MEASURING ENERGY EFFICIENCY IN THE INDUSTRIAL SECTOR OF THE UNITED STATES' ECONOMY: A BEGINNING

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Increasing emphasis has been placed on energy efficiency as a vital component of the Nation's energy strategy. The amount of energy saved or improvements in energy efficiency needs to be measured in a robust way. At the present time, the U.S. Energy Information Administration (EIA), the independent statistical agency of the U.S. Department of Energy (DOE) is undertaking a project to address this issue. There are no standards either in the definition of energy efficiency or its measurement. This project is a "beginning" analysis of energy efficiency and its measurement for all of the sectors of the U.S. economy. Only the industrial sector is presented in this paper.

In the development of the energy-efficiency indicators, DOE, EIA, and outside industrial specialists furnished feedback in the form of written reviews and comments at an industrial seminar. The materials presented in this paper are not intended as a definitive statement on these issues, but rather, a means of focusing the thinking of our customers and obtaining their input. Even with the assistance from experts, this paper is still nothing more than a "strawman."

Energy efficiency is a term that refers to the relative thrift or extravagance with which energy inputs are used to provide services. The terms energy efficiency and energy efficient are used in conjunction with other terms such as energy intensity or energy intensive in describing the mathematical relationship between energy use and service output. Energy intensity is defined as the ratio of energy consumption to a unit of measurement (e.g. value added, value of shipments, etc.). A decrease in energy intensity over time corresponds to an increase in energy efficiency. When using energy intensity as an indicator of energy efficiency, other effects must also be considered such as: weather, behavioral or structural effects. As many of these effects that are unrelated to energy efficiency need to be separated out. However, it is impossible to extricate all of the effects.

INTRODUCTION TO THE INDUSTRIAL SECTOR

The industrial sector encompasses over three million establishments in manufacturing, agriculture, forestry, fishing, construction, and mining businesses. These industries require energy to light, heat, cool, and ventilate facilities (these are characterized as energy needed for comfort). They also use energy to harvest crops, process livestock, drill and extract minerals, power various manufacturing processes, move equipment and materials, raise steam, and generate electricity (boiler fuel). Some industries require additional energy fuels for use as raw materials (feedstocks) in their production processes while other industries use byproduct fuels to satisfy part of their energy requirements. For most manufacturing and nonmanufacturing industries, energy used by processes dwarfs the energy demand for comfort.

In this paper, only the manufacturing sector is considered in the development of energy-intensity indicators. Insufficient data or data not consistent with the availability of manufacturing data do not permit at this time, the robust development of energy-efficiency indicators for the nonmanufacturing sector.[2] Industrial energy consumption and associated output (demand) data are classified by Standard Industrial Classification (SIC) in most surveys of establishments.[3] Next to the transportation sector, the manufacturing sector consumes the most energy in the United States. In 1991, 20.3 quadrillion Btu of energy for all purposes including use as feedstocks, or about one-third of the total end-use energy was consumed in the manufacturing sector.

Historically, even manufacturing has been the sector where data and understanding of energy use has also been the least enlightening relative to the variety of energy inputs and energy-using activities. These complexities

unquestionably make energy-use analysis more difficult here than in the other sectors. At the same time, an opportunity is available. A well-conceived efficiency analysis could be mort important and potentially more beneficial here than any other sector because of the amount of energy consumption represented in the sector and the perceived potential for additional efficiency improvements.

Of the 20 major industry groups in the manufacturing sector, in 1991, only 6 industry groups accounted for 88 percent of the consumption of energy for all purposes; food and kindred products; paper and allied products; chemical and allied products; petroleum and coal products; stone, clay, and glass products; and primary metals. These six account for only 40 percent of the output valued for manufacturing, and as a result, are very energy intensive in their production, the exception being the food and kindred products SIC group. This SIC industry is a high consumer, but not very energy intensive.

For the purpose of this analysis, the manufacturing sector is divided into three major groups; the highest energy consumers; the high-valued added consumers; and the lowest energy consumers. These are summarized in Table 1. The most important group, the highest energy users is presented in detail.

In this paper, first, the major data sources are described in detail. The trend in energy consumption in the manufacturing sector is shown, followed by a discussion of the demand indicators that influence the amount of energy consumed, namely gross output, value of shipments, industrial production, value added, and gross product originating. Changes in these indicators will be discussed as well as possible adjustments such as capacity and inventory adjustments.[4] The most-used energy-intensity indicators will be compared, followed by a comparison of capacity- and inventory-adjusted intensities as a form of "closing in on energy-efficiency indicators". Lastly, the strength and limitations of the energy-intensity indicators will be explored.

MAJOR DATA SOURCES

Census of Manufactures/Annual Survey of Manufactures: Historical and Current Series

The Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM) conducted by the U.S. Department of Commerce, Bureau of the Census, provide economic data, such as sales, employment, and expenditures by SIC. The CM and ASM collect the same information, and together provide an annual series. The CM is conducted every 5 years, and collects the same information from essentially the entire population of manufacturing establishments. The CM does not collect data from very small establishments, which are represented instead by administrative records from other sources. In the years when the CM is not conducted, the ASM collects the same information from a sample of 45,000 to 55,000 establishments.

Manufacturing Energy Consumption Survey: Current Triennial Series

The Manufacturing Energy Consumption Survey (MECS), conducted by the EIA, provides more detailed energy data than the ASM previously did or currently does. The MECS is the most comprehensive source of national-level data on energy-related information for the manufacturing sector. The MECS provides three different measures of manufacturing energy consumption. These measure differ in terms of how offsite-produces energy, feedstocks, and byproduct energy are accounted for. The MECS measure of office-produced energy corresponds to the ASM "purchased fuels" definition.

The MECS is a sample of approximately 12,000 establishments subsampled from the ASM sample. Thus the population represented by the MECS matches that covered by the ASM. However, because the MECS is only a sample from the ASM, the MECS estimates do not exactly coincide with the ASM for a given survey year, due to sampling variability.

The MECS was conducted first in 1985, 1988 and most recently in 1991. The next MECS will be conducted for the reporting year 1994.

Table 1. Type of Manufacturing Groups

Standardized Industrial Code	Major Industry Group	Description
High Energy Consumers		
20	Food and Kindred Product	The high energy consumers convert raw materials into finished goods primarily by chemical (not physical) means. Heat is essential to their productions, and steam provides much of the heat. Natural gas, byproduct and waste fuels are the largest sources of energy for this group. All except Food and Kindred Products are the most energy intensive industries.
26	Paper and Allied Products	
28	Chemicals and Allied Products	
29	Petroleum and Coal Products	
32	Stone, Clay, and Glass Products	
33	Primary Metal Industries	
High-Value Added Consumers		
34	Fabricated Metal Products	This group produces high value-added transportation vehicles, industrial machinery, electrical equipment, instruments, and miscellaneous equipment. The primary end uses are motor-driven physical conversion of materials (cutting, forming, assembly) and heat treating, drying and bonding. Natural gas is the principal energy source.
35	Industrial Machinery and Equipment	
36	Electronic and Other Electric Equipment	
37	Transportation Equipment	
38	Instruments and Related Products	
39	Miscellaneous Manufacturing Industries	
Low Energy Consumers		
21	Tobacco Manufactures	This group is the low energy consuming sector and represents a combination of end use requirements. Motor drive is one of the key end uses.
22	Textile Mill Products	
23	Apparel and Other Textile Products	
24	Lumber and Wood Products	
25	Furniture and Fixtures	
27	Printing and Publishing	
30	Rubber and Miscellaneous Plastics	
31	Leather and Leather Products	

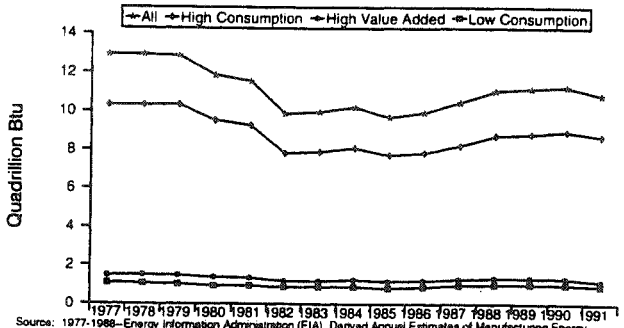
Federal Reserve Board: Annual Production Indices

The Federal Reserve Board (FRB) produces an annual series of production indices, by two-digit manufacturing SIC. The basis of this index is specific to each SIC. In many cases, it is tons of product, indexed to a base year. In other cases, a different production measure is used, indexed to the same base year. The FRB production indices are given for manufacturing as a whole, and for most two-digit manufacturing SIC's. For SIC 23 (Apparel) and SIC 39 (Miscellaneous), however, no FRB production index is defined.

Other Data Sources

U.S. Department of Labor, Bureau of Labor Statistics provided the data on the costs of production in the manufacturing sector. The U.S. Department of Commerce, Bureau of Economic Analysis provided the gross product originating data as well as the deflators used to obtain constant dollar estimates.

Figure 1. Offsite-Produced Energy Consumed for Heat and Power by Group, 1977-1991



Source: 1977-1986–Energy Information Administration (EIA), Derived Annual Estimates of Manufacturing Energy Consumption, 1977-1988 (August 1992), Table 1; 1989-forward–EIA, Form EIA-846, 1991 Manufacturing Energy Consumption Survey.

ENERGY CONSUMPTION IN THE MANUFACTURING SECTOR

Background

Manufacturers use energy sources in two major ways. The first use is to produce heat and power and to generate electricity. The second way in which manufacturers use energy is as a raw material input to the manufacturing process or for some other purpose usually referred to as nonfuel uses. The text box located on this page describes the three general measures of energy consumption used by the EIA. The energy consumption measures used in this analysis do not include the losses in the generation, transmission, and distribution of energy sources, thus referred to as "site" energy. According to the 1991 MECS, the amount of Site Consumption of Energy for All Purposes was 20.3 quadrillion Btu. About two-thirds (13.9 quadrillion Btu) of this was used to produce heat and power and to generate electricity, with about one-third (6.4) quadrillion Btu) being consumed as raw material. This measure does not include byproduct fuels. The Total Inputs measure, which does include byproduct fuels, is most useful in discussions of how energy use in the manufacturing sector compares with energy use in the residential and commercial sectors. This measurement measures only the energy used for its energy content and not as an input into a manufacturing process. The Total Inputs measure is used in the development of energy-intensity indicators in this paper.

Three General Measures of Energy Consumption

- ***Site Consumption of Energy - Used for All Purposes*** is the most comprehensive measure of energy consumption and represents the first use of energy sources no matter whether they are consumed as a fuel or as a nonfuel (raw material). It does not include byproduct fuels.
- ***Total Inputs of Energy*** - It includes all energy sources used to produce heat and power and to generate electricity whether produced offsite or onsite. It excludes raw materials.
- ***Offsite-Produced Energy*** - It includes all energy sources purchased or transferred from offsite to produce heat and power and to generate electricity.

Energy Trends

It would be ideal if we could show lengthy historical consumption trends for all three measures for the manufacturing sector. This is not possible since the first comprehensive data series (MECS) was only first fielded in 1985. There is one measure, Offsite-Produced Energy, where trend data can be displayed. The MECS's Offsite-Produced Energy measure can be used to continue the data series, "Purchased Fuels and Electric Energy," which was previously collected for EIA by the Bureau of Census as a supplement to its ASM.[5] Since at least 70 percent of Total Inputs of Energy is made of energy sources produced offsite, the Offsite-Produced Energy measure does provides some insight into changes in energy consumption in the manufacturing sector from 1977 to 1991.

Figure 1 shows the consumption trends for each of these groups from 1977 to 1991. The High Consumers, as a group, reduced energy consumption between 1979 and 1982, but since then and until recently, consumption seemed to have been growing but only at a small rate. The High-Value Added and Low Consumers seem to have maintained a consistent level of consumption over time. In 1991, for all manufacturing groups, Offsite-Produced Energy represented an insignificant 2 percent of the total production costs faced by US manufacturers.[6]

Although this percentage does increase to 3.5 percent for the High Consumers, it still is a very small portion of all of the costs of production that manufacturers face. However, in 1991, the costs of energy equated to $32.9 billion (constant 1987 dollars) for the High Consumers.

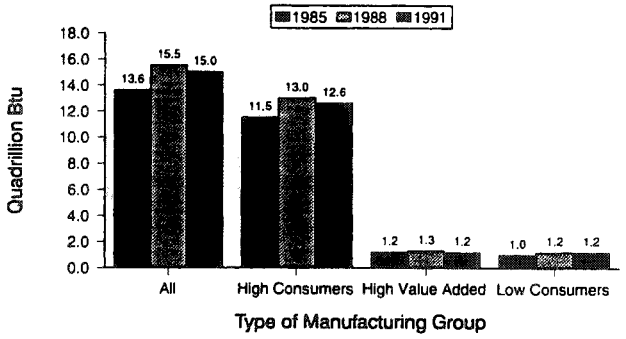
Table 2. Total Inputs of Energy for High Energy Consumers in the Manufacturing Sector, 1985-1991

Manufacturing Groups	Trillion Btu			Percent Change		
	1985	1988	1991	1985-1988	1988-1991	1985-1991
Largest Energy Consumers	11,482	12,950	12,639	12.8	-2.4	10.1
Food and Kindred Products	946	996	953	5.2	-4.2	0.8
Paper and Allied Products	2,190	2,347	2,472	7.2	5.3	12.9
Chemicals and Allied Products	2,443	2,862	3,040	17.1	6.2	24.4
Petroleum and Coal Products	2,593	3,122	2,987	20.4	-4.3	15.2
Stone, Clay and Glass Products	917	1,000	894	9.1	-10.7	-2.5
Primary Metal Industries	2,393	2,622	2,292	9.6	-12.6	-4.2

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

The most recent trends of energy consumption in the manufacturing are placed into two economic driven categories, 1985 to 1988 and 1988 to 1991, the years of "growth" and "recession". Using these categories in the analysis will allow comparisons of Total Input Energy for heat and power and electricity generation (including Offsite-Produced Energy) between the years of growth and recession. This will allow the usage of the most comprehensive data available for the manufacturing sector, the MECS, in the actual development and discussion of energy-intensity indicators in the manufacturing sector.

Figure 2. Total Inputs of Energy for Heat and Power and Electricity Generation, 1985-1991



Source: Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, Public Use Data Tapes.

Total Input Energy for heat and power and electricity generation is shown in Figure 2 for each of the three manufacturing groups. The High Consumers do consume most of the energy used in the manufacturing sector. All three groups are consistent in that during the years of growth, the energy consumption increased while declining during the recessionary years. The largest percentage decline of Total Input Energy was experienced by the High-Added Value Consumers. These consumers' energy consumption declined by 10.4 percent (.1 quadrillion Btu). During the recessionary period 1988-1991, the greatest decrease in energy demand was experienced by firms engaged in producing goods such as jewelry, bicycles, computers, apparel, and leather that fluctuate with changes in personal income.

The High Consumers faced a .4 quadrillion Btu decline in consumption (2.4 percent decline). This group, however, did not experience declines in consumption for each member of the group. Paper and Allied Products and Chemical and Allied Products continued to grow after 1988, despite reductions by almost all other industry groups. These two industry groups actually experienced increases in energy consumption during the recessionary years. Chemicals manufacturers exhibited the fastest growth in Total Inputs Energy throughout the entire 1985 to 1991 (24 percent) (Table 2).

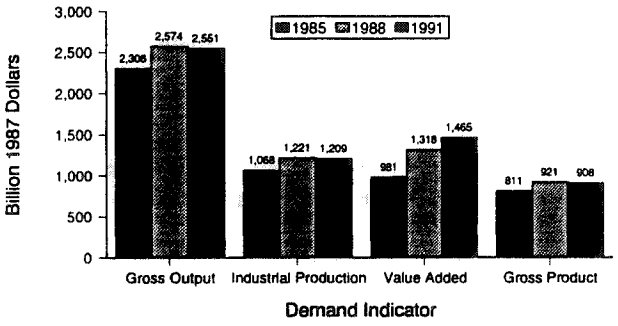
DEMAND INDICATORS

In the industrial sector, the diversity of processes and ways in which energy is consumed makes it difficult to single out characteristics that drive energy consumption activities for all industries. At the two-digit SIC level, there are no consistent physical units that can be used to measure demand. The demand indicators that are presented in detail in this paper are considered surrogates for production. The five different dollar-denominated production surrogates

considered as potential demand indicators are: gross output, value of shipments, industrial production, value added, and gross product originating (GPO).

All five are presented in constant 1987 dollars to compensate for inflation-induced price fluctuations. In constant dollars, these measures can still fluctuate due to changes in energy prices, cost of capital, domestic and international taxes, consumer demand, and production cycles. Descriptions of the demand indicators are presented briefly in the text box on this page and described in detail in the industrial sector section of the glossary in this report.

Figure 3. Demand Indicators In The Manufacturing Sector, 1985-1991



Sources: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, fixed 1987 weights," Table C1, "Gross Output by Industry, fixed 1987 weights" and; Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94; U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2; Table D4 GPO deflators

The number of establishments, number of workers, and weight of manufactured goods could be considered as potential demand "drivers" or indicators of energy consumption in the manufacturing sector. These three, though, have characteristics that would render them unsuitable for usage in the development by EIA of indicators of energy intensity in the manufacturing sector. The following describes some of these reasons why each of the three potential demand indicators may not be suitable and thus not presented further in this paper:

Manufacturing Sector Demand Indicators

- **Gross Output** - The most comprehensive measure of manufacturing production that includes sales or receipts and other operating income plus inventory change.
- **Value of Shipments** - The value of shipments includes the receipts for products manufactured,services rendered, and resales of products bought and resold without further manufacture.
- **Industrial Production** - An index calculated by compiling indices of physical output and weighing by U.S. Census' value added, and adding it to the cost of materials. This is multiplied by the Federal Reserve Board's "real value added" to convert industrial production into dollars.
- **Value Added** - It is a measure of activity derived by subtracting the cost of materials, supplies, containers, purchased fuel and electricity, and contract work from the value of shipments. In essence, it is the value of an establishment's output minus the value of the inputs.
- **Gross Product Originating (GPO)** - It is the contribution of each industry to gross domestic product (GDP). GPO is equal to an industry's gross output minus its intermediate inputs from other industries.

(1) Number of Industrial Establishments:
   a. Substantial variation in terms of size and equipment in operation;
   b. Establishments are surveyed by the Bureau of the Census only once every five years;
   c. Establishment data are not used to benchmark MECS;

(2) Number of Employees[7]:
   a. Large variation in plant size and automation;
   b. The most labor-intensive industries are not the most energy intensive;

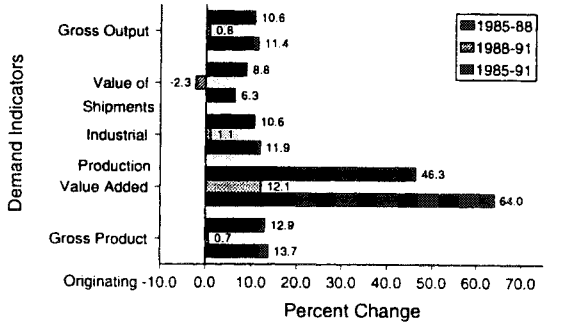
(3) Weight of the Manufactured Goods:

a. The weight of the manufactured goods is not collected across all industries, and would tilt demand towards industries producing heavier materials (e.g., cement and steel) and machinery.

Trends in Demand Indicators

As can be seen in Figures 3, increases in each of the demand indicators occurred during the growth period of 1985 to 1988. The demand indicator experiencing the largest increase in these growth years is the value-added demand indicator (34.3 percent). This indicator also is the only demand indicator that did not experience an overall reduction during the recessionary years of 1988 to 1991.

Figure 4. Demand Indicators In The High Energy Consumer Manufacturing Group, 1985-1991



Sources: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, fixed 1987 weights," Table C1, "Gross Output by Industry, fixed 1987 weights" and; Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94. U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2, Table D4 GPO deflators

High Energy Consumers

During the recessionary years, the growth in the various demand indicators for High Energy Consumers was either minimal or negative (Figure 4). With the exception of GPO, most of the slow or negative growth during the recessionary years is due to the lack of growth in the Stone, Clay and Glass Products and the Primary Metals industries. The Primary Metals industries did, though, actually posted an 8.7 percent increase in 1988 to 1991 in GPO. The Primary Metals industries did also post the largest increase in value added during the growth years, 1985 to 1988.

High Value-Added Consumer

The High Value-Added Energy Consumers accounted for 47 percent of value added in 1985. This group did reduce its share of value added as a whole to 41 percent by 1991 because industrial machinery and electronic products both lost out to cost-competitive imported products.

The High-Value Added Energy Consumers also were the largest contributors to industrial production and GPO, accounting for 45 percent and 47 percent respectively in 1991. With the exception of value added, all of the other demand indicators, decreased during the recessionary years (Figure 5).

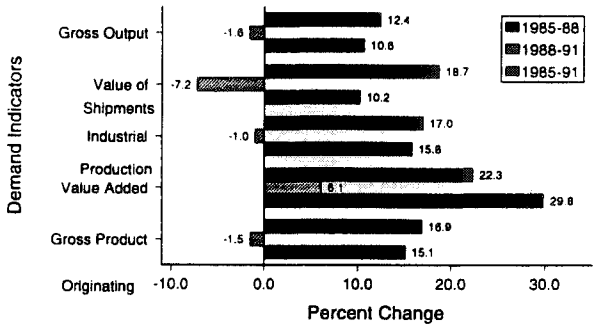
Low Energy Consumer

The Low Energy Consumers faced reductions in each of the demand indicators, the exception being value added (Figure 6). These reductions do also seem to be greater than the other two groups. Most of the industry groups within the Low Energy consumers, seemed to have fared poorly during the recessionary years. One apparent exception was the Rubber and Miscellaneous Plastics industry which posted increases in all of the demand indicators.

Demand Indicator Adjustments

As is demonstrated in the previous discussion, the economic environment can have major impacts on the levels of the demand indicators that "drive" energy consumption. These effects, are however, structural effects and need to be considered when measuring changes in energy intensity overtime in the manufacturing sector. The key drawback for the shipments-based demand indicators is that they measure the product shipped from industries, whether manufactured this year or taken from inventory. Stock changes can obscure production activity in the manufacturing

Figure 5. Demand Indicators in the High Value-Added Consumer Manufacturing Group, 1985-1991



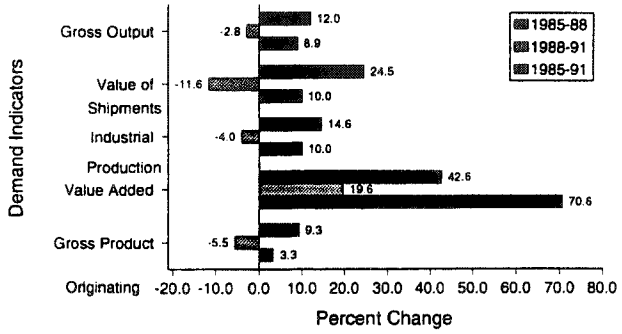
Sources: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, fixed 1987 weights," Table C1, "Gross Output by Industry, fixed 1987 weights" and; Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94; U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2, Table D4 GPO deflators.

sector. Industries that build up stocks will underestimate actual production. Similarly, for industries depleting their stocks, actual production will be overestimated. All manufacturers reduced inventory during the growth years and built up some inventories during the recessionary years (Figure 7). These movements in inventory need to be considered when choosing a "best" indicator of energy intensity in the manufacturing sector.

The best demand indicator that considers inventory changes is gross output. The problem is that, with the exception of value of shipments demand indicator, gross output and the other demand indicators presented in this paper have not been corrected for the SIC reclassification in 1987 from a 1972 base. Using these as demand indicators will not provide as accurate a trend analysis for the years before 1987. Value of shipments data in MECS has been corrected to SIC 1987 basis in all years, adjusted by MECS weights and then deflated to constant 1987 dollar.

Although, the value of shipments demand indicator does not consider inventory changes, it can be revised to reflect these changes. Inventory-adjusted value of shipments or namely, value of production estimates, act much like degree-day adjusted estimates in the residential and commercial sectors. If stocks are drawn down during the base year (1985), then the value of production will be less than the value of shipments for that year.

Figure 6. Demand Indicators in the Low Consumer Manufacturing Group, 1985-1991



Sources: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, fixed 1987 weights," Table C1, "Gross Output by Industry, fixed 1987 weights" and; Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94; U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2, Table D4 GPO deflators.

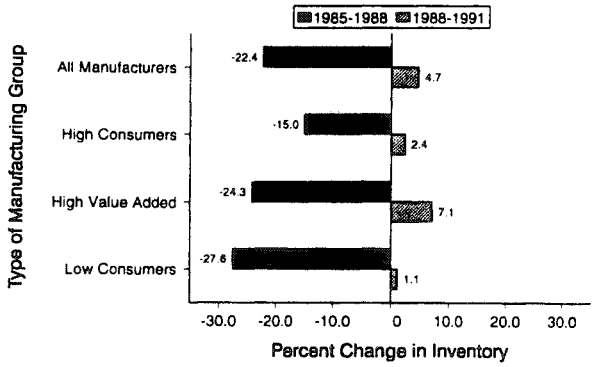
During the growth years, as inventories were being drawn down, the percentage increase in the value of shipments was less than the percentage increase in the value of production which reflects the more accurate levels of production. This was true for all three energy consuming groups (Figure 8). If inventory adjustments do not take place, then decreases in energy-intensity indicators and thus increases in energy efficiency during these years is overestimated. During the recessionary years,inventories increased. The value of shipments was less than the value of production, reflecting a lower level of production than actually occurred. Although some of the value of the production did not leave the establishments as value of shipments, the actual production of this inventory did take place and energy was used in the production process. If this inventory adjustment is not made, then decreases in energy-intensity indicators and thus increases in energy efficiency are underestimated.

Capacity-Adjusted Value of Production

Production levels vary in accordance with capacity levels and utilization rates. In some cases, manufacturers predetermine the utilization rate to maximize profits or minimize operating losses. The utilization rate takes into

account scheduled maintenance on plant and facilities, vacation plans, and investment in new capital equipment. Other events may alter utilization rates, e.g., unscheduled outages, labor strikes or slowdowns, and materials supply bottlenecks. If an establishment is not operating at capacity, energy may still be used but this energy should not be considered when attempting to measure changes in energy intensity. However, at the other end, if an establishment is operating at or near full capacity, it may be using all of the equipment it can including some of the old, inefficient equipment.

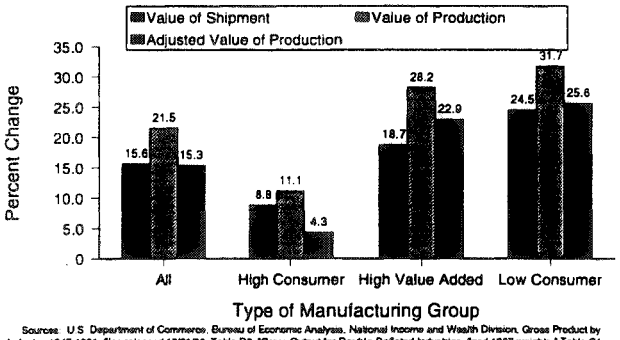
Figure 7. Changes in Inventory, U.S. Manufacturing Sector, 1985-1991



Source: U.S. Department of Commerce, Bureau of the Census, "Annual Survey of Manufactures, 1985, 1988, and 1991," Table 2.

Accounting for changes in both inventory and capacity utilization yields a capacity-adjusted value of production demand indicator. It is derived by comparing the rate of capacity utilization reported by the Federal Reserve Board for each year and the 26-year average (1967-1993) for all major industry groups. Not surprisingly, for most of the major industry groups, the average capacity utilization rate is higher than the reported annual rate in 1985 and 1991 (when inventories were being drawn down) and the average capacity utilization rate was below the reported annual rate in 1988 (when stocks were built). This adjustment smoothes the value of production estimates by raising the output in years of low capacity utilization (e.g. 1985 and 1991) and lowering output in years of high capacity utilization (e.g. 1988). If this adjustment is not applied e.g. in years of low capacity utilization and little reduction in the amount of energy consumed for heat and power and electricity generation, any measure of energy intensity would cause its corresponding measurement, energy efficiency to be underestimated.

Figure 8. Comparison of Value of Shipments, Value of Production, and Adjusted Value of Production, 1985-1988



Sources: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, fixed 1987 weights," Table C1, "Gross Output by Industry, fixed 1987 weights" and, Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94; U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2, Table D4 GPO deflators.

ENERGY-INTENSITY INDICATORS IN THE MANUFACTURING SECTOR

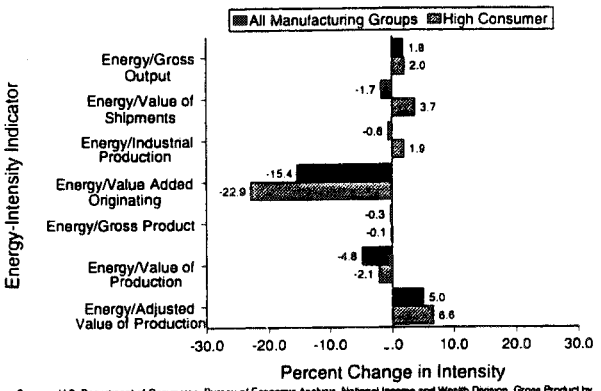
Energy consumption and the "drivers" of energy consumption, the demand indicators for the manufacturing sector have been discussed in detail. The next step is to construct measures of energy intensity using the two components. The ideal would to be able to measure energy efficiency in its purest form. The best that can be accomplished is to measure changes in energy intensity, adjust where adjustments are possible, and be aware that although reductions in energy intensity reflect increases in energy efficiency, these reflections also contain some structural and behavioral influences. A general measure of energy intensity used in the manufacturing sector is energy (1000 Btu) per demand indicator (in 1987 dollars). There are choices, though, as to what measure of energy intensity to use. Table 3 shows the choices and the values of the different choices for energy-intensity indicators. Over all the indicators of intensity, the High Energy Consumers are not only high users of energy, they are the most intensive per 1987 dollar of output. One exception is the Food and Kindred Products industry group. This industry group is a high user of energy, but not a very intensive user of energy.

The energy-intensity indicators using gross output, value of shipments, value of production, and adjusted value of production are comparable while the remaining three measures are roughly twice the value in thousand Btu per dollar. The leading difference between gross output and value of shipments is that gross output considers inventory changes while value of shipments do not implying that gross output and value of production are very comparable. One can see the difficulties in selecting an energy intensity measure when e.g. measuring the impacts of a particular energy program.

Energy-Intensity Indicator Trends

Figures 9 and 10 add to the choice dilemma when looking at the changes in the various energy intensity indicators for all industry and High Energy Consumers. The outlier by far is value added. The problem with using an energy intensity indicator that

Figure 9. Energy-Intensity Indicators, 1985-1988



Source: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, file released 12/31/93, Table D3 and Table C1, Gross Output by Industry, fixed 1987 weights; Gross Product by Industry, 1949-1991, file released 12/13/93, Table D4 GPO deflators; "Gross Output for Double-Deflated Industries, fixed 1987 weights;" Deflators from electronic data released 12/13/93, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2; U.S. Department of Treasury, Federal Reserve Board, table provided by Charles Gilbert, 10/12/94; Federal Reserve Statistical Release, August 15, 1994, Table 3 (average).

Table 3. Energy Intensity Measures in the Manufacturing Sector, 1985 to 1991

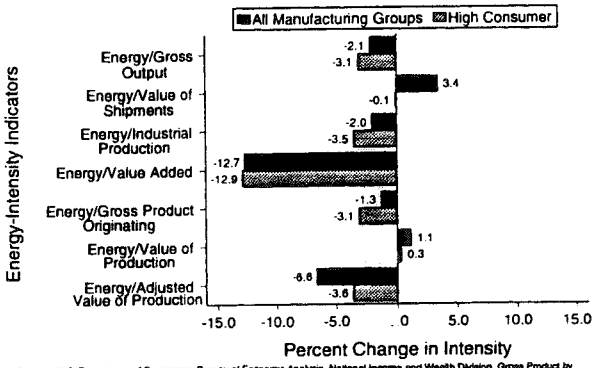
Type of Manufacturing Group	Energy Intensity Measure: Energy/Demand Indicator (Thousand Btu/Constant 1987 Dollar)						
	Demand Indicator						
	Gross Output	Industrial Production	Value Added	Gross Product Originating	Value of Shipments	Value of Production	Capacity-Adjusted Value of Production
All Industrial Groups							
1985	5.9	12.8	13.9	16.8	6.1	6.3	6.2
1988	6.0	12.7	11.8	16.8	6.0	5.9	6.1
1991	5.9	12.4	10.3	16.5	6.2	6.2	6.0
High Energy Consumers							
1985	12.6	31.2	35.7	44.1	12.3	12.5	12.0
1988	12.9	31.8	27.5	44.0	12.7	12.7	13.0
1991	12.4	30.7	24.0	42.7	12.7	12.7	12.6
High Value Added							
1985	1.2	2.5	2.5	3.2	1.3	1.4	1.3
1988	1.3	2.4	2.4	3.1	1.2	1.2	1.2
1991	1.1	2.2	2.0	2.8	1.2	1.2	1.1
Low Energy Consumers							
1985	1.6	3.1	4.9	3.9	2.5	2.6	2.6
1988	1.8	3.5	4.2	4.6	2.5	2.5	2.5
1991	1.8	3.6	3.5	4.8	2.8	2.8	2.6

Sources: •Energy Information Administration, Manufacturing Energy Consumption Surveys, 1985, 1988, 1991, Public Use Data Tapes. • Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, "Gross Product by Industry," 1947-1991, files released 12/31/93, Table D2, "Gross Output for Double-Deflated Industries, Fixed 1987 weights," Table C1, "Gross Output by Industry, Fixed 1987 weights." •Federal Reserve Board, Industrial Production, provided by Charles Gilbert (202-452-3197) 10/25/94. •U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2 and Table D4. GPO Deflators.

uses value added as the demand indicator, is that the changes could be a reflection that U.S. manufacturing is responsible for less finished goods production as final assembly and processing occurs out of the country. One also has to remember that only the energy-intensity indicators using value of shipments or adjusted value of shipments has been standardized to the 1987 SIC classification.

Figure 9 shows the changes in the energy intensity indicators over the growth years. There seems to be conflicting messages, depending on which energy-intensity indicator is used. It does seem though, with the clear exception of the intensity indicator using value added, that there has been very slight decreases in energy intensity and thus improvements in energy efficiency in industry as a whole and in those industries using a lot of energy has been limited. When looking

Figure 10. Energy-Intensity Indicators, 1988-1991



Source: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, Gross Product by Industry, 1947-1991, file released 12/31/93, Table D3 and Table C1, Gross Output by Industry, fixed 1987 weights; Gross Product by Industry, 1949-1991, file released 12/13/93, Table D4 GPO deflators; "Gross Output for Double-Deflated Industries, fixed 1987 weights." Deflators from electronic data released 12/13/93; Bureau of the Census, Annual Survey of Manufactures, 1988, 1989, and 1991, Table 2; U.S. Department of Treasury, Federal Reserve Board, table provided by Charles Gilbert, 10/12/94, Federal Reserve Statistical Release, August 15, 1994, Table 3 (average)

Table 4. Strengths and Limitations of Energy-Intensity Indicators

Energy-Intensity Indicator	Strength of Demand Indicator Used in the Intensity Indicator	Limitation of Demand Indicator Used in the Intensity Indicator
Energy/Gross Output	• Most comprehensive measure of production - includes inventory change • Available annually	• Pre-1987 data are based on the 1972 SIC classification • Establishment data not available
Energy/Industrial Production	• Available annually	• Pre-1987 data are based on the 1972 SIC classification • Establishment data not available
Energy/Value Added	• Represents the unique contribution of an industry group to the production of finished goods • Available for most nonmanufacturing industries • Published consistently by developed countries and used in international comparisons	• Pre-1987 data are based on the 1972 SIC classification • Establishment data not available • Underestimates the contribution of primary industries because they do not provide high-value components for final goods
Energy/Gross Product Originating	• Includes inventory change • Available annually • Provides a better approximation of value added	• Pre-1987 data are based on the 1972 SIC classification • Establishment data not available
Energy/Value of Shipments	• Consistent 1987 SIC classifications • Collected by EIA as part of a detailed energy survey	• Data available every three years • Does not consider inventory changes • Industry value of shipments data are confidential
Energy/Value of Production	• Consistent 1987 SIC classifications • Collected by EIA as part of a detailed energy survey • Includes adjustments for changes in inventory	• Data available every three years • Industry value of shipments data are confidential
Energy/Adjusted-Capacity Value of Production	• Consistent 1987 SIC classifications • Collected by EIA as part of a detailed energy survey • Includes adjustments for changes in inventory and capacity	• Data available every three years • Industry value of shipments data are confidential

at the years of recession as shown in Figure 10, the picture changes. It seems that for the most part, energy intensities fell implying increases in energy efficiency. Again though, the reader must be aware that structural change, e.g. recession could be the influential factor. A huge price increase or other market fluctuation could augment e.g. the value of shipments and make energy intensity appear reduced. Adjusting for capacity utilization helps strip away certain economic effects, however, a dollar-denominated energy intensity measure will always be susceptible to such market changes.

STRENGTHS AND LIMITATIONS OF THE ENERGY-INTENSITY INDICATORS

Energy-intensive indicators were developed only for the manufacturing sector. Most of the energy used in the industrial sector is used in the manufacturing sector. This does not lessen the importance attached to the

development of nonmanufacturing energy-intensive indicators. Future work needs to incorporate the development of these indicators as more data become available or new methodologies are developed that will allow the use of limited nonmanufacturing data.

The energy-intensity indicators developed in this paper are varied. Each have certain strengths and limitations (Table 4). These are all dollar-denominated surrogates for actual output and as such, a huge price change or other market fluctuation could augment e.g. the value of shipments and make energy-intensity indicators appear higher or lower than the actual change in intensity which equates to underestimations and overestimations of energy efficiency.

ENDNOTES

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

[2] Agriculture, mining, and construction is represented in the Census Bureau's set of quinquennial economic censuses which provide data on expenditures for purchased energy. The 1992 Census reports are not available at the present time. In addition, The Census of Mineral Industries collects and publishes data on consumption of purchased energy and consumption of onsite-produced energy. Also, the Annual Farm Costs and Returns Survey, conducted by the U.S. Department of Agriculture, is a source of annual data on energy expenditures and respondent-estimated prices for certain fuels. These data could only be used for rudimentary analysis.

[3] The Office of Management and Budget derived this hierarchial system. Wherever possible, data presented correspond to the 1987 SIC reclassification. As a result, 1985 and 1988 data may not match previously published data.

[4] Due to space limitations in this paper, the methodology for these adjustments and other technical information will be included in EIA's publication, *Measuring Energy Efficiency in the United States' Economy* which is planned for publication early fall 1995.

[5] Since the MECS does not collect annual data, EIA developed a method to derive estimates for the missing years 1982-84, 1986-87, and 1989-1990. This methodology is developed in *Derived Annual Estimates of Manufacturing Energy Consumption 1974*-1988 (DOE/EIA-0555(92)/3).

[6] See U.S. Department of Labor, Bureau of Labor Statistics *Multifactor Productivity in U.S. Manufacturing, 1949-1991*. Data points in 1985 are based on 1972 SIC; 1988 and 1991 data points are based on 1987 SIC.

[7] Includes production and non-production workers.