Energy Use in Manufacturing: Reviewing the Results of the 1998 MECS

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ABSTRACT

The Manufacturing Energy Consumption Survey (MECS) is the Federal Government's only comprehensive survey of manufacturing energy consumption in the United States. Analysts and policymakers look to the MECS, now a quadrennial survey, for a snapshot of that part of the economy, both to verify other data sources and to examine the reasons behind observed trends. The authors first discuss the methodological considerations of the 1998 MECS and what has changed since 1994. Results point to smaller-than-expected total energy consumption, especially when examining measures of manufacturing output. The authors examine factors that may have lead to such a result. The authors examine energy efficiency, weather, and manufacturing structure as factors. They present strong evidence that a large part of the unexpected drop in consumption was a structural shift in manufacturing away from energy-intensive industries. The examination of MECS end-use estimates showed that weather did not appear to influence differences in energy consumption between 1994 and 1998.

Other results show an increase in electricity demand between 1994 and 1998 without a commensurate increase in electricity generation. That result may partly depend on the way the MECS measures establishment onsite generation.

In addition, updates on technology adoption and energy-management programs are highlighted. Participation in 1998 was compared to that of 1994. In general, the participation in most of the energy management activities increased. There is also increased usage in most general technologies. Usage of cogneration technologies has declined, which parallels the finding of flattened demand for cogenerated electricity.

Introduction

What Is the MECS

The Manufacturing Energy Consumption Survey (MECS) is the only Federal Government survey that collects data on energy consumption in the U.S. manufacturing sector. The MECS also collects data on prices, expenditures, utility and nonutility purchases, energy-management activities, and technologies in use. The 1998 survey is the fifth such survey conducted, the prior year being 1994. The MECS employs a scientifically designed sample of the manufacturing population. The unit of measurement is the establishment as defined by boundaries established by the Bureau of the Census. The Census Bureau also supplies the list of establishments from which the sample is drawn. By having the Bureau

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

conduct and process the survey, the Energy Information Administration (EIA) is able to furnish respondents strict confidentiality assurances.

What's Different

Due to budgetary reductions, the sample size for the MECS has decreased for the first time, changing from approximately 22,000 to 18,000. This decrease necessitated a reduction in the amount of geographical detail that that could be tabulated. In 1994, the MECS had detail at the level of nine Census Divisions for many of its estimates, but for 1998, the extent of geographic detail was scaled back to four Census Regions.

Since 1997, the Federal Government has required agencies to shift their classification of industries to the North American Industry Classification System (NAICS) from the Standard Industrial Classification (SIC) system. The purposes of the switch were to recognize the new industries brought about by technological advances, emphasize process similarity rather than product, better delineate the more than 150 new service industries, and provide data comparability with the other countries of North America.

The number of industries shown separately for the MECS in 1998 is 57 NAICS 3-, 4-, and 6-digit types. In 1994, the number of industries was 72 2-, 3-, and 4-digit SIC industry groups and industries. This decrease was again necessitated partly by a decrease in the sample. Because the MECS has switched from SIC to NAICS, the 1998 MECS has bridge tables that show manufacturing consumption on an SIC basis to allow national comparisons with the NAICS basis. To accommodate an SIC basis for 1998 data, some establishments were sampled that were no longer considered part of the manufacturing base under NAICS.

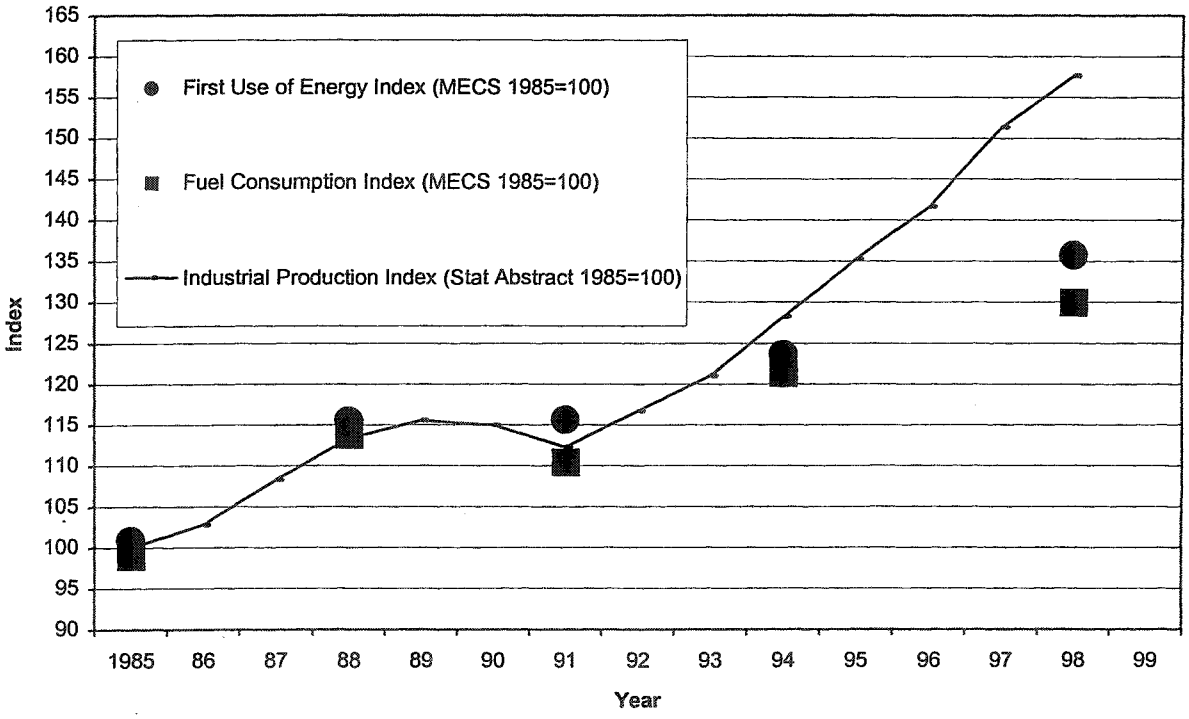
EIA must constantly update the MECS in the face of changing requirements for data brought about by a very fluid energy economy. Changes in industry structure led to modifications in how the MECS collects data on energy-management activities. Due to electric industry restructuring, it is likely that utility-sponsored demand-side management programs either would be phased out or else would no longer be sponsored by entities that could be described strictly as "utilities." For that reason, we modified the section on energy-management activities to collect only whether an establishment had undertaken a program or activity. We no longer asked about utility or other sponsorship. However, we have now added a question for each activity about how much of the cost of the program the establishment itself incurred. Additionally, we have modified the list of activities to include a question on whether there is an onsite energy manager.

Results of the 1998 MECS

Changes in Energy Consumption

First Use of Energy is the MECS measure of total energy consumption. It is the unduplicated net total of all energy sources used as a fuel and nonfuel (e.g., feedstock). The total First Use of Energy, 23,796 trillion Btu, can be said to be the total manufacturing energy consumption in 1998. First Use has risen 9.8 percent since 1994, the last year that the MECS was conducted, while Fuel Consumption has increased 7.1 percent during that time period.

Figure 1. Energy Consumption in U.S. Manufacturing Sector Compared to Industrial Production Index, History since 1985

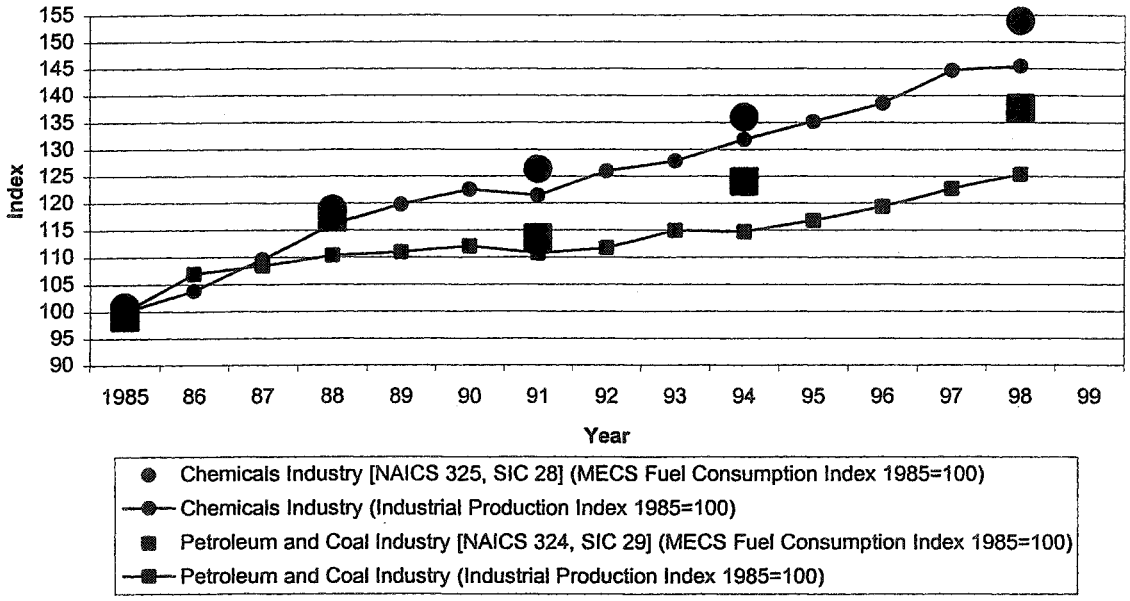


Manufacturing has shown tremendous growth since 1985, the first year that the MECS was conducted. Figure 1 shows the pattern of manufacturing production using industrial production indices from the Federal Reserve Board (Department of Commerce, 2000). Both First Use and Fuel Consumption appear to follow the production changes fairly well through 1994. However, by 1998, production had risen 23 percent but energy consumption had not kept pace.

There are many possible reasons for that deviation. The first is that manufacturing is getting more energy efficient—that is, consumes less energy for a unit of production. Manufacturers now have a greater motivation to become more energy efficient than perhaps they did during the late 1980's and early 1990's, when energy prices were stable or declining (EIA 2000). The perception of higher energy prices could cause manufacturers to make more efficiency improvements. A further motivation has been the possibility of enforced greenhouse gas compliance. The 1998 MECS has confirmed a previous report that industrial greenhouse gas emissions did not grow as fast as production, largely because of slow-growing energy consumption (EIA 1999).

As that report suggested, another possibility is the structural shift of manufacturing away from energy-intensive industries. Even though overall production has risen and consumption has not kept pace, one can use the MECS to look at the changes in individual industries to see whether they mirror the overall change. In fact, the two most energy-intensive groups, Chemicals and Petroleum & Coal Products, have fuel consumption that actually rose faster than production (see Figure 2).

Figure 2. Fuel Consumption Compared to Industrial Production Index for the 2 Most Energy-Intensive Manufacturers in U.S., History since 1985



A different set of production measures, constant-dollar value of shipments from the Bureau of Economic Analysis (BEA), confirms the overall size of the production increase of manufacturing from 1994 to 1998 of approximately 22 percent. We can compute ratios of energy consumption per dollar value of shipments, which we will denote as energy intensity, using MECS fuel consumption and BEA constant dollar value of shipments. By so doing, we obtain an observed 1994 value of 4.80 thousand Btu per dollar value of shipments and 4.22 thousand Btu per dollar for 1998. Thus, from 1994 to 1998 there was a drop in energy intensity of 12.2 percent. Part of the efficiency gains may be due to a shifting away from higher intensive industries into lower ones. Previous analyses have verified those types of shifts for earlier years (see for example, EIA 1998). We can rebase the 1998 energy intensity value to reflect the industry structure of 1994, by applying the 1994 BEA value of shipments ratios to each 1998 individual industry energy intensity.[2] Thus, the manufacturing 1998 energy intensity rebased to 1994 industry structure computes to 4.62 thousand Btu per dollar value of shipments. Comparing that value to the 1994 intensity yields a drop of intensity of only 3.7 percent.

Although the rebased intensity decrease cannot be deemed properly to be the "real" efficiency gain, it is a better value to use when trying to evaluate the efficiency improvements that manufacturers have been making. Later in this paper, we will look at their participation in energy-management programs. Additionally, by looking at the relative contribution of non-process energy use, we will try to see what influence the unusually mild weather may have had on consumption.

[2] An application of the Lespeyres index.

Other Measures of Energy Consumption

One advantage to the MECS is that it features four different measures of energy consumption. Already mentioned above were First Use and Fuel Consumption. Fuel Consumption was formerly known as Total Inputs for Heat, Power, and Electricity Generation. It represents all Fuel Consumption, both purchased and that which was produced onsite. Fuel Consumption has increased approximately 7.1 percent since 1994, somewhat less than the almost 10 percent increase of first use consumption. Four industry sectors, Chemicals, Petroleum and Coal Products, Paper, and Primary Metals together account for 71 percent of Fuel Consumption. That proportion is virtually unchanged from 1994.

Nonfuel (feedstock) use is a measure of energy sources consumed for the purposes other than the production of heat and power. Nonfuel use in 1998 increased 9.3 percent since 1994. Two of the industry sectors, Petroleum & Coal Products and Chemicals, account for 89 percent of the nonfuel use in manufacturing. The MECS measure of nonfuel use is *not* simply the difference between First Use of Energy and Fuel Consumption. First Use excludes energy consumption that arises from the feedstock use of another energy source. This ensures that First Use would not count the same consumption twice as different substances. Thus, First Use counts the coal that enters the coke oven to produce coal coke. It does not count the coke that is used in the blast furnace from the coal input. Fuel Consumption would count the coke but not the nonfuel use of coal.

The fourth measure of energy consumption measured by the MECS is Offsite-Produced Fuel Consumption. Unlike Total Fuel Consumption, Offsite-Produced Fuel Consumption excludes the fuel produced onsite from byproducts or from captive mines and wells. The relative contribution of Offsite-Produced Fuel Consumption to total fuel is approximately 75 percent. That proportion is relatively unchanged from the 1994 ratio.

Electricity Demand and Generation

When the MECS looks at the consumption measures described above, electricity consumption does not duplicate the fuels that went into onsite generation. For that reason, electricity consumption in the first use and total fuel measures is estimated as "Net Electricity." Net Electricity is defined as the sum of electricity purchases, transfers in, generation from noncombustible renewable energy, minus sales and transfers offsite. Cogeneration and conventional electric generation are excluded from the net electricity quantity to avoid double counting.

Often users have a special interest in the total amount of electricity consumed at the establishment, regardless of any inherent double counting brought about by onsite generation. The MECS measure of Net Demand for Electricity is then the appropriate measure. Unlike Net Electricity, Net Demand adds back in all the onsite generation, then has sales and transfers offsite deducted. Net Demand for Electricity in 1998 was 1,025,149 million kilowatthours, an increase of 12 percent from 1994. However, somewhat unexpectedly, onsite generation remained unchanged from 1994. In other words, onsite generation actually accounted for a greater proportion of demand for electricity in 1994 than in 1998.

While the 1998 MECS was in progress, analysts discovered that there were several cases of manufacturing establishments that had previously operated onsite generation facilities that they had since sold. Many then purchased the electricity back from the facility

that they had once owned. One explanation is that manufacturing establishments no longer felt capable or willing to operate onsite generation facilities that competed with other company resources to perform their primary function of manufacturing. Under the new economic outlook brought about by electricity restructuring, potential operators now found those plants more attractive to take on. It is possible that the MECS data will contradict other sources of electricity generation data. The MECS only includes as onsite generation those facilities that are owned by and co-located with manufacturing establishments. Those generation facilities that may themselves be owned by manufacturing *companies* but are not co-located with manufacturing plants are excluded from MECS tallies of onsite generation.

If the switch from onsite-generated electricity to purchases is indeed occurring as the MECS indicates, that may support the finding above of a decline in energy consumption per unit of output. The manufacturing population as measured by the MECS is no longer including the fuels used to generate the electricity, along with losses, but rather counting only the lower Btu-value electricity itself.

Energy End-Use and Weather

The MECS collects data on the end-use of major fuels. Manufacturers allot their fuel use to wide-ranging end-use categories. One of those categories is facility heating, ventilation and air conditioning (HVAC). In 1994, of the fuel that MECS respondents allocated to end-uses, 5.6 percent went to direct HVAC[3]. Due to the unusually mild winter weather of 1998, one might expect to see a discernible decrease in HVAC use relative to the other uses. In fact, in 1998, the relative proportion of HVAC appeared to increase to 6.1 percent[4], although the result was not statistically signficant.

MECS end-use estimates have shown stable proportional relationships since they were first introduced in the 1991 MECS. That may be due in part to the categories themselves, which were broadly defined. For significant changes to be detectable, new operating procedures and technological upgrades would have to be both extremely influential and widely adopted. End-use data are not necessarily, and probably not, derived from the direct reporting of metered equipment and processes. Best-guess estimates were acceptable and most likely used, especially in nonprocess end-use estimates. The analysis of end-use changes may have the greatest usefulness within a narrowly defined population in which widespread change affecting energy consumption is known to the analyst.

Energy-Management Activities

The MECS attempts to measure the extent of manufacturers' participation in any energy-management activity (EMA). EMA is defined as those practices, procedures, and programs designed to reduce an establishment's use of energy in performing specific functions that are part of normal building operations.

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[3] The word "direct" is used here to indicate that steam and hot water produced from boilers are not allocated to end-uses by MECS respondents.

[4] Due to the way MECS data were processed, no accurate estimate for sampling error exists for these particular ratios. As a surrogate test, we examined HVAC use of natural gas alone, the most widely used heating fuel. The difference in ratios proved not to be statistically significant.

The 1998 MECS asked manufacturers about their involvement in 17 specific EMAs, the most commonly used of which are shown in Table 1. Counts of the number of establishments participating in each of these 17 EMAs have been tabulated at the level of 3-digit NAICS codes, for display on the MECS website. In 1994, the five most-used EMAs were:

- Energy Audits (26,443 count compared to 24,338 in 1998);
- Equipment installation or retrofit to improve energy efficiency affecting Facility Lighting (18,074 count compared to 25,354 in 1998);
- Electricity Load Control (17,558 count compared to 20,922 in 1998);
- Equipment Rebates (12,668 count compared to 4,861 in 1998);
- Power Factor Correction or Improvement (12,597 count compared to 19,541 in 1998).

However in 1998, as shown in Table 1, increased emphasis has been placed on other EMAs, such as equipment improvements for Compressed Air, HVAC, and Machine Drive. In fact, Equipment Rebates suffered the largest drop in establishment participation as utility sponsorship waned.

For the first time ever, the MECS asked establishments if they had on staff a full-time Energy Manager whose major function is to direct or plan energy strategies relating to energy use and energy-efficient technology within the plant. Only 1.0% of the manufacturing establishments (2,245 count) declared that Energy Managers were in place.

Also for the first time ever, the MECS asked, in general terms, how much of the cost associated with a specific EMA was paid for by the establishment itself. In this way, the MECS can provide a gauge of the likelihood of manufacturers to undertake a particular EMA under their own auspices, without financial aid or sponsorship from outside sources, such as utility or Government. There were only two EMAs (Energy Audits and Electricity Load Control) in which considerably less than 50% of the participating manufacturers claimed to pay for <u>all</u> of the costs associated with the energy-saving activity. Only 29% of those participating in Energy Audits paid for all of the associated costs, while 41% paid for absolutely none of the Audit costs. Likewise, only 37% of participants in Electricity Load Control paid for all of its costs, with 25% paying no costs at all for Load Control.

General Technologies

The use of modern-day technology is essential in the conservation and efficient use of energy. The MECS specifically asked manufacturers about the use of four specific technologies, noted in Table 2. Usage of three of the four general technologies increased during 1998. Usage of Computer Control of Building-Wide Environment, which declined, was affected by the loss of 12,000 publishing establishments (newspapers, magazines, books) from the manufacturing base due to the classification conversion from SIC to NAICS codes; in 1994, one out of eight publishers utilized this type of Computer Control.

Table 1. Number of Establishments Participating in Energy-Management Activities: Comparison of 1998 versus 1994 National Data for the United States

Type of EMA	1998 Sample Frame: 226,813 Establishment Count	1998 Sample Frame: 226,813 Percent of Total	1994 Sample Frame: 246,925 Establishment Count	1994 Sample Frame: 246,925 Percent of Total
Participation in any EMA	75,448	33.3%	44,735	18.1
Top 5 EMAs in 1998:				
• Equipment Installation or Retrofit Primarily to Improve Energy Efficiency affecting Compressed Air Systems (compressors, sizing, leak reduction)	29,531	13.0%	Not collected	
• Equipment Installation or Retrofit Primarily to Improve Energy Efficiency affecting Facility Lighting	25,354	11.2%	18,074	7.3
• Equipment Installation or Retrofit Primarily to Improve Energy Efficiency affecting Facility Heating, Ventilation, and Air Conditioning (HVAC)	24,421	10.8%	11,707	4.7
• Energy Audits	24,338	10.7%	26,443	10.7
• Equipment Installation or Retrofit Primarily to Improve Energy Efficiency affecting Direct Machine Drive (adjustable-speed drives, motors, pumps)	22,201	9.8%	10,986	4.4

Table 2. Number of Establishments Using a Particular General Technology: Comparison of 1998 versus 1994 National Data for the United States

	1998		1994	
	Sample Frame: 226,813		Sample Frame: 246,925	
Type of Gen Tech	Establishment Count	Percent of Total	Establishment Count	Percent of Total
• Adjustable-Speed Motors	48,842	21.5%%	41,960	17.0%
• Computer Control of Processes or Major Energy-Using Equipment (boilers, furnaces, conveyor)	28,472	12.6%	25,441	10.3%
• Computer Control of Building-Wide Environment (lights, equipment for space heating and cooling)	17,048	7.5%	25,942	10.5%
• Waste Heat Recovery	11,867	5.2%	10,250	4.2%

Cogeneration Technology

Cogeneration is the production of electrical energy and another form of useful energy, such as heat or steam, through the sequential use of energy. There are five technologies commonly associated with cogeneration, as listed in Table 3, and the MECS specifically asked manufacturers about their use of each.

Usage of cogeneration technologies in 1998 declined somewhat from 1994 levels, for which there are several reasons. As mentioned earlier, electricity restructuring continues to impact the way in which manufacturers conduct business to acquire electric power at favorable rates. Specific cases have been documented whereby a manufacturer has sold an onsite generation facility that was formerly owned, with accompanying electricity buy-back arrangement with the generation facility. Increased competition in the supplier market has spawned alternative sources from which to purchase electricity. Such sources, other than local utilities, include independent power producers, brokers, marketers, marketing subsidiaries of utilities, or cogenerators not located at the establishment site.

Conclusions

The 1998 MECS recorded a gain of 9.8 percent in First Use of Energy in the U.S. manufacturing sector, in comparison to the 1994 level. However, that increase appeared smaller-than-expected when judged against the strength of the industrial sector, which grew 22.9 percent since 1994 in terms of the industrial production indices. Various reasons were offered for this discrepancy in growth: continuing progress in energy efficiency, lessening impact of energy-intensive industries, stagnating demand for onsite electricity generation, and growing use of energy-management activities.

Table 3. Number of Establishments Using a Particular Cogeneration Technology: Comparison of 1998 versus 1994 National Data for the United States

Type of Cogen Tech	1998 Sample Frame: 226,813 Establishment Count	1998 Sample Frame: 226,813 Percent of Total	1994 Sample Frame: 246,925 Establishment Count	1994 Sample Frame: 246,925 Percent of Total
Use of any of 5 Listed Cogen Tech	1,382	0.61%	2,109	0.85%
• Steam Turbines Supplied by Conventional or Fluidized Bed Boilers	859	0.38%	1,315	0.53%
• Conventional Combustion Turbines with Heat Recovery	304	0.13%	375	0.15%
• Steam Turbines Supplied by Heat Recovered from High-Temperature Processes	290	0.13%	456	0.18%
• Internal Combustion Engines with Heat Recovery	290	0.13%	370	0.15%
• Combined-Cycle Combustion Turbines	84	0.04%	60	0.02%

The year 1998 was perceived to be a milder period in terms of weather, especially during the winter months of January through March. However, the MECS data for end-use consumption, particularly for Facility Heating, Ventilation, and Air Conditioning, failed to detect a statistical difference from that of past years for which data were collected.

EIA expects to expand on the use of the 1998 MECS data by conducting studies on the changes in energy intensity in the U.S. manufacturing sector, including structural shift in consumers' demand for manufactured products. As available, results will be posted on the MECS website at: http://www.eia.doe.gov/emeu/mecs/contents.html.

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