,88}) \doteq \frac{1}{Q_{s,85} \cdot Q_{s,88} \cdot I_{s,85} \cdot I_{s,88}} \cdot COV[(E_{s,85} - I_{s,85} \cdot Q_{s,85}), (E_{s,88} - I_{s,88} \cdot Q_{s,88})]. \quad (19)$$

Expanding Equation (19) and applying the methodology for calculating covariances given in the EIA report, *Manufacturing Energy Consumption Survey: Methodological Report 1985*, the rel-covariance, under Poisson sampling, can be approximated and substituted into Equation (15), taking advantage of the dependent sample selection procedures by calculating relative standard errors which include rel-covariances.

³²W. G. Cochran, *Sampling Techniques*, Third Ed. (New York: John Wiley & Sons, Inc., 1977), p. 181.

Table B1. Standard Errors for Estimates of Percent Change In Energy Intensity

SIC Code	Industry Group	Standard Error 1980-1985	Standard Error 1985-1988	Standard Error 1980-1988
20	Food and Kindred Products	5.5	7.3	4.0
21	Tobacco Products	NA	NA	NA
22	Textile Mill Products	2.8	3.4	3.4
23	Apparel and Other Textile Products	NA	NA	NA
24	Lumber and Wood Products	NA	NA	NA
25	Furniture and Fixtures	3.5	5.5	3.7
26	Paper and Allied Products	4.1	4.5	3.7
27	Printing and Publishing	NA	NA	NA
28	Chemicals and Allied Products	3.9	4.2	3.8
29	Petroleum and Coal Products	2.3	3.4	2.3
30	Rubber and Misc. Plastics Products	2.5	2.5	2.5
31	Leather and Leather Products	NA	NA	NA
32	Stone, Clay, and Glass Products	5.1	4.0	4.7
33	Primary Metal Industries	2.0	2.6	2.5
34	Fabricated Metal Products	5.0	3.6	4.6
35	Industrial Machinery and Equipment	3.5	4.8	3.2
36	Electronic and Other Electric Equipment	3.0	4.3	3.5
37	Transportation Equipment	2.1	3.3	3.00
38	Instruments and Related Products	11.5	8.5	11.4
39	Misc. Manufacturing Industries	5.9	6.4	5.9
--	All Manufacturing	2.1	1.8	2.1

NA=Withheld because the MECS sampling process did not sufficiently represent the diverse size or economic diversity of the industry group to produce viable estimates of changes in energy intensity.

Sources: Manufacturing Energy Consumption Survey and Bureau of the Census

Nonsampling Errors and Bias

Nonsampling errors that affect MECS survey data can be divided into four major categories:

1. *Operational errors*, including editing, coding, and tabulation errors,
2. *Errors of measurement*, including a lack of precision by the respondent, failure of the respondent to understand instructions, etc.,
3. *Errors of estimation*, including the assumptions underlying the values for maximum consumption,
4. *Errors of nonobservation*, including nonresponse and noncoverage.

These errors are collectively referred to as nonsampling errors because they are not related to the sampling process, and thus would be equally likely to occur in a complete census or a sample survey.

It is felt that operational errors are not a major concern for the estimates included in this report. The quality control procedures that were employed for check-in, editing, coding and keying the returned questionnaires (see Appendix A) are standard procedures that are in place at the Bureau of the Census and have withstood the test of time. Data tabulations were verified by comparing marginal totals in tables generated from files supplied to EIA with corresponding totals generated directly from microdata files held at the Bureau of the Census.

Errors of measurement are a concern in any data collection activity. The survey results for the MECS were subjected to extensive editing procedures that were specifically designed to detect errors of measurement. Failure of any of these tests for reasonableness and consistency resulted in the respondent being called by an analyst familiar with manufacturing processes and energy use. Major errors, including omissions and misreporting by orders of magnitude, were corrected. No editing procedure is capable of identifying all measurement errors, however, and some small

errors will remain. To the extent that these errors are due to random, rather than systematic misjudgments, they are compensating in the aggregate totals presented in this report, and it is believed that there are few large systematic biases that result from them.

Errors of estimation could have resulted from the assumptions used to estimate the consumption of offsite-produced energy sources—the measure of consumption that was used to prepare the energy intensity ratios used in this report. The MECS estimate of offsite-produced energy consumption is a derived value that is dependent upon two basic assumptions. First, it is assumed that any energy produced onsite is disposed of as it is produced. A corollary of that assumption is that any energy source that was produced offsite and consumed onsite was acquired only if there was not sufficient onsite production to meet the establishment's needs for that energy source. Second, it was assumed that the priority use of onsite production is first as an input or feedstock and then as a fuel. These assumptions are believed to reflect the energy-use patterns of the vast majority of manufacturing establishments, but not all.

The estimates of the consumption of offsite-produced energy sources could be biased if these assumptions are in error. For example, the assumption that energy produced onsite is consumed as a feedstock before any is consumed as a fuel could result in consistently underestimating the consumption of offsite-produced feedstocks and overestimating the consumption of offsite-produced fuels. If this were the case, the energy intensity ratios would also be overestimated.

The purpose of this report, however, is to examine the *change* in energy intensity ratios from one period to another. Since the methodology for calculating the derived values is applied in a consistent manner from one cycle of the MECS to another, it follows that any bias due to errors of estimation (faulty assumptions) would be present to approximately the same degree in both cycles; that is, the bias would be persistent over time. Because the primary interest is intensity change rather than intensity as such, persistent bias eliminates itself. Therefore, bias in the changes in energy intensity due to errors of estimation is believed to be minimal.

Finally, several potential sources of nonsampling error and bias appear to result from errors of nonobservation. As described in Appendix A, the 1988 MECS consumption estimators were adjusted for nonresponse. In addition, an adjustment was made to extend the MECS coverage to the entire manufacturing universe. Both of these adjustment procedures involved a ratio adjustment of the weighted data for respondents, and both primarily affected the contribution of relatively small establishments. The coverage adjustment was designed to include the contribution of establishments with fewer than 5 employees, or those with less than 20 employees having small values of shipments (i.e., the establishments that were excused from filing a CM report). Similarly, the nonresponse adjustment included primarily the contribution of small establishments since they tended to have the highest nonresponse rates to the MECS. Clearly, had these adjustments not been undertaken, the MECS estimators produced from only the responding establishments would not have been representative of the target universe, and would have been biased. The adjustments were an attempt to mitigate the effects of such a bias.

Implicit in these adjustment procedures is the assumption that the nonrepresented establishments (i.e., the nonresponding sample establishments and the excluded establishments) share the same energy consumption and product shipment patterns relative to their size as do their responding, mostly larger counterparts. The adjusted MECS consumption estimators will be unbiased if the consumption patterns are identical, and biased to the extent that the consumption patterns differ.

As shown in Equation (7) of Appendix A, neither the nonresponse nor the coverage adjustments have any effect on the intensity ratio within an industry group. Therefore, the intensity ratio for an industry group for any given year reflects the bias that resulted from estimates produced from the responding sample establishments only. However, nonresponding and excluded establishments are historically stable from one cycle of the MECS to another. Thus, the direction and magnitude of bias due to errors of nonobservation in the intensity measures for a particular industry group is likely to persist over time. As was pointed out above, persistent bias eliminates itself. Therefore, bias in the changes of energy intensity due to errors of nonobservation is also believed to be minimal.

Appendix C

MECS Coverage Related to EIA Supply Surveys

Appendix C

MECS Coverage Related to EIA Supply Surveys

The estimates of energy intensity are based on the MECS measure of the consumption of offsite-produced energy. The MECS also collects information to estimate total primary consumption—a measure of the total requirement for energy sources, whether or not they are used for their energy content. The MECS also presents estimates of total input energy. That measure represents a final-use accounting of energy used for its heat content. The comparison of consumption estimates presented in this appendix is on the basis of total primary consumption.

In addition to the MECS, the EIA conducts a number of supply surveys. These surveys are directed to the suppliers and marketers of specific energy sources. They measure the quantities of specific energy sources produced and/or supplied to the market. The results of these surveys are published by EIA in several energy-specific publications and in the *Monthly Energy Review* (MER). There are important differences between the supply surveys and the MECS. These differences need to be taken into account in any analysis that uses both data sources.

In order to fully appreciate the differences between the MECS and the EIA supply surveys,³³ it is necessary to compare the MECS' measures of consumption to the supply surveys. Table C1 presents these estimates.

Table C1. Comparison of EIA Energy Consumption Estimates, 1988

Type of Energy	Manufacturing Only		Total Industrial Sector ^a		
	MECS	Quarterly Coal Report	Monthly Energy Review ^b	Electric Power Annual	Natural Gas Annual
Electricity (billion kilowatthours)	703	--	896	896	--
Natural Gas (billion cubic feet)	5,695	--	7,479	--	6,383
Coal (thousand short tons)	97,582	69,546	118,162	--	--
Petroleum Products (thousand barrels per day)	1,112	--	4,381	--	--

^aThe industrial sector includes manufacturing, construction, mining, agriculture, and fishing and forestry.

^bThe consumption estimates presented in the *Monthly Energy Review* for the industrial sector are presented in British thermal units. These estimates have been converted to physical units for comparative purposes only.

Source: Energy Information Administration.

A major difference between the estimates for "Manufacturing Only" and the "Total Industrial Sector" in Table C1 is coverage. The manufacturing sector (SIC 20 through 39) includes establishments engaged in manufacturing operations, while the total industrial sector includes manufacturing as well as construction, mining, agriculture, and fishing and forestry (SIC 01 through 39). In addition, there are also differences in the respondents to the surveys. The unit of data collection in the MECS is the manufacturing establishment and the estimates represent energy consumption by manufacturing establishments. The unit of data collection for the industrial sector surveys is an energy supplier—for example, a utility. The estimates represent *deliveries to customers*, which may not be the same as *consumption by establishments*. Moreover, the designation of a customer's account by an energy supplier is frequently based on the rate class to which a customer belongs rather than direct knowledge of a customer's type of operations. Therefore, it is likely that some "industrial" customers are, in fact, classified as "commercial," and

³³For further discussion of the discrepancy in supply and consumption data, see Energy Information Administration, *Energy Consumption by End-Use Sector: A Comparison of Measures by Consumption and Supply Surveys*, DOE/EIA-0533 (Washington, DC, April 6, 1990).

visa versa, depending on their rate class. In addition, there are other differences that are specific to individual energy sources.

Electricity. The estimates of electricity from the MECS³⁴ represent "net electricity," defined as the sum of purchases, transfers in, and generation from noncombustible renewable resources, minus the quantities sold and transferred out. Net electricity does not include electricity inputs from the onsite cogeneration or generation of electricity from combustible fuels. The estimates of electricity appearing in the MER³⁵ are taken directly from the *Electric Power Annual*³⁶. This estimate represents sales by electric utilities to industrial customers. Thus, in addition to the major differences outlined above, the estimates differ in the definition of electricity.

Natural Gas. The estimates of natural gas from the MECS represent consumption as a fuel and a raw material input by manufacturers. The estimates appearing in the MER represent sales to customers in the industrial sector and would also includes natural gas consumed as a fuel and raw material input. The MER estimates are taken from the *Natural Gas Annual* and represent the sum lease and plant fuel consumption and deliveries to industrial customers.³⁷ Lease and plant fuel is consumed primarily at natural gas extraction sites, which are excluded from the MECS because they are classified as mining establishments.

Coal. There are numerous differences between the estimates of coal consumption as reported by the MECS and the *Quarterly Coal Report*. The estimates of coal consumption at manufacturing plants in the *Quarterly Coal Report*³⁸ are the only non-MECS estimates that are based on a survey of manufacturing establishments. Therefore, the difference between the MECS estimates and the estimates in the *Quarterly Coal Report* cannot be attributed to sectoral coverage or to the collection of delivery data rather than consumption data. There are, however, other differences between the two series. The MECS estimates include the coal consumed as a raw material input at coke plants. Coking coal is excluded from the manufacturing plant estimates in Table 30 of the *Quarterly Coal Report* and shown separately in Table 23 of that report. The sum of these two *Quarterly Coal Report* estimates is included as the industrial sector estimate in the MER. Moreover, the coal consumed at coal gasification projects in included in the manufacturing plant estimates appearing in Table 30 of the *Quarterly Coal Report*. These estimates are excluded from the MECS because such plants would be classified in the mining sector. Finally, the estimates for manufacturing plants appearing in Table 30 of the *Quarterly Coal Report* include the coal consumed at electric generating facilities owned by manufacturing plants, but not located on a manufacturing establishment site. These establishments are excluded from the MECS because, according to the *Standard Industrial Classification Manual*, such operations are not classified as manufacturing, but as "electrical services" (SIC 4911).³⁹

Petroleum Products. There are major differences between the MER estimates of total petroleum product and the MECS estimates. The MER estimate of petroleum products includes *all* of the petroleum products consumed by the industrial sector—aviation gasoline, asphalt, distillate fuel oil (including diesel fuel), jet fuel, kerosene, LPG, lubricants, motor gasoline, petroleum coke, and residual fuel oil. The MECS estimates shown in Table C1 include only distillate and residual fuel oil, and LPG.

³⁴Energy Information Administration, *Manufacturing Energy Consumption Survey, Consumption of Energy 1988*, DOE/EIA-0512(88) (Washington, DC, May 28, 1991), Table 1.

³⁵Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0035(91/05) (Washington, DC, May 1991), Table 2.4.

³⁶Energy Information Administration, *Electric Power Annual 1988*, DOE/EIA-0348(88) (Washington, DC, December 1989), Table 19.

³⁷Energy Information Administration, *Natural Gas Annual 1988, Volume 1*, DOE/EIA-0131(88)/1 (Washington, DC, October 1989), Tables 16 and 17.

³⁸Energy Information Administration, *Quarterly Coal Report, October - December 1989*, DOE/EIA-0121(89/4Q) (Washington, DC, May 1990), Table 30.

³⁹A special analysis was undertaken to determine which MECS manufacturing establishments received electricity from company-owned, offsite generation facilities. These identified generating facilities were then matched to the respondents to "Quarterly Coal Report—Manufacturing Plants," Form EIA-3. The coal consumed by these identified generating facilities accounted for much of the difference between the MECS estimates and those appearing in the *Quarterly Coal Report*. This analysis provided additional evidence that the separate estimates are, indeed, correct, given the populations that the respective surveys are intended to cover. Specific results of this analysis cannot be published because of the confidentiality provisions under which the MECS was conducted.

Fuels Consumed at Refineries. In addition to estimates of the primary consumption of energy, the MECS publishes estimates of total inputs of energy for the production of heat and power.⁴⁰ These estimates are available for specific manufacturing industries including "petroleum refining," SIC 2911. Estimates of "refinery fuel use" are also published in the *Petroleum Supply Annual*.⁴¹ The MECS estimates for the fuel consumption by the petroleum refining industry are uniformly higher than the estimates appearing in the *Petroleum Supply Annual*. These differences are due to the fact that the estimates in the *Petroleum Supply Annual* are prepared from the "Annual Refinery Report," Form EIA-820, which collects data for petroleum processing operations (including refiners and blenders) only. The MECS data, on the other hand, cover the entire establishment site including any co-located petrochemical operations, which would be excluded from the EIA-820.

⁴⁰Energy Information Administration, *Manufacturing Energy Consumption Survey: Consumption of Energy 1988*, Table 3.

⁴¹Energy Information Administration, *Petroleum Supply Annual 1988, Volume 1*, DOE/EIA-0340(88)/1 (Washington, DC, May 1989), Table

Appendix D

Descriptions of Industry Groups and Selected Industries

Appendix D

Descriptions of Major Industrial Groups and Selected Industries

This appendix contains descriptions of industrial groups and selected industries taken from the *Standard Industrial Classification Manual, 1987* (SIC).⁴⁰ This appendix includes descriptions of the 30 groups that comprise the strata of the Manufacturing Energy Consumption Survey. These are the 20 major industrial groups (2-digit SIC) and the 10 major energy-consuming industries (4-digit SIC). The Standard Industrial Classification system is described in Appendix A.

SIC 20—Food and Kindred Products: This major group includes establishments manufacturing foods and beverages for human consumption and certain related products such as manufactured ice, chewing gum, vegetable and animal fats and oils, and prepared feeds for animals and fowls.

SIC 21—Tobacco Products: This major group includes establishments engaged in manufacturing cigarettes, cigars, smoking and chewing tobacco, snuff, and reconstituted tobacco and in stemming and redrying tobacco.

SIC 22—Textile Mill Products: This major group includes establishments engaged in performing any of the following operations: (1) preparation of fiber and subsequent manufacturing of yarn, thread, braids, twine, and cordage; (2) manufacturing broadwoven fabrics, narrow woven fabrics, knit fabrics, and carpets and rugs from yarn; (3) dyeing and finishing fiber, yarn, fabrics, and knit apparel; (4) coating, waterproofing, or otherwise treating fabrics; (5) the integrated manufacture of knit apparel and other finished articles from yarn; and (6) the manufacture of felt goods, lace goods, nonwoven fabrics, and miscellaneous textiles.

SIC 23—Apparel and Other Textile Products: This major group, known as the cutting-up and needle trades, includes establishments producing clothing and fabricating products by cutting and sewing purchased woven or knit textile fabrics and related materials, such as leather, rubberized fabrics, plastics, and furs.

SIC 24—Lumber and Wood Products: This major group includes establishments engaged in cutting timber and pulpwood; merchant sawmills, lath mills, shingle mills, cooperage stock mills, planing mills, and plywood and veneer mills engaged in producing lumber and wood basic materials; and establishments engaged in manufacturing finished articles made entirely or mainly of wood or related materials.

SIC 25—Furniture and Fixtures: This major group includes establishments engaged in manufacturing household, office, public building, and restaurant furniture; and office and store fixtures.

SIC 26—Paper and Allied Products: This major group includes establishments primarily engaged in the manufacture of pulps from wood and other cellulose fibers, and from rags; the manufacture of paper and paper board; and the manufacture of paper and paperboard into converted products, such as paper coated off the paper machine, paper bags, paper boxes, and envelopes.

SIC 2621—Paper Mills: Establishments primarily engaged in manufacturing paper from wood pulp and other fiber pulp, and which may also manufacture converted paper products.

SIC 2631—Paperboard Mills: Establishments primarily engaged in manufacturing paperboard, including paperboard coated on the paperboard machine, from wood pulp and other fiber pulp.

⁴⁰Executive Office of the President, Office of Management and Budget, *Standard Industrial Classification Manual, 1987*, pp. 67-263.

SIC 27—Printing and Publishing: This major group includes establishments engaged in printing by one or more common processes, such as letterpress, lithography (including offset), gravure, or screen; and those establishments which perform services for the printing trade, such as bookbinding and platemaking.

SIC 28—Chemicals and Allied Products: This major group includes establishments producing basic chemicals, and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products to be used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

SIC 2819—Industrial Inorganic Chemicals, Not Elsewhere Classified: Establishments primarily engaged in manufacturing industrial organic chemicals, excluding alkalies and chlorine, industrial gases, and inorganic pigments.

SIC 2821—Plastics Materials and Resins: Establishments primarily engaged in manufacturing synthetic resins, plastics materials, and nonvulcanizable elastomers.

SIC 2869—Industrial Organic Chemicals, Not Elsewhere Classified: Establishments primarily engaged in manufacturing industrial organic chemicals, excluding gum and wood chemicals, and cyclic organic crudes and intermediates, and organic dyes and pigments.

SIC 2873—Nitrogenous Fertilizers: Establishments primarily engaged in manufacturing nitrogenous fertilizer materials or mixed fertilizers from nitrogenous materials produced in the same establishment.

SIC 29—Petroleum Refining and Related Industries: This major group includes establishments primarily engaged in petroleum refining, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials.

SIC 2911—Petroleum Refining: Establishments primarily engaged in producing gasoline, kerosene, distillate fuel oils, residual fuel oils, and lubricants, through fractionation or straight distillation of crude oil, redistillation of unfinished petroleum derivatives, cracking or other processes.

SIC 30—Rubber and Miscellaneous Plastics Products: This major group includes establishments manufacturing products, not elsewhere classified, from plastics, resins, and from natural, synthetic, or reclaimed rubber, gutta percha, balata, or gutta siak.

SIC 31—Leather and Leather Products: This major group includes establishments engaged in tanning, currying, and finishing hides and skins, leather converters, and establishments manufacturing finished leather and artificial leather products and some similar products made of other materials.

SIC 32—Stone, Clay, Glass, and Concrete Products: This major group includes establishments manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, cut stone, abrasive and asbestos products, and other products from materials taken principally from the earth in the form of stone, clay, and sand.

SIC 3241—Cement, Hydraulic: Establishments primarily engaged in manufacturing hydraulic cement, including portland, natural, masonry, and pozzolana cements.

SIC 33—Primary Metal Industries: This major group includes establishments engaged in smelting and refining ferrous and nonferrous metals from ore, pig, or scrap; in rolling, drawing, and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable.

SIC 3312—Steel Works, Blast Furnaces (Including Coke Ovens), and Rolling Mills: Establishments primarily engaged in manufacturing hot metal, pig iron, and silvery pig iron from iron ore and iron and steel scrap;

converting pig iron, scrap iron, and scrap steel into steel; and in hot-rolling iron and steel into basic shapes, such as plates, sheets, strips, rods, bars, and tubing.

SIC 3334—Primary Production of Aluminum: Establishments primarily engaged in producing aluminum from alumina and in refining aluminum by any process.

SIC 34—Fabricated Metal Products: This major group includes establishments engaged in fabricating ferrous and nonferrous metal products such as metal cans, tinware, handtools, cutlery, general hardware, nonelectric heating apparatus, fabricated structural metal products, metal forgings, metal stampings, ordnance (except vehicles and guided missiles), and a variety of metal and wire products, not elsewhere classified.

SIC 35—Industrial Machinery and Equipment: This major group includes establishments engaged in manufacturing industrial and commercial machinery and equipment and computers.

SIC 36—Electronic and Other Electric Equipment: This major group includes establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and utilization of electrical energy.

SIC 37—Transportation Equipment: This major group includes establishments engaged in manufacturing equipment for transportation of passengers and cargo by land, air, and water.

SIC 38—Instruments and Related Products: This major group includes establishments engaged in manufacturing instruments (including professional and scientific) for measuring, testing, analyzing, and controlling, and their associated sensors and accessories; optical instruments and lenses; surveying and drafting instruments; hydrological, hydrographic, meteorological, and geophysical equipment; search, detection, navigation, and guidance systems and equipment; surgical, medical, and dental instruments, equipment and supplies; ophthalmic goods; photographic equipment and supplies; and watches and clocks.

SIC 39—Miscellaneous Manufacturing Industries: This major group includes establishments primarily engaged in manufacturing products not classified in any other major group.

Appendix E

Related EIA Publications on Energy Consumption

Appendix E

Related EIA Publications on Energy Consumption

These publications are available from the National Energy Information Center or the Superintendent of Documents. See the inside cover of this report on how to obtain copies of these publications. Please note that the prices quoted here are subject to change.

In addition to the reports listed below, public use data tapes and data diskettes for the residential, residential transportation and commercial sectors are available from the National Technical Information Service (NTIS). To obtain information on how to order the tapes/diskettes, you may call NTIS at 703/487-4807, FAX number 703/321-8547. Data diskettes can also be obtained from GPO. For ordering information call 220/275-0186.

Industrial Sector

Manufacturing Energy Consumption Survey: Manufacturing Fuel Switching Capability 1988, September 1991, DOE/EIA-0515(88), GPO Stock No. 061-003-00720-1, \$9.00.

Manufacturing Energy Consumption Survey: Consumption of Energy, 1988; May 1991, DOE/EIA 0512(88), GPO Stock No. 061-003-00703-8, \$11.00.

Manufacturing Energy Consumption Survey: Energy Efficiency in Manufacturing, 1985; January 1990, DOE/EIA-0516(85), GPO Stock No. 061-00300650-7, \$4.25.

Manufacturing Energy Consumption Survey: Fuel Switching Capability, 1985; December 1988, DOE/EIA-0515(85), GPO Stock No. 061-00300601-9, \$3.50.

Manufacturing Energy Consumption Survey: Methodological Report, 1985; November 1988, DOE/EIA-0514(85), GPO Stock No. 061-00300595-1, \$6.00.

Manufacturing Energy Consumption Survey: Consumption of Energy, 1985; November 1988, DOE/EIA-0512(85), GPO Stock No. 061-00300594-2, \$6.00.

"Manufacturing Sector Energy Consumption 1985 Provisional Estimates," Monthly Energy Review, January 1987, DOE/EIA-0035(87/01), pp. vii-x.

Report on the 1980 Manufacturing Industries' Energy Consumption Study and Survey of Large Combustors; February 1983, DOE/EIA-0358, GPO Stock No. 061-003-00293-5, \$5.00.

Industrial Energy Consumption, "Survey of Large Combustors: Report on Alternate Fuel-Burning Capabilities of Large Boilers in 1979"; February 1982, DOE/EIA-0304, GPO Stock No. 061-003-0233-1, \$2.50.

Methodological Report of the 1980 Manufacturing Industries Survey of Large Combustors (EIA-463); March 1982, DOE/EIA-0306 (no GPO Stock No.).

Commercial Sector

Note: The name of the Nonresidential Buildings Energy Consumption Survey was changed to the Commercial Buildings Energy Consumption Survey, beginning with the 1989 survey. The survey name was also dropped from the report title.

Characteristics of Buildings

Commercial Buildings Characteristics 1989; May 1991, DOE/EIA-0246(89), GPO Stock No. 061-003-00699-0, \$18.00.

Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings, 1986; September 1988, DOE/EIA-0246(86), GPO Stock No. 061-003-00580-2, \$16.00.

Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings, 1983; July 1985, DOE/EIA-0246(83), GPO Stock No. 061-003-00439-3, \$7.50.

Nonresidential Buildings Energy Consumption Survey: Characteristics of Commercial Buildings, 1983; A Supplemental Reference, DOE/EIA-M008, \$22.95. Available from the NTIS, Order No. DE-85015581.

Nonresidential Buildings Energy Consumption Survey: Fuel Characteristics and Conservation Practices; June 1981, DOE/EIA-0278, GPO Stock No. 061-003-00200-5, \$9.00.

Nonresidential Buildings Energy Consumption Survey: Building Characteristics; March 1981, DOE/EIA-0246, GPO Stock No. 061-003-00171-8, \$6.50.

Consumption and Expenditures

Nonresidential Buildings Energy Consumption Survey: Commercial Buildings Consumption and Expenditures 1986; May 1989, DOE/EIA-0318(86), GPO Stock No. 061-003-00613-2, \$19.00.

Nonresidential Buildings Energy Consumption Survey: Commercial Buildings, Consumption and Expenditures 1983; September 1986, DOE/EIA-0318(83), GPO Stock No. 061-003-00496-2, \$13.00.

Nonresidential Buildings Energy Consumption Survey: 1979 Consumption and Expenditures, Part 1: Natural Gas and Electricity; March 1983, DOE/EIA-0318/1, GPO Stock No. 061-003-00298-6, \$9.50.

Nonresidential Buildings Energy Consumption Survey: 1979 Consumption and Expenditures, Part 2: Steam, Coal, Fuel Oil, LPG, and Total Fuels; December 1983, DOE/EIA-0318(79)/2, GPO Stock No. 061-003-00366-4, \$6.00.

Residential Transportation Sector

Note: The survey name was dropped from the beginning of the report title starting with the 1988 data report, and the report title changed to "Household Vehicles Energy Consumption 1988."

Household Vehicles Energy Consumption 1988; February 1990, DOE/EIA-0464(88), GPO Stock No. 061-003-00652-3, \$11.00.

Residential Transportation Energy Consumption Survey: Consumption Patterns of Household Vehicles 1985; April 1987, DOE/EIA-0464(85), GPO Stock No. 061-003-00521-7, \$8.50.

Residential Transportation Energy Consumption Survey: Consumption Patterns of Household Vehi-

cles, 1983; January 1985, DOE/EIA-0464(83), GPO Stock No. 061-003-00420-2, \$4.50.

Residential Energy Consumption Survey: Consumption Patterns of Household Vehicles, Supplement: January 1981 to September 1981; February 1983, DOE/EIA-0328, GPO Stock No. 061-003-00297-8, \$4.75.

Residential Energy Consumption Survey: Consumption Patterns of Household Vehicles, June 1979 to December 1980; April 1982, DOE/EIA-0319 (no GPO Stock No.).

Residential Sector

Housing Characteristics

Note: The survey name was dropped from the beginning of the report title starting with the 1987 data reports.

Housing Characteristics 1987; May 1989, DOE/EIA-0314(87), GPO Stock No. 061-003-00619-1, \$13.00.

Residential Energy Consumption Survey: Housing Characteristics 1984; October 1986, DOE/EIA-0314(84), GPO Stock No. 061-003-00499-7, \$12.00.

Residential Energy Consumption Survey: Housing Characteristics, 1982; August 1984, DOE/EIA-0314(82), GPO Stock No. 061-003-00393-1, \$7.00.

Residential Energy Consumption Survey Housing Characteristics, 1981; August 1983, DOE/EIA-0314(81), GPO Stock No. 061-003-00330-3, \$6.50.

Residential Energy Consumption Survey: Housing Characteristics, 1980; June 1982, DOE/EIA-0314, GPO Stock No. 061-003-00256-1, \$11.00.

Residential Energy Consumption Survey: Characteristics of the Housing Stock and Households, 1978; February 1980, DOE/EIA-0207/2, GPO Stock No. 061-003-00093-2, \$4.25.

Residential Energy Consumption Survey: Conservation; February 1980, DOE/EIA-0207/3, GPO Stock No. 061003-00087-8, \$6.00.

Preliminary Conservation Tables from the National Interim Energy Consumption Survey; August 1979, DOE/EIA-0193/P (no GPO Stock No.).

Characteristics of the Housing Stock and Households: Preliminary Findings from the National Interim Energy Consumption Survey; October 1979, DOE/EIA-0199/P (no GPO Stock No. available).

Consumption and Expenditures

Note: The survey name was dropped from the beginning of the report title starting with the 1987 data reports. The titles were changed to *Household Energy Consumption and Expenditures 1987, Part 1: National and Part 2: Regional*.

Household Energy Consumption and Expenditures 1987, Part 1: National Data; October 1989, DOE/EIA-0321/1(87), GPO Stock No. 061-003-00635-3, \$15.00. Note: Energy end-use data are included in this report.

Household Energy Consumption and Expenditures 1987, Part 2: Regional Data; DOE/EIA-0321/2(87) (no GPO Stock No available), \$16.00.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1984 Through March 1985, Part 1: National Data; March 1987, DOE/EIA-0321/1(84), GPO Stock No. 061-003-00519-5, \$9.50.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1984 Through March 1985, Part 2: Regional Data; May 1987, DOE/EIA-0321/2(84), GPO Stock No. 061-003-00528-4, \$17.00. Note: Energy end-use data are included in this report.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1982 Through March 1983, Part 1: National Data; November 1984, DOE/EIA-0321/1(82), GPO Stock No. 061-003-00411-3, \$7.00.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1982 Through March 1983, Part 2: Regional Data; December 1984, DOE/EIA-0321/2(82), GPO Stock No. 061-003-00414-8, \$9.50.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1981 Through March 1982, Part 1: National Data; September 1983, DOE/EIA-0321/1(81), GPO Stock No. 061-003-00340-1, \$6.00.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1981 Through March 1982, Part 2: Regional Data; October 1983, DOE/EIA-0321/2(81), GPO Stock No. 061-003-00357-5, \$8.00.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1980 Through March 1981, Part 1: National Data; September 1982, DOE/EIA-0321/1(80), GPO Stock No. 061-003-00278-1, \$7.50.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1980 Through March 1981, Part 2: Regional Data; June 1983, DOE/EIA-0321/2(80), GPO Stock No. 061-003-00319-2, \$7.00.

Residential Energy Consumption Survey: 1979-1980 Consumption and Expenditures, Part 1: National Data (Including Conservation); April 1981, DOE/EIA-0262/1, GPO Stock No. 061-00300191-2, \$6.50.

Residential Energy Consumption Survey: 1979-1980 Consumption and Expenditures, Part II: Regional Data; May 1981, DOE/EIA-0262/2, GPO Stock No. 061-003-00189-1, \$8.50.

Residential Energy Consumption Survey: Consumption and Expenditures, April 1978 Through March 1979; July 1980, DOE/EIA-0207/5, GPO Stock No. 061-003-00131-9, \$7.50.

Single-Family Households: Fuel Oil Inventories and Expenditures: National Interim Energy Consumption Survey; December 1979, DOE/EIA-0207/1, GPO Stock No. 061-003-00075-4, \$3.50.

Other Publications on the Residential Sector

"End-Use Consumption of Residential Energy" (Article), pp. vii-xiv, *Monthly Energy Review*, July 1987, DOE/EIA-0035(87/07).

Residential Energy Consumption Survey: Trends in Consumption and Expenditures 1978-1984 June 1987, DOE/EIA-0482, GPO Stock No. 061-003-00535-7, \$12.00.

Residential Conservation Measures; July 1986, SR/EEUD/86/01 (no GPO Stock No.).

An Economic Evaluation of Energy Conservation and Renewable Energy Tax Credits; October 1985, Service Report (no GPO Stock No.).

Residential Energy Consumption and Expenditures by End Use for 1978, 1980, and 1981; December 1984, DOE/EIA-0458, GPO Stock No. 061-003-00415-6, \$4.50.

Weatherization Program Evaluation, SR-EEUD-84-1; August 1984 (available from the Office of the Assistant Secretary for Conservation and Renewable Energy, Department of Energy).

Residential Energy Consumption Survey: Regression Analysis of Energy Consumption by End Use; October 1983, DOE/EIA-0431, GPO Stock No. 061-003-00347-8, \$5.00.

National Interim Energy Consumption Survey: Exploring the Variability In Energy Consumption; July 1981, DOE/EIA-0272, GPO Stock No. 061-003-00205-6, \$5.00.

National Interim Energy Consumption Survey: Exploring the Variability in Energy Consumption--A Supplement; October 1981, DOE/EIA-0272/S, GPO Stock No. 061-003-00217-0, \$4.50.

Energy Use by U.S. Households; November 1980, DOE/EIA-0248 (brochure, no GPO Stock No.).

Cross-Sector

Energy Consumption by End-Use Sector: A Comparison of Measures by Consumption and Supply Surveys; April 6, 1990, DOE/EIA-0533 (no GPO Stock No. available), \$2.50.

Natural Gas: Use and Expenditures; April 1983, DOE/EIA-0382, GPO Stock No. 061-003-00307-9, \$5.50.

Public Use Tapes

Note: All tapes are available through the NTIS.

Residential and Residential Transportation Sectors

Residential Energy Consumption Survey: 1987 and Residential Transportation Energy Consumption Survey, 1988, Order No. PB90-501461, \$220.

Residential Energy Consumption Survey: 1984 and Residential Transportation Energy Consumption Survey, 1985; Order No. PB87-186540, \$220.

Residential Energy Consumption Survey: 1982 and Residential Transportation Energy Consumption Survey, 1983; Order No. PB85-221760, \$220.

Residential Energy Consumption Survey: Consumption and Expenditures, 1980-1981; Monthly Billing Data; Order No. PB84-166230, \$220.

Residential Energy Consumption Survey: Housing Characteristics, 1981; Consumption and Expenditures, 1981-1982; Monthly Billing Data; Order No. PB84-120476, \$220.

Residential Energy Consumption Survey: Housing Characteristics, Annualized Consumption and Expenditures, 1980-1981; Order No. PB83-199554, \$220.

Residential Energy Consumption Survey: Household Transportation Panel Monthly Gas Purchases and Vehicle and Household Characteristics, 6/79-9/81; Order No. PB84-162452, \$220.

Residential Energy Consumption Survey: Household Screener Survey, 1979-1980; Order No. PB82-114877, \$220.

Residential Energy Consumption Survey: Household Monthly Energy Consumption and Expenditures, 1978-1979; Order No. PB82-114901, \$220.

National Interim Energy Consumption Survey (Residential), 1978; Order No. PB81-108714, \$220.

Commercial Sector

Nonresidential Buildings Energy Consumption Survey: 1986 Data; Order No. PB90-500034, \$220.

Nonresidential Buildings Energy Consumption Survey: 1979 and 1983 Data; Order No. PB88-245162, \$220.

Public Use Diskettes

Note: Diskettes are available through the NTIS and GPO.

Residential Energy Consumption Survey 1987 Data, NTIS - ASCII format: Order No. PB-91-505115,

\$130, and dBASE format: Order No. PB-91-505107, \$130.

GPO - ASCII/dBASE format, order by title, \$45 for each set.

Nonresidential Buildings Energy Consumption Survey 1986 Data, ASCII format: Order No. PB91-506808, \$130.

Residential Transportation Energy Consumption Survey 1988 Data, NTIS - ASCII format: Order No. PB91- 507269, dBASE format: Order No. PB91-507277, \$50 each.

GPO - ASCII/dBASE format, order by title, \$15 for each set.

Commercial Buildings Consumption and Expenditures 1989; planned for early 1992.

Housing Characteristics 1990; planned for March 1992.

Household Energy Consumption and Expenditures 1990, Part 1: National Data; planned for September 1992.

Household Energy Consumption and Expenditures 1990, Part 2: Regional Data; planned for December 1992.

Household Vehicles Energy Consumption 1991; planned for December 1992.

Note: the Energy Information Administration also publishes the *State Energy Data Report Consumption Estimates* annually, DOE/EIA-0214.

Planned Publications

Manufacturing Energy Consumption Survey: Changes in Energy Consumption 1985 - 1988; planned for 1992.

Glossary

Anthracite: A hard, black, lustrous coal containing a high percentage of fixed carbon and a low percentage of volatile matter. It is often referred to as hard coal.

Barrel: A volumetric unit of measure equivalent to 42 U.S. gallons.

Biomass: Organic (animal waste), nonfossil plant material constituting an exploitable energy source.

Bituminous Coal: A soft coal (the most common solid fossil fuel), which is high in carbonaceous matter, with a volatility greater than anthracite.

Blast Furnace: A shaft furnace in which solid fuel is burned with an air blast to smelt ore in a continuous operation.

Blast Furnace Gas: The waste combustible gas generated in a blast furnace when iron ore is being reduced with coke to metallic iron. It is commonly used as a fuel within the steel works.

Breeze: The residue from the fine screenings of crushed coke.

British Thermal Unit (Btu): The amount of energy required to raise the temperature of one pound of water one degree Fahrenheit.

Butane (C_4H_{10}): A normally gaseous, paraffinic hydrocarbon extracted from natural gas or refinery gas streams. It includes isobutane (a branch-chain configuration) and normal butane (a straight-chain configuration). It is used primarily for blending into high-octane gasoline, for residential and commercial heating, and for industrial uses, especially the manufacture of chemicals and rubber.

Butylene (C_4H_8): A normally gaseous, olefinic hydrocarbon recovered from the refinery processes, and converted to alkylate, a high-octane gasoline blending component.

Byproduct: A secondary or additional product resulting from the feedstock use of energy or the processing of nonenergy materials. For example, the more common byproducts of coke ovens are coal gas,

tar, and a mixture of benzene, toluene, and xylenes (BTX).

Census Region: A geographic area defined by the Bureau of the Census, consisting of various States selected according to population size and physical location. The States are grouped into four regions:

1. Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.
2. South: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.
3. Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.
4. West: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Coal Coke: The strong, porous residue, consisting of carbon and mineral ash, which is formed when the volatile constituents of bituminous coal are driven off by heat in the absence of or with a limited supply of air. Coal coke is used primarily in blast furnaces.

Cogeneration: The production of electrical energy and another form of useful energy (such as heat or steam) through the sequential use of energy.

Coke Oven Gas: The mixture of permanent gases produced by the carbonization of coal in a coke oven at temperatures in excess of 1,000 degrees Celsius.

Consumption: The use of energy as a source of heat or power, or as an input to the manufacturing process.

Conversion Factor: A number which translates units of one system into corresponding values of another system. Conversion factors are used to translate physical units of measure for various energy sources into their Btu equivalents.

Crude Oil: A mixture of hydrocarbons that exists in a liquid state in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Crude oil is reported as liquid equivalents at the surface (excluding basic sediment and water), measured in terms of stock tank barrels of 42 U.S. gallons at atmospheric pressure, and corrected to 60 degrees Fahrenheit.

Distillate Fuel Oil: A general classification for light fuel oils distilled during the refining process. The classification includes products known as Nos. 1, 2, and 4 fuel oils; and Nos. 1, 2, and 4 diesel fuels. Distillate fuel oil is used primarily for space heating, on-and-off highway engine fuel, and electric power generation.

Energy: The capacity for doing work as measured in the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy).

Energy Source: A substance such as natural gas, coal, or electricity that supplies heat or power.

Establishment: As defined by the *1987 Standard Industrial Classification Manual*, "...an economic unit, generally at a single physical location, where business is conducted or where services or industrial operations are performed." (See **Manufacturing Establishment**.)

Ethane (C₂H₆): A colorless, odorless, gaseous hydrocarbon extracted from natural gas or refinery gas streams. Ethane is used primarily as a petrochemical feedstock for the production of chemicals and plastic materials.

Ethylene (C₂H₄): A colorless, flammable, gaseous olefinic hydrocarbon recovered from natural gas and petroleum. Ethylene is used primarily as a petrochemical feedstock for numerous chemical applications and the production of consumer goods.

Expenditures: Funds spent for energy purchased and paid for, or delivered to a manufacturer during a calendar year. For the purposes of the MECS, the expenditure dollar includes State and local taxes and delivery charges.

Fossil Fuel: Any naturally occurring organic fuel, such as coal crude oil, and natural gas.

Fuel: Any substance that can be burned to produce heat.

Fuel Use (of Energy): Use of energy in the production of heat, steam, power, or the generation of electricity.

Generation: The process of producing steam or electrical energy by transforming other forms of energy.

Geothermal Energy: Hot water or steam, extracted from reservoirs in the earth's crust, which is generally supplied to steam turbines that drive generators to produce electricity.

Hydroelectric Power: Electricity generated by a turbine driven by falling water.

Hydrogen (H₂): A colorless, odorless, highly flammable gaseous element; the lightest of all gases and the most abundant element in the universe.

Industrial Sector: A subdivision of U.S. economic activity defined by the Energy Information Administration to include manufacturing, construction, mining, agriculture, fishing, and forestry establishments.

Kilowatthour (kWh): A unit of work or energy, measured as 1,000 watts (1 kilowatt) of power expended for 1 hour. Once generated, one kWh is equivalent to 3,412 Btu.

Liquefied Petroleum Gases (LPG): Ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutane produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas plant liquids.

Lease Condensate: A natural gas liquid recovered from gas well gas (associated and nonassociated) in lease separators or field facilities. Lease condensate consists primarily of pentanes and heavier hydrocarbons. Volumes are reported in terms of barrels of 42 U.S. gallons, at atmospheric pressure, and corrected to 60 degrees Fahrenheit.

Lease Separator: A facility located at the surface for the purposes of (1) separating casinghead gas from produced crude oil and water at the temperature and pressure conditions of the separator; and (2) separating gas from that portion of associated gas and nonassociated gas which liquefies at temperature and pressure conditions of the separator.

Lignite: A brownish-black coal of low rank with a high percentage of inherent moisture and volatile matter content. It is also referred to as brown coal.

Manufacturing Establishment: An economic unit at a single physical location where mechanical or chemical transformation of materials or substances into new products are performed. These operations are generally conducted in facilities described as plants, factories, or mills, and characteristically use power-driven machines and materials-handling equipment. In addition, the assembly of components of manufactured products is considered manufacturing, as in the blending of materials such as lubricating oils, plastics, resins, or liquors. (See **Establishment**.)

Manufacturing Sector (Division): One of 10 fields of economic activity defined by the *Standard Industrial Classification Manual*. The manufacturing sector includes all establishments engaged in the mechanical or chemical transformation of materials or substances into new products. Other divisions of the U.S. economy are agriculture, forestry, fishing, hunting, and trapping; mining; construction; transportation, communications, electric, gas, and sanitary services; wholesale trade; retail trade; finance, insurance, and real estate; personal, business, professional, repair, recreation, and other services; and public administration. The establishments in the manufacturing sector constitute the universe for the MECS.

Motor Gasoline: A complex mixture of relatively volatile hydrocarbons, with or without small quantities of additives, obtained by blending appropriate refinery streams to form a fuel suitable for use in spark-ignition engines. Motor gasoline includes both leaded and unleaded grades of finished motor gasoline, blending components, and gasohol.

Natural Gas: A mixture of hydrocarbon compounds and small quantities of various nonhydrocarbons existing in the gaseous phase or in solution with oil in natural underground reservoirs at reservoir conditions. Natural gas may be subclassified as:

1. **Associated Gas:** Free natural gas, commonly known as gas-cap gas, which overlies and is in contact with crude oil in the reservoir.
2. **Dissolved Gas:** Natural gas which is in solution with crude oil in the reservoir at reservoir conditions.
3. **Nonassociated Gas:** Free natural gas not in contact with crude oil in the reservoir.

All natural gas volumes are reported in cubic feet at a pressure base of 14.73 psia, at 60 degrees Fahrenheit.

Nonfuel Use (of Energy): Use of energy as a feedstock or raw material input.

Petroleum Coke: A solid residue, high in carbon content and low in hydrogen, which is the final product of thermal decomposition in the condensation process in cracking crude oil. Petroleum coke can yield almost pure carbon or artificial graphite suitable for the production of carbon or graphite electrodes, structural graphite, motor brushes, dry cells, and similar products.

Petrochemical Feedstock: Chemical feedstocks derived from petroleum, and used principally for the manufacture of chemicals, synthetic rubber, and a variety of plastics.

Plant: Commonly used as a synonym for an establishment. However, the term can also be used to refer to a particular process within an establishment.

Propane (C_3H_8): A colorless, gaseous hydrocarbon extracted from natural gas or refinery gas streams. It is used primarily for residential and commercial heating and cooling, and also as a fuel for transportation. Industrial applications include use as a petrochemical feedstock.

Propylene (C_3H_6): A gaseous hydrocarbon recovered from refinery processes. Propylene is used primarily as a petrochemical feedstock.

Pulping Liquor (Black Liquor): The alkaline spent liquor removed from the digesters in the process of chemically pulping wood. After evaporation, the liquor is burned as a fuel in a recovery furnace that permits the recovery of certain basic chemicals.

Quadrillion Btu: Equivalent to 10^{15} Btu.

Refinery: A plant, device, or process which heats crude oil so that it separates into chemical components, which are then distilled off as more usable substances.

Relative Standard Error (RSE): A percentage measure of the precision of a survey statistic. The RSE is defined as the standard error of a survey estimate divided by the survey estimate and multiplied by 100. The standard error is the square root of the variance.

Residual Fuel Oil: The general classification for the heavier oils that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. The classification includes No. 5 (light and heavy), No. 6 (including heavy-grade, so called Bunker C oil), and Navy Special fuel oil.

Roundwood: Wood cut specifically for use as a fuel.

Short Ton: A unit of weight equal to 2,000 pounds.

Solar Energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Standard Industrial Classification (SIC): A classification scheme developed by the Office of Management and Budget, which categorizes establishments into groups with similar economic activities.

Still Gas (Refinery Gas): Any form or mixture of gas produced in refineries by distillation, cracking, reforming, and other processes, the principal constituents of which are methane, hydrogen, ethane, ethylene, propane, propylene, butanes, butylene, etc. Still gas is used as a petrochemical feedstock and as a fuel in refineries.

Storage Capacity: For the purposes of the MECS, storage capacity includes any volumetric capacity (including tank tops and tank bottoms) that is on the establishment site even if it is dedicated or leased for the storage of an energy source by other establishments.

Subbituminous Coal: A dull, black coal of intermediate rank between lignite and bituminous coal. Subbituminous coal, like bituminous coal, is used as a fuel.

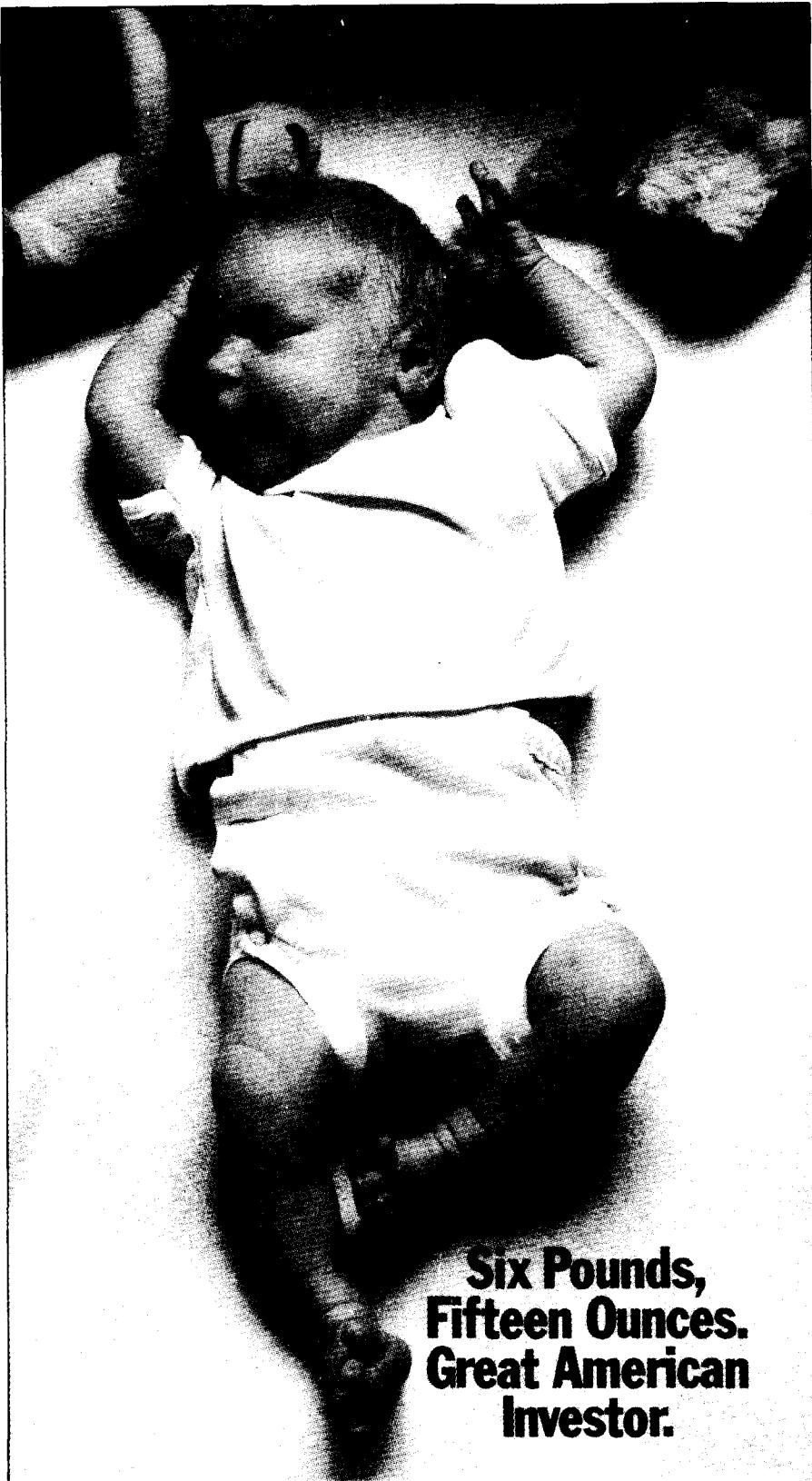
Turbine: A machine for generating rotary mechanical power from an energy stream (such as water, steam, or hot gas). Turbines convert kinetic energy to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

Waste Materials: Otherwise discarded combustible materials which, when burned, produce energy for such purposes as space heating and electric power generation. The size of the waste may be reduced by shredders, grinders, or hammermills. Noncombustible materials, if any, may be removed. The waste may be dried and then burned, either alone or in combination with fossil fuels.

Waste Oils and Tar: Petroleum-based materials that are worthless for any purpose other than fuel use.

Wind Energy: Energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators. Wind pushes against sails, vanes, or blades radiating from a central rotating shaft.

Wood Waste: Wood byproducts used as a fuel. Included are limb wood, wood chips, bark, sawdust, forest residues, charcoal, and pulp waste.



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