

Energy Consumption Series

Measuring Energy Efficiency in the United States' Economy: A Beginning

October 1995

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**Measuring Energy Efficiency in the
United States' Economy: A Beginning**

October 1995

Energy Information Administration
Office of Energy Markets and End Use
U.S. Department of Energy
Washington, DC 20585

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This report was undertaken as a first step to define and measure energy efficiency. We encourage customer comments and participation in this project. Participation from the readers of this report will allow us to enhance our methodology and presentation of energy-efficiency indicators. Focus questions are provided on the following page to guide you as you review this report.

If you have comments or suggestions or wish to participate in either our in-house workshops or Internet workshops, please contact Stephanie J. Battles by phone at (202) 586-7237, by FAX at (202) 586-0018, or by e-mail at sbattles@eia.doe.gov. The mailing address is:

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Focus Questions

1. There are two types of energy-efficiency indicators:
 - a. Aggregate indicators that use data, which are frequently available and are easier to construct
 - b. Comprehensive more detailed indicators where the data are not as frequently available and the indicators are more complex to construct.

Considering the trade-offs, which type of indicators should EIA present and why?

2. Should EIA aggregate the sectoral coverage or leave the coverage disaggregated; that is, should there be:
 - a. Buildings sector indicators versus separate residential and commercial sector indicators
 - b. Transportation sector indicators versus passenger and freight indicators
 - c. Industrial sector indicators versus separate indicators for manufacturing, agriculture, mining, and construction?
 3. Should EIA deal with the energy losses incurred in the generation, transformation, transmission, and distribution stages at the entire economy level, sectoral level, or both levels? How should EIA deal with these losses? Should only the losses in the electricity generation sector be considered or should the losses be considered in the other energy sectors as well?
 4. For each sector, should EIA have a single indicator or multiple indicators to illustrate the variability of efficiency trends, depending on the approach used?
 5. In your estimation, which of the energy-intensity indicators presented in this report are the most robust, valid, and reproducible? Please explain.
 6. Do you use any other potential energy-intensity indicators that are robust, valid, and reproducible? Please describe.
 7. With what frequency should EIA publish the chosen indicators of energy efficiency?
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Executive Summary

Energy efficiency is a vital component of the Nation's energy strategy. One of the Department of Energy's missions are to promote energy efficiency to help the Nation manage its energy resources. The ability to define and measure energy efficiency is essential to this objective. In the absence of consistent defensible measures, energy efficiency is a vague, subjective concept that engenders directionless speculation and confusion rather than insightful analysis.

The task of defining and measuring energy efficiency and creating statistical measures as descriptors is a daunting one. This publication is not a final product, but is EIA's first attempt to define and measure energy efficiency in a systematic and robust manner for each of the sectors and the United States' economy as a whole. In this process, EIA has relied on discussions, customer reviews, in-house reviews, and seminars that have focused on energy efficiency in each of the sectors. EIA solicits the continued participation of its customers in further refining this work.

The term energy intensity is used to describe a statistical ratio estimator of energy use relative to energy service demand. This estimator is often used as a measurement indicator of energy efficiency; and in fact, the concepts of intensity and efficiency are sometimes used interchangeably. Intensity measures must be based on available data, and so may not reflect factors that might, if measurable, allow energy intensity to approximate energy efficiency more precisely; however, trends in the energy-intensity indicators are generally suggestive of trends in energy efficiency. Trends in energy intensity can be influenced by factors other than energy efficiency. As a practical matter, it is virtually impossible to remove, or even to consider, all of the behavioral or structural factors that would be necessary to obtain a pure measurement of energy efficiency, however broadly energy efficiency may be defined.

In this report, the focus is on the measurement of energy intensity. Wherever possible, available data are used to remove from the energy-intensity indicator influencing factors such as weather, capacity, and inventory changes that are commonly viewed as not related to changes in energy efficiency. For each sector, the number of different energy-intensity indicators presented is limited by the data available.

Each chapter covering an economic sector contains discussions of:

- *Trends in energy consumption* for the economic sector and the factors that influence changes in energy consumption
- *Description of the data* used to develop indicators of energy-intensity
- *Demand indicators* that influence the amount of energy consumed as well as their changes over time
- *Energy-intensity indicators* that compute the ratio of energy consumption to a unit of measurement, for example, Btu per square foot of floorspace, or Btu per household
- *Strengths and limitations of the energy-intensity indicators* such as whether data adequately cover the sector, whether data are of good quality and timely, or whether demand indicators characterize energy demand for all required services.

Each energy-intensity indicator is examined over two intervals of time: one beginning and ending with years of economic growth and one beginning with growth and ending with recession or in the case of the commercial building sector, beginning with recession and ending with recovery. The following is a summary of findings for each economic sector and the economy as a whole. A graphical presentation (Figures ES1 a-l) of these findings follows the sector discussions.

Residential Sector

In the residential sector, four different energy-intensity indicators were developed using data from EIA's Residential Energy Consumption Survey (RECS) (Figures ES1a and ES1b). Each of the indicators was adjusted for the influence of weather. These adjustments led either to lower reductions in the energy-intensity indicators during the growth/growth interval (1984 to 1987) or to actual increases in energy-intensity indicators during the growth/recession interval (1987 to 1990). Adjustments for the effects of weather appear to be valid. Without these adjustments, efficiency gains in the residential sector would be overestimated. Real efficiency gains appeared to have been made in the residential sector, since most intensity indicators displayed reductions; however, the magnitude of the gain cannot be determined from available data. Other structural influences, such as changes in disposable income and the mix of housing types and energy sources, may play a significant role, and the methodology to account for these and other behavioral and structural effects needs to be developed.

Commercial Building Sector

Energy-intensity indicators in the commercial buildings sector increased during the growth/growth interval (1986 to 1989), with the exception of the Btu per square-foot-hour indicator. Five energy-intensity indicators were developed, four with data from EIA's Commercial Buildings Energy Consumption Survey (CBECS) (Figures ES1c and ES1d). All five energy-intensity indicators decreased during the recession/recovery interval (1989 to 1992). Adjustments for weather and vacancy effects, for the most part, damped the increases in energy-intensity indicators during the growth/growth interval and reduced the decrease in the energy-intensity indicators during the recession/recovery interval.

It is difficult to ascertain if real efficiency gains were made in the commercial buildings sector. Only one energy-intensity indicator was consistent over both the growth/growth and recession/recovery intervals, Btu per square-foot-hour. This indicator encompasses both the size of the building and hours of usage, two major factors affecting energy usage. This indicator does show possible efficiency gains over both time intervals. More work needs to be done to capture other structural and behavioral effects that may influence changes in energy usage in this sector.

Transportation Sector

The transportation sector is one of the most difficult and complex sectors in which to determine whether efficiency gains have been made. Data are very sparse for this sector. No one survey covers the entire transportation sector in the same way the residential or commercial sector is covered, either for passenger transportation or freight. EIA fields the Residential Transportation Energy Consumption Survey (RTECS), where the fuel consumption and expenditures are based on estimates using vehicle efficiencies from the U.S. Environmental Protection Agency (EPA). RTECS does not collect data to determine passenger miles traveled, and it dropped consumption data based on fuel logs in 1985. Other passenger mode and freight mode data are collected from other sources such as *Transportation Statistics: Annual Report 1994*, published by the Bureau of Transportation Statistics, and the *Transportation Energy Data Book: Edition 14*, developed by the Oak Ridge National Laboratory for the Department of Energy. The National Personal Transportation Survey is fielded by the U.S. Department of Transportation only once every 7 years. Therefore, any energy-intensity indicators developed for the passenger, freight, or the transportation sector as a whole, should be viewed with caution.

For the **passenger transportation sector**, the best energy-intensity indicator seems to be thousand Btu per passenger mile. This intensity indicator accounts for the differences in passenger loads between the automobile and mass transit. For all passenger transportation modes, the energy-intensity indicator appeared to be on the decline or at least flat over the growth/growth interval (1985 to 1988) (Figures ES1e and ES1f). Energy-intensity indicator for mass transit seemed to be on the rise over the growth/recession interval (1988 to 1991) as passenger loads dipped. In general, the passenger transportation sector appears to be less energy intensive, a finding that implies that it may have become more energy efficient over both time intervals.

Changes in the energy-intensity indicator, energy per ton mile, for the **freight transportation sector** produced mixed results over the different modes (Figures ES1g and ES1h). It is difficult to determine whether a particular mode in the sector became more or less intensive over both time intervals. The growth/growth interval (1985 to 1988) shows a large percent increase in the energy-intensity indicator (54.5 percent). This distortion is due to the fact that small package data collection for air carriers, such as United Parcel Service, did not begin until 1986. However, for the growth/recession interval (1988 to 1991), the air-carrier mode seems to have become slightly more energy intensive. Rail is the only mode with energy-intensity indicators declining over both intervals, implying decreases in energy-intensity and increases in energy efficiency. Again, effects other than efficiency may influence these declines.

Industrial Sector

Even more troublesome data problems exist in the industrial sector. Data for the agriculture, mining, and forestry sectors are suitable only for rudimentary analysis, and they are not presented in this publication.

The Manufacturing Energy Consumption Survey (MECS), fielded by EIA, is the most comprehensive source of manufacturing energy consumption data, although several other sources exist. Seven different energy-intensity indicators are presented for the manufacturing sector as a whole, and for each of three consuming groups: High-Energy Consumers, High-Value added Consumers, and Low-Energy Consumers.

Improvements in energy efficiency in the manufacturing sector seemed to be slight, even when the effects of changes in inventory and capacity were considered (Figures ES1i and ES1j). After adjustments for these two effects, the indicator (energy per adjusted value of production) actually increased 5.0 percent over the growth/growth interval (1985 to 1988) and fell by 6.6 percent over the growth/recession interval (1988 to 1991), leaving only a 1.6-percent decrease in this energy-intensity indicator over both intervals of time.

Economy

An economy-wide energy-intensity indicator that is consistent over all sectors does not exist, except for one that uses an economic-demand indicator such as Gross Domestic Purchases, Gross Domestic Product (GDP) or population. In this report, the approach was to build a composite indicator from intensity changes and shares for each sector of the economy. EIA consumption surveys are fielded in rotating years, e.g., MECS in 1985, CBECS in 1986, and RECS in 1987, and a methodology to compensate for this obstacle was developed. Although far from perfect, the composite indicators represent a beginning in the development of an economy-wide, energy-intensity indicator.

All three of the composite indicators, as well as the energy per Gross Domestic Purchases presented in Figure 7.1 and discussed in Chapter 7, showed little or no reductions in energy intensity over both time intervals, indicating very little efficiency gains (Figures ES1k and ES1l). One exception was site energy per capita during the growth/growth interval (1985 to 1988), which increased by 6.1 percent and decreased by only 2.6 percent during the growth/recession interval (1988 to 1991). Such a finding may indicate the influence of structural and behavioral effects rather than true gains/losses in efficiency. More research is needed to refine these composites.

This report is intended to stimulate discussion and invite reader feedback and future participation.

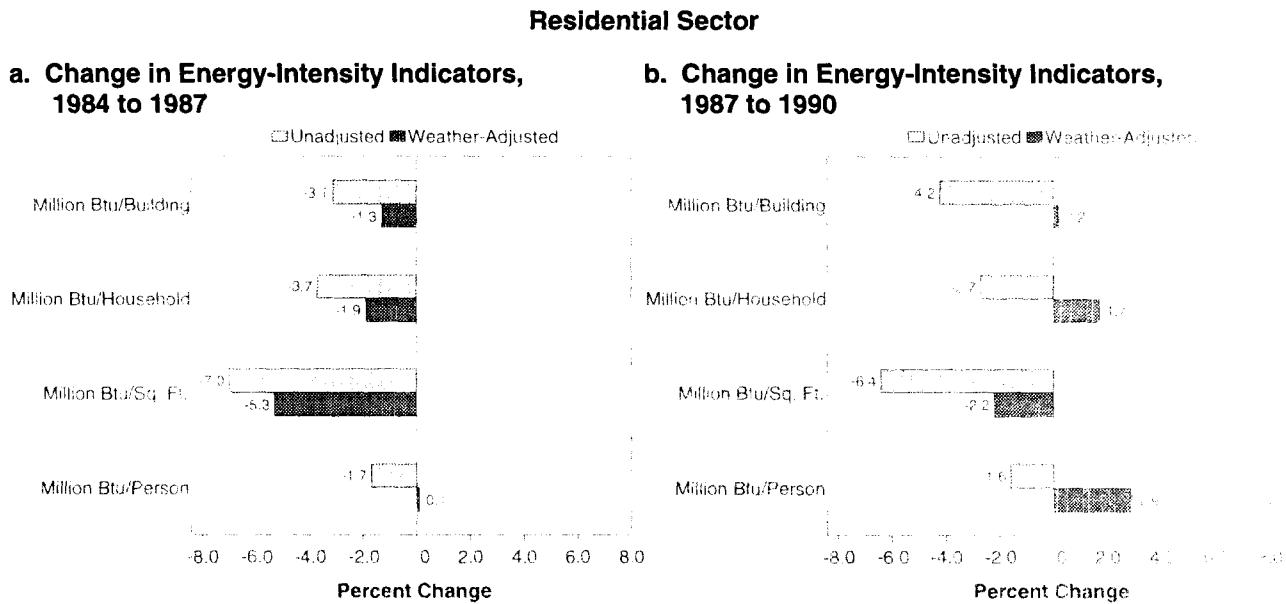
This is indeed a beginning task. EIA, with the assistance of its customers, needs to refine the energy-intensity indicators as presented.

Refining these indicators will require more work, such as:

- **Development of indicators of energy-intensity**—some demand indicators, like floorspace for commercial and residential sectors, do not completely capture the energy-demand profile. Other demand indicators or combinations of indicators need to be defined.
- **Identification and analysis of structural and behavioral effects**—energy estimates for each sector were adjusted for factors such as weather, occupancy, inventory changes, and capacity utilization; however, other effects may influence energy efficiency as well. Methodology is needed to adjust for other structural and behavioral effects.

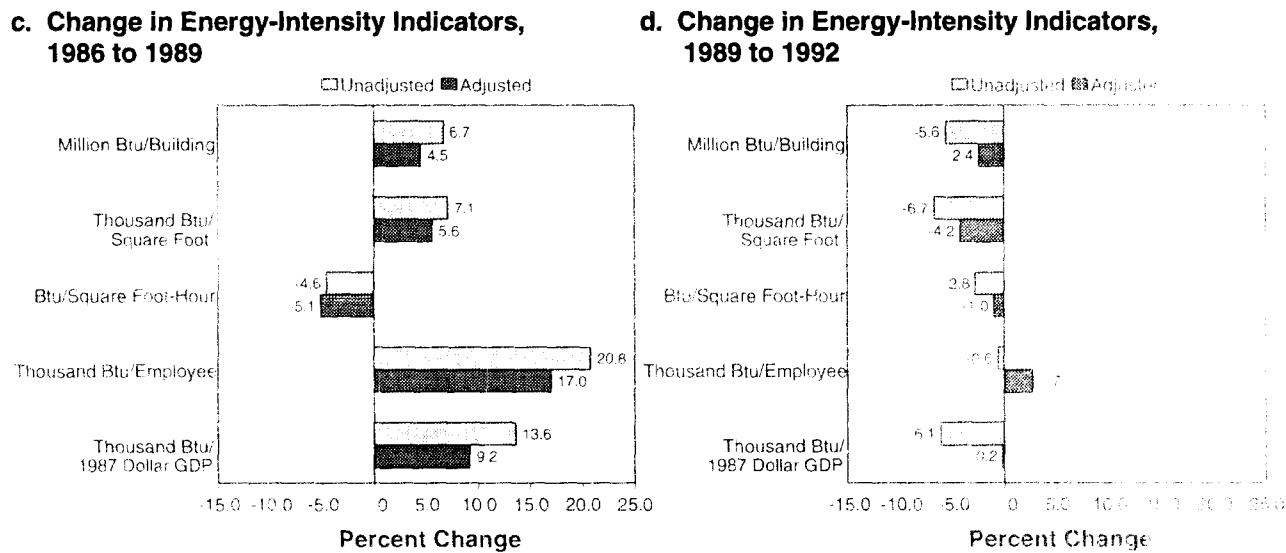
Customer participation in the form of report feedback and workshop participation will assist in obtaining the most feasible and robust indicators within the limitation of the data and resources available.

Figure ES1. Energy-Intensity Indicators for the U.S. Economy, by Sector



Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Survey; Public-Use Data Files. •U.S. Department of Commerce, Bureau of the Census, *Current Population Reports*, p. 25.

Commercial Building Sector



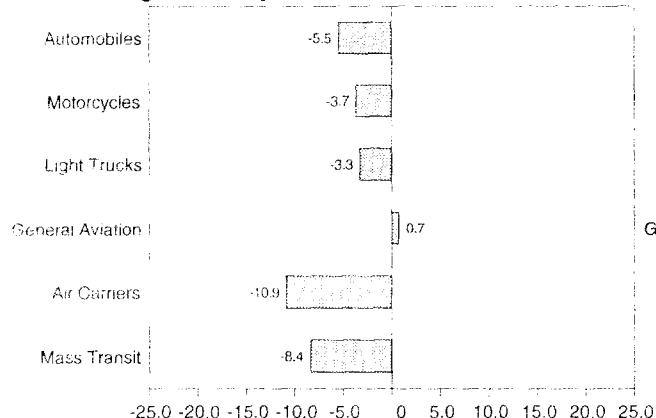
Note: "Adjusted" includes adjustments for weather and vacancy.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files. •U.S. Bureau of Labor Statistics, *Employment and Earnings*, monthly March issues. •U.S. Bureau of the Census, *Current Construction Report*, series C30 and press release CB-92-14. •U.S. Bureau of Economic Analysis, *National Income and Product Accounts of the United States*, Volume 2, 1959-1988; and *Survey of Current Business* (March 1993).

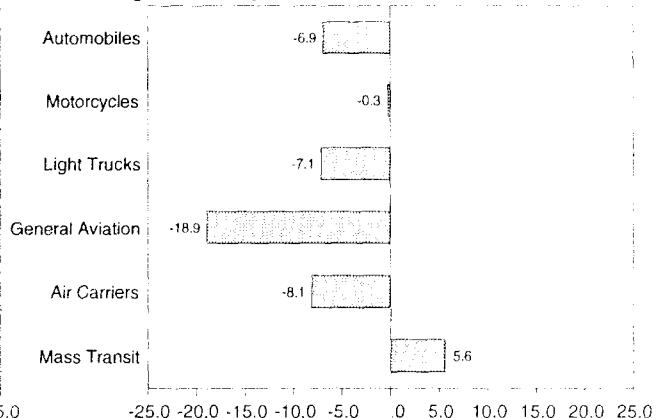
Figure ES1. Energy-Intensity Indicators for the U.S. Economy, by Sector (Continued)

Passenger Transportation Sector

e. Change in Energy-Intensity Indicator, by Passenger-Transportation Mode, 1985 to 1988



f. Change in Energy-Intensity Indicator, by Passenger-Transportation Mode, 1988 to 1991

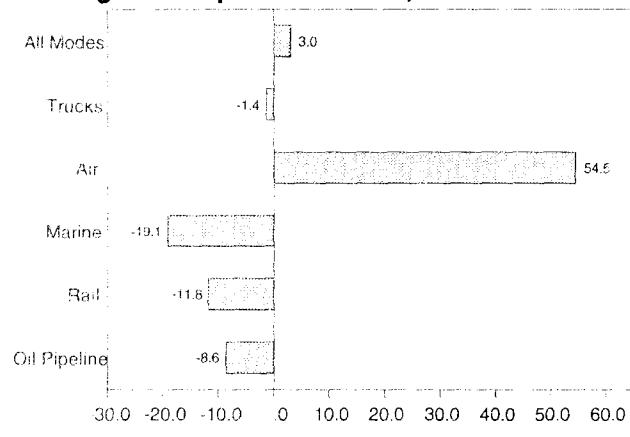


Notes: •Mass transit includes buses and passenger rail. •Derivation of these numbers are described in the Transportation section of Appendix A.

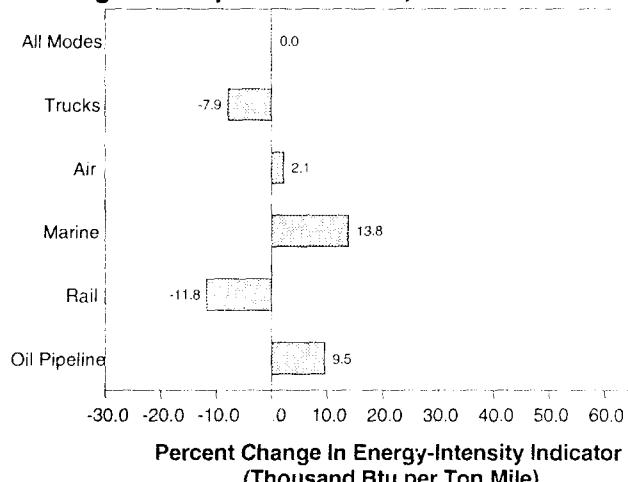
Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6.

Freight Transportation Sector

g. Change in Energy-Intensity Indicator, by Freight-Transportation Mode, 1985 to 1988



h. Change in Energy-Intensity Indicator, by Freight-Transportation Mode, 1988 to 1991



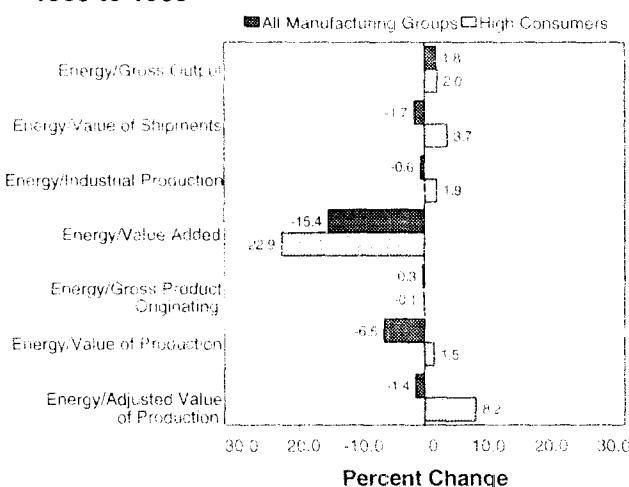
Notes: •In this graph, the share of oil pipeline in total freight consumption was less than 1 percent. •Energy for moving water and natural gas is excluded.

Sources: U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Edition 8, Table 1.5; Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. •Eno Transportation Foundation, Inc., *Transportation in America 1994*, 12th Edition, p. 44.

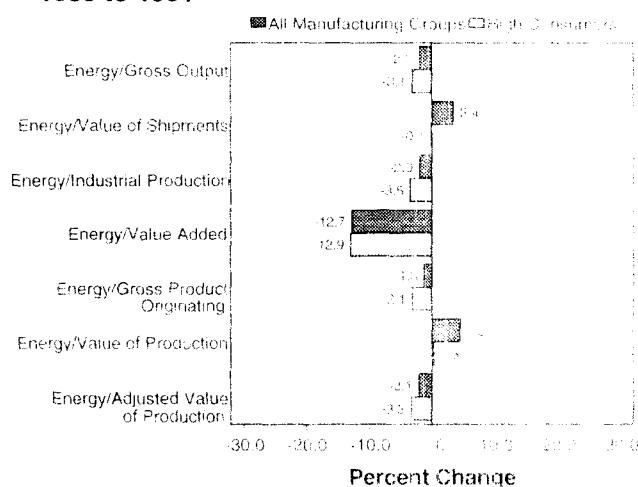
Figure ES1. Energy-Intensity Indicators for the U.S. Economy, by Sector (Continued)

Manufacturing Sector

I. Change in Energy-Intensity Indicators, 1985 to 1988



j. Change in Energy-Intensity Indicators, 1988 to 1991

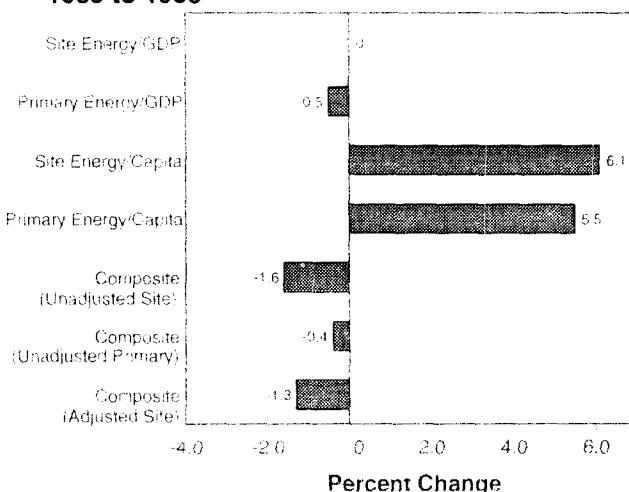


Note: The ratio of the energy-intensity indicator represents changes in thousand Btu per 1987 dollars.

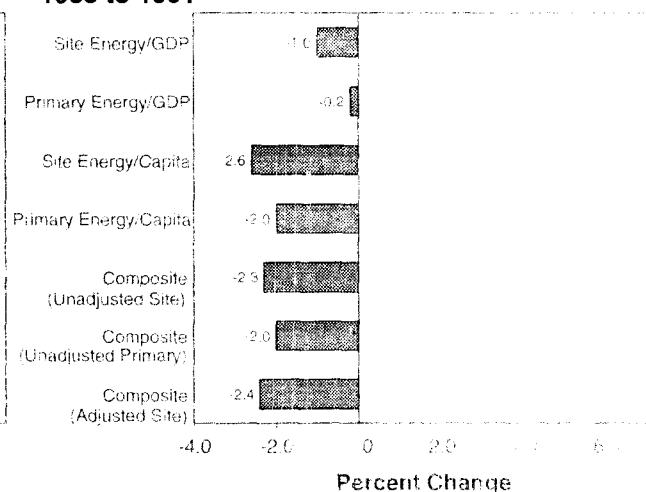
Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Wealth Division, "Gross Product by Industry," 1947-1991, files released 12/31/93, Table D3, "Gross Output for Double-Deflated Industries, Fixed 1987 Weights;" Table C1, "Gross Output by Industry, Fixed 1987 Weights;" and Table D4, "GPO Deflators." •Federal Reserve Board, Industrial Production, provided by Charles Gilbert 10/25/94. •U.S. Department of Commerce, Bureau of the Census, 1985, 1988, and 1991 Annual Survey of Manufactures, Table 2.

U.S. Economy

k. Change in Energy-Intensity Indicators, 1985 to 1988



l. Change in Energy-Intensity Indicators, 1988 to 1991



Note: In these figures GDP stands for Gross Domestic Purchases and Gross Domestic Purchases is in constant 1987 dollars.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 1.5 and 2.1; 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys; 1984, 1987, and 1990 Residential Energy Consumption Surveys; 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, National Income and Products Accounts, Quality series. •U.S. Department of Energy, Oak Ridge National Laboratory, *Transportation Energy Data Book*, Editions 11 and 14. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics* (September 1993), Tables 1, 4, and 6. •Eno Transportation Foundation, Inc., *Transportation in America 1994*, pp. 44 and 49.

1. Introduction

Measuring Energy Efficiency in the United States Economy: A Beginning is a unique publication of the Energy Information Administration (EIA). Instead of reporting survey results or summarizing the energy-related characteristics of an economic sector or industry, this report presents the first step in a development process, a work in progress that you, our customer, can help in improving and refining.

Energy efficiency has recently become the focus of increasing attention as a vital component of the Nation's energy strategy. Energy-efficiency improvement is the first objective addressed in the Department of Energy's current mission statement, "To achieve efficiency in energy use." Additionally, a major emphasis of the Energy Policy Act of 1992 (EPACT) is on energy efficiency. The ability to assess the contribution of energy efficiency towards the country's continuing efforts to manage its energy demand requires a consensus on the definition of energy efficiency. Indicators of energy efficiency are needed that are precise, valid, reproducible, and as robust as possible for each economic sector, within the limitations of data availability.

Generally, the concept of efficiency improvement is easy to rally behind. Defining and measuring it are more difficult tasks, but they must be addressed if efficiency improvement is to be a viable part of our Nation's energy strategy. In meeting its customers' needs, EIA is the most logical agency to define and measure energy efficiency. In this publication, EIA begins to address these two tasks: (1) obtain a definitional understanding of energy efficiency and (2) develop indicators of energy efficiency.

The report is not intended to be 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 in the report preparation, this publication is still nothing more than a "straw man." Many questions need to be answered, and you as our customer, if you desire, can become one of our valuable expert reviewers. As you read this report, please consider the precision and reproducibility of each methodology. Questions located on the page iii, titled "Focus Questions" at the beginning of this report may serve as a study guide for you to use as you read this report.

Preparation of this report has involved written reviews and other forms of feedback from offices within EIA—Energy Markets and End Use, Integrated Analysis and Forecasting, and Statistical Standards. Additionally, review comments were furnished by offices within the Office of the Assistant Secretary for Energy Efficiency and Renewable Energy (EE). Further comments were obtained from a series of internal seminars, which also included experts within EIA, the Department of Energy, and the National Laboratories.

Further comments on the report's contents will be sought through additional sources such as responses to an "interactive" Home Page on the Internet, electronic bulletin board workshops, and a series of 1-day sector-specific workshops to begin winter 1995. The goal of this approach will be to obtain the most robust indicators of energy efficiency that may be used over time as the standards in the measurement of energy efficiency for each sector of the U.S. economy.¹ These robust indicators will allow EIA and its customers to assess the contribution of energy efficiency toward meeting the country's continuing efforts in managing its energy demand.

Organization of the Report

This report addresses the definitional and methodological issues surrounding the measurement of energy efficiency. Since energy efficiency can rarely be measured directly, the report focuses on the changes in energy-intensity with various techniques in each of the sectors.

¹See the box on page ii for further information.

Report Organization

Chapter 2 addresses issues on definition and measurements which relate to energy efficiency. Each of the next four chapters covers one of the major sectors of the U.S. economy. In each chapter, an indexed trend in energy consumption is shown followed by an organization section and a description of the data used in that chapter. Next, a discussion of energy consumption and changes in consumption for the sector is presented. The demand indicators that influence the amount of energy consumed are explored as well as their changes over time. The energy-intensity indicators are then presented as well as the changes in these indicators over two intervals of time—an interval of economic “growth/growth” and an interval of “recession/recovery” or “growth/recession”.² Each of the chapters ends with a discussion of the strengths and limitations of the energy-intensity indicators.

Chapter 7 presents the U.S. economy as a whole. The energy-intensity indicators developed in the sectoral chapters are the inputs into an economy-wide energy-intensity indicator. Since the sectoral indicators are unique to each sector, a methodology is presented in this chapter to overcome this obstacle. This chapter also addresses the importance of including energy generation, transmission, and distribution losses in the economy-wide energy-intensity indicators. Economy-wide energy-intensity indicators are developed taking the losses into account.

Meeting Different Customer Interests and Needs

The report is designed to be read and understood by different types of customers. This is accomplished by using three methods to provide additional information, shaded boxes with text, methodology appendix, and a glossary. The shaded boxes with text, appendix, and the Glossary are designed to give the reader fast access to definitional or technical documentation.

Shaded Box with Text

Shaded boxes with text are placed frequently throughout the report. These boxes provide brief definitions or information that assists in a better understanding of the material presented.

Appendix A: Adjustments to the Data Methodology

In many cases the methodology behind the development of the energy-intensity indicators is complex. For this reason, the methodology for each indicator, estimates of energy consumption measures, and other technical issues are placed in the appendix in the appropriate section. A reference can be found either in the text or in a footnote that directs the reader; e.g., see “Primary Conversion Factors for Site Electricity” in the U.S. economy section of Appendix A for the methodology and an example.

Glossary

The Glossary, located in the back of this report, is divided into different sections. The first section is an overall general section, which includes information that is general in nature, e.g., definition of demand indicator. The next sections are sector-specific. The last section includes definitions that pertain to the economy, e.g., Gross Domestic Purchases and Gross Domestic Product.

²Two intervals of time will allow comparisons during different periods of economic activity. Additionally, the consumption survey data used in the development of the energy-intensity indicators were not available for the manufacturing and residential transportation sectors prior to 1985.

2. Defining Energy Efficiency and Its Measurement

The vast size and complexity of the U.S. economy makes consistent, meaningful, and understandable measurement of any broad-based characteristic a daunting task. Energy efficiency is no exception.

Concept of Energy Efficiency

The words "energy efficient" and "energy efficiency" are in common use qualitatively, but are difficult to define or even to conceptualize. An engineer may define energy efficiency in a very restrictive equipment sense, whereas an environmentalist may have a more broad view of energy efficiency. An economist, politician, sociologist, etc., may each have a different concept of energy efficiency.

This report, puts forth two concepts of energy efficiency, a technical concept and a more broad, subjective concept. Often the words "energy efficiency" have been used to describe what actually may be conservation. For example, consider an office building that post signs, "BE MORE ENERGY EFFICIENT—USE THE STAIRS INSTEAD OF THE ELEVATOR." If people heed the sign and take the stairs instead of the elevators, is this an increase in energy efficiency? Less energy is used, but services are reduced. Behavior has changed, leading to reductions in energy use. People with a social view of energy efficiency might consider the energy savings to be an efficiency gain, while those with a more technical view of efficiency would classify the savings as conservation rather than efficiency improvement.

Consider another example: A household undertakes measures such as adding storm doors, high-efficiency light bulbs, and attic insulation. At the same time, in the winter the household raises the thermostat and leaves the lights on for longer periods, using the same amount of energy it used previously. Has this household improved its energy-use efficiency? In a very restrictive technical sense, yes. The household is receiving higher levels of services (warmer interior) for the same energy input, and the individual services are being performed with less energy intensity (fewer watts per lumen and fewer Btu per degree temperature rise). According to an outcome-based concept, however, energy efficiency is not affected unless the higher temperatures and longer lighting hours meet additional household needs. (Box 2.1a)

Energy efficiency in a more subjective sense may refer to the relative thrift or extravagance with which energy inputs are used to provide services (Box 2.1b). Energy services encompass a myriad of activities, such as powering a vehicle or a toaster, firing a boiler, cooling an office, or lighting a parking lot. To be energy efficient per se is to provide services with an energy input that is small relative to a fixed standard or normal input.

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. Box 2.2 depicts the basic equation relating the energy use and service output relationship. The intensity component, the energy use rate, is the commonly used basis for measuring and assessing efficiency since measurement of any narrow technological definition of energy efficiency is not feasible (Box 2.3). Intensity and efficiency are not related, in an absolute sense, across energy services. Just because more energy is required to heat a ton of steel than to cook a hot dog, cooking a hot dog is not a more efficient process—it simply has smaller unit energy requirements, i.e., is less energy intensive.

Box 2.1.

Energy-Efficiency Concepts

- a. Increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs.
- b. Energy efficiency is the relative thrift or extravagance with which energy inputs are used to provide goods or services.

Box 2.2.

Relationship Between Energy Use and Service Output

$$C_s = I_s * Q_s$$

where: C_s = Energy consumption of service s,
 I_s = Intensity of energy use per service unit (or demand indicator), and
 Q_s = Measure of the total amount service s provided.

The commonly used basis for measuring and assessing efficiency since measurement of any narrow technological definition of energy efficiency is not feasible (Box 2.3). Intensity and efficiency are not related, in an absolute sense, across energy services. Just because more energy is required to heat a ton of steel than to cook a hot dog, cooking a hot dog is not a more efficient process—it simply has smaller unit energy requirements, i.e., is less energy intensive.

However, to the extent that the intensity measure is perceived as a use rate that reflects efficiency, intensity is inversely related to efficiency for a given service; that is, the less energy required to perform a given service, the greater the efficiency. It follows that a decrease in energy-intensity over time may correspond to an increase in energy efficiency depending on the level of other structural and behavioral effects.³

Box 2.3.

Energy Intensity

Energy intensity is the ratio of energy consumption to a unit of measurement (e.g., floorspace, households, number of workers, etc.)

Measuring Energy Efficiency

Change in energy use over time is driven by a combination of efficiency, weather, behavioral, and structural effects that may be only partially separable and may differ among energy services. Therefore, the task of measuring and assessing energy efficiency and its change over time consists of the following:

- Deciding which effects should be considered as inherent in efficiency measurement and which are due to weather, behavioral, and structural changes to be eliminated or, at least, recognized in the measurements
- Creating an appropriate categorization of energy services that provides the best possible framework of efficiency measures
- Combining these statistical measures into a meaningful and understandable assessment of energy efficiency and its trends.

There are two approaches to address energy-efficiency trends:

- **Market Basket.** The market-basket approach is based on consistent measures of consumption per service unit for a benchmark set of energy services.
- **Comprehensive Approach.** The comprehensive approach attempts to take all energy use into account.

Market-Basket Approach

This approach is comparable to the procedure for computing the Index of Industrial Production. The approach estimates energy-consumption trends for a controlled set of energy services (the market basket) with individual categories of energy services controlled relative to their share in the index. This method of indexing is a type of "bottom-up" approach. If a market-basket approach is used, the energy service for which efficiency is measured should encompass the broadest range of services.⁴

Limitations of the Market-Basket Approach

The overriding problem may be a lack of efficiency measures for certain classes of services and the nature of the available efficiency measures. Some of the measures may be special-purpose, specific to certain brands or population subclasses, often derived in test conditions rather than actual use, and produced without a firm plan for periodic updates. With new ways of delivering energy services appearing frequently, problems with keeping current can interfere with trend measurements. Additionally, there is a problem with consumer product substitution. If prices change, consumers have a tendency to substitute another comparable product.

³Structural and behavioral effects could mitigate any improvements in energy efficiency, resulting in actual increases in the energy-intensity indicator.

⁴For further information see "Quantity Index" in the economy section of Appendix A.

Comprehensive Approach

The comprehensive approach starts the measurement process with the broadest available measures of energy use and demand indicators available. Over time, changes in such measures reflect changes in behavior, weather, structure, and energy efficiency. In order to be a viable for assessing energy efficiency, structures of energy measures need to be produced that it is possible to separate the effects unrelated to energy efficiency. This approach can be thought of as a "top-down" approach. It is like peeling away all the effects until energy efficiency is all that remains.

The measurement of the energy efficiency in the U.S. economy or even just sectors of the U.S. economy is beyond the scope of currently available data, EIA or otherwise. This being said, the broader measure, energy intensity, which includes both the narrowly defined efficiency changes as well as some behavioral and structural changes that cannot be totally separated given currently available data, is still of interest. A "good" measure of energy intensity should identify (or remove from the measure) as many of the behavioral and structural changes that affect energy intensity, but are generally agreed to be unrelated to energy efficiency, as is computationally feasible within budget limitations and data availability.

Limitations of the Comprehensive Approach

Increased service detail provides an increased understanding of and more precise control over the concept of efficiency being measured. At the same time that energy intensities associated with energy services are changing, the amount and nature of service demands are also changing. Deciding which change should be embodied in measuring energy-efficiency change is a critical and potentially controversial subject.

Using energy-intensity as the indicator of energy efficiency and separating those changes that are not changes in energy efficiency (e.g., weather) requires service detail in both the numerator (energy consumption) and denominator (demand indicator). It is impossible to extricate all weather, structural, and behavioral changes from efficiency assessment using the comprehensive approach. Some economic sectors have poor or nonexistent information on energy use and/or characteristics associated with energy use.

Box 2.4.

Energy Consumption

Energy consumption used in the intensity indicator can either be **primary energy** or **site energy**.

- **Primary energy** is the amount of energy delivered to an end user (e.g., residential housing unit) adjusted to account for the energy that is lost in the generation, transmission, or distribution of the energy.
- **Site Energy** is the amount of energy delivered to an end user that is **not** adjusted to account for the energy lost in the generation, transmission, and distribution of the energy.

Demand Indicator

A Demand Indicator is a measure of the number of energy-consuming units, or the amount of service or output, for which energy inputs are required.

Approach Used in this Report

This report uses the comprehensive approach. The categorization of energy-using sectors and the discussion of energy consumption and demand indicators as they are related to energy intensities will originate largely from EIA's end-use consumption surveys. There are many other data sources, originating both within and outside of EIA, that also are used as tools for this analysis. Some data, such as information from the Department of Transportation, are of considerable use in deriving energy-intensity indicators for particular energy-service categories that are not covered by consumption surveys or are covered in insufficient detail.

EIA's consumption surveys are triennial data collections that presently cover four sectors: residential households, residential personal-use vehicles, commercial buildings, and manufacturing establishments. They are designed to provide information on energy consumption and expenditures and on characteristics of the energy-consuming units that affect energy use.

There are other more rigorous approaches than the one used in this report. The U.S. Department of Energy's Office of Policy in April 1995, released the report, *Energy Conservation Trends* (DOE/PO-0034). This report uses the Divisia approach, which mathematically decomposes any time trend as a product of component elements.⁵ EIA's consumption surveys are relatively new and therefore time trend data based on these surveys are not available at this time. Additionally, formal econometrics and statistical analysis were not employed since the time trend data from the surveys were limited and budget limitations did not permit a more rigorous approach at this time.

Box 2.5.

Energy Information Administration End-Use Consumption Surveys

Strengths

- Cover broad, well-defined subsets of the U.S. economy that are delineated by their energy needs and use patterns
- Representative of the entire United States
- Measure actual energy use, rather than examples of use under test conditions or other special circumstances
- Measure use of major energy sources for most purposes within the sector
- Provide information on the ways in which energy is used, characteristics of the users, and energy consumption
- Statistical methods have been/are being developed to partition energy use from these surveys into service categories, e.g., space heating.

Limitations

- Incomplete coverage of the sectors, especially the industrial and transportation sectors
- Data collections are every 3 years
- Years for the sector data collections do not overlap
- Lack of energy end-use specific data for several sectors
- Lag between data collection and its availability for analysis
- Precision limitations of energy estimates
- Lack direct information on equipment efficiency on usage rates.

⁵For additional information comparing the Divisia and other methods, see Boyd G.A., D.A. Hanson, and T. Stemmer (October 1988), "Decomposition of Changes in Energy Intensity: A Comparison of Divisia Index and Other Methods," *Energy Economics*, pp. 309-312. Another source is Howarth, R.B., L. Schipper, P.A. Duerr, and S. Strom. (April 1991) "Manufacturing Energy Use in Eight OECD Countries," *Energy Economics*, pp. 135-142.

3. The Residential Sector

Introduction

More than 90 million single-family, multifamily, and mobile home households encompass the residential sector. Households use energy to cool and heat their homes, to heat water, and to operate many appliances such as refrigerators, stoves, televisions, and hot tubs.

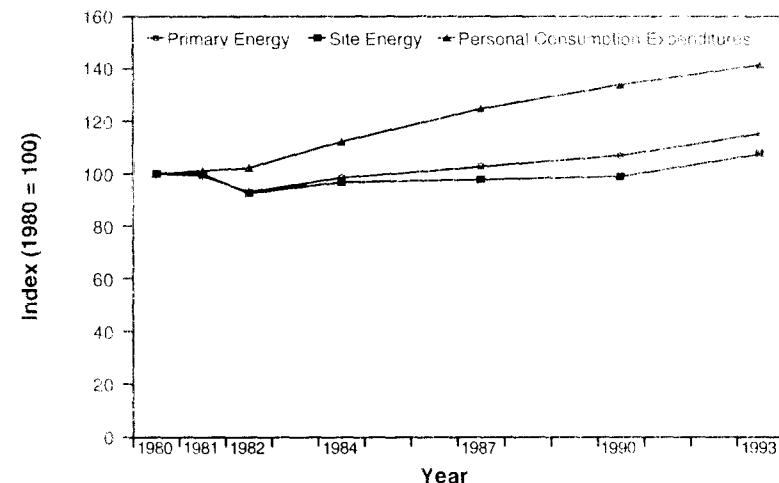
The energy sources utilized by the residential sector include electricity, natural gas, fuel oil, kerosene, liquefied petroleum gas (propane), coal, wood, and other renewable sources such as solar energy.⁶

Early in the 1980's total energy consumption in the residential sector started to decline, although personal consumption expenditures continued to increase (Figure 3.1). Since this slight dip in the early 1980's, energy use has remained near its 1980 level to the present time, while personal consumption expenditures have continued to rise. During this time, when personal consumption expenditures were increasing, the percent of energy in total personal consumption expenditures was falling. Additionally, even though households were purchasing more energy for appliances such as televisions and dishwashers, many of the appliances were using less energy than older models.

Act (NAECA) of 1987 mandated minimum energy efficiency standards for several types of household appliances and equipment such as refrigerators, freezers, room air conditioners, television sets, furnaces, water heaters, and heat pumps. This followed the earlier voluntary appliance efficiency targets of the Energy Policy and Conservation Act (EPCA) of 1975 and various State appliance-efficiency standards. In response to these various standards, manufacturers have improved the energy efficiency of household appliances and equipment over the past 20 years.

As, Figure 3.1 shows, an increasing gap has developed between primary and site energy consumed in the residential sector. Site electricity consumption as a percent of total site energy has climbed from 27 percent in 1982 to 33 percent in 1993.⁷ Greater usage of electricity, due mainly to more widespread use of electric heat pumps, central air conditioning, and appliances, is largely responsible for this widening gap. The losses in the generation, transmission, and distribution of electricity are more than twice the amount of electricity delivered to the household. These losses are incorporated into the primary energy estimates.

Figure 3.1. Total Site Residential Energy Consumption and Personal Consumption Expenditures Indices, 1980 to 1993



Notes: •Personal consumption expenditures used to develop the index are in constant 1987 dollars. •These expenditures include all personal expenditures and not only those for energy. •Energy sources include: natural gas, electricity, liquefied petroleum gas, fuel oil, and kerosene. •Preliminary RECS data used for 1993.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 2.1 and 5.17; 1980, 1981, 1982, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files. •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, *National Income and Product Accounts*, Quantity series.

⁶In this chapter, total site energy consumption includes only: natural gas, electricity, liquefied petroleum gas, fuel oil, and kerosene.

⁷Based on preliminary data from the 1993 Residential Energy Consumption Survey (RECS) since final 1993 RECS data were not available at the time of this analysis.

Chapter Organization

In this chapter, the major data source, EIA's Residential Energy Consumption Survey, is described first. This is followed by a discussion of energy consumption in the residential sector and the necessity of adjusting consumption for changes in weather before any analysis is undertaken. Next, the demand indicators—households, buildings, household members, and floorspace—are described along with the trends in these demand indicators. Four energy-intensity indicators are presented, followed by a discussion of the strengths and limitations of these energy-intensity indicators.

Major Data Sources

Energy Information Administration

Residential Energy Consumption Survey (RECS)

The RECS is conducted every 3 years by the EIA. It is a national sample survey of more than 5,000 residential housing units and their energy suppliers. The RECS is the only comprehensive source of national-level data on energy-related information such as energy consumption for the residential sector.

The RECS is a national multistage probability sample survey. Housing unit and household characteristics data are collected via personal interview with the householder. Householders are asked to sign authorization forms allowing their suppliers of energy to release billing information about their households. A mail survey is used to collect this information on energy consumption from the energy suppliers. Using the RECS data, end-use estimates for space heat, air conditioning, water heating, and appliances are obtained by disaggregations of actual bills using a nonlinear technique.⁸

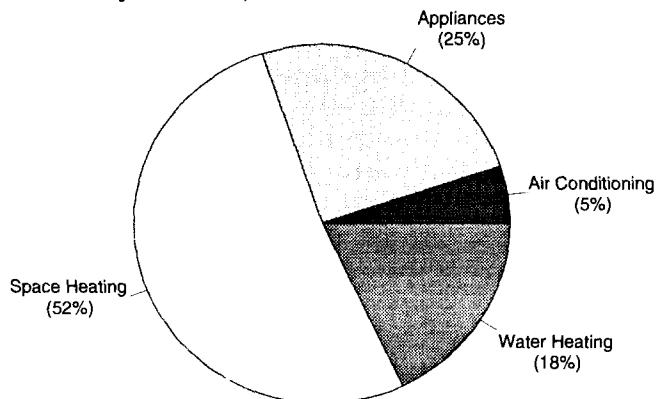
Energy Consumption in the Residential Sector

Background

Residential energy provides numerous services associated with household living, including space heating and cooling, water heating, cooking, refrigeration, lighting, and the powering of a wide variety of other appliances. Space heating is the dominant energy service. In 1990, 52 percent of the total site energy was used to provide space heating, followed by 25 percent used for appliances (Figure 3.2).

Energy demand is shaped by a variety of factors, including type of housing unit, location, and climate. The dominant housing type in the residential sector by far is the single-family detached housing unit. In 1990, 62 percent of the 94 million housing units were detached single-family units (Figure 3.3). Single-family detached housing units consumed 72 percent of total site energy (Figure 3.4). In fact, single-family detached homes are the most energy-intensive housing type, consuming 113 million Btu per household compared with an average of 98 million Btu per household for all housing types in 1990.

Figure 3.2. Percent of Total Site Energy Consumption by End Use, 1990



Note: Energy sources are electricity, natural gas, fuel oil, kerosene, and liquefied petroleum gas.

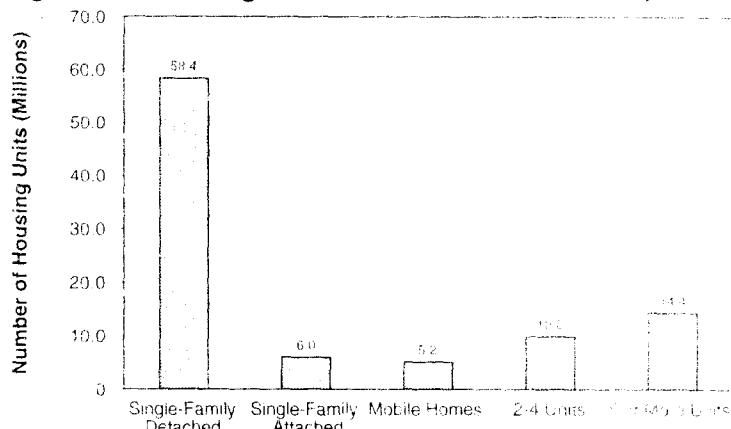
Source: Energy Information Administration, Office of Energy Markets and End Use, 1990 Residential Energy Consumption Survey, Public-Use Data Files.

⁸See *Household Energy Consumption and Expenditures 1990*, Appendix D, "End-Use Estimation Methodology," for details on the procedures used to calculate the end-use estimates. This EIA publication also describes the RECS sample design, data collection procedures, and limitations of the RECS data.

Location is an important factor in determining energy consumption. Different regions of the country face different weather patterns, building codes, energy-related behavior, fuel mixes, and equipment needs and suitability. In 1990, the Midwest used 31 percent of the total site energy, whereas the West used only 16 percent, half the amount that the Midwest used with only 16 percent fewer households (Figure 3.4). Weather played a large part in this difference. Eighty-five percent of the housing units in the Midwest were located where heating-degree-days (HDD)⁹ for 1990 exceeded 5,500. On the other hand, only 24 percent of housing units in the West were located where the HDD's for 1990 were more than 5,500.

Energy consumption in the residential sector is examined for two time intervals, a growth/growth interval (1984-1987) and a growth/recession interval (1987-1990).¹⁰

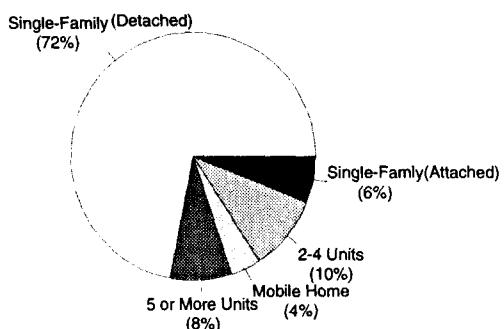
Figure 3.3. Housing Units in the Residential Sector, 1990



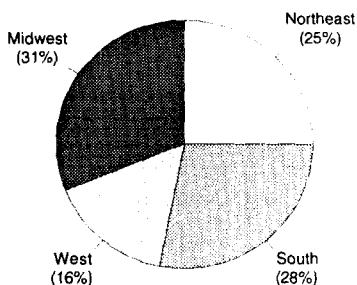
Source: Energy Information Administration, Office of Energy Markets and End Use, 1990 Residential Energy Consumption Survey, Public-Use Data Files.

Figure 3.4. Percent of Total Site Energy Consumption, 1990

a. Housing Type



b. Census Region



Note: Energy sources are electricity, natural gas, fuel oil, kerosene, and liquefied petroleum gas.

Source: Energy Information Administration, Office of Energy Markets and End Use, 1990 Residential Energy Consumption Survey, Public-Use Data Files.

Energy Trends

Among all households, the growth of total site energy consumption was nearly stable, with a recorded growth of approximately 1 percent per time interval (Figure 3.5). However, this pattern of growth was not the same for each of the individual housing types. Total site energy consumption grew during the growth/growth interval for each of the housing types with the exception of multifamily units (Figure 3.6). This trend continued partially during the growth/recession interval and reductions in total site energy consumption were even more pronounced for all households in large multifamily buildings. From 1987 to 1990, the number of occupied units in large buildings decreased by about half a million.¹¹ Attached single-family housing units, which had experienced growth in total consumption during the growth/growth interval, actually experienced reductions during the growth/recession interval.

⁹See "Heating-Degree-Days" and "Cooling-Degree-Days" in the general terminology section of the Glossary.

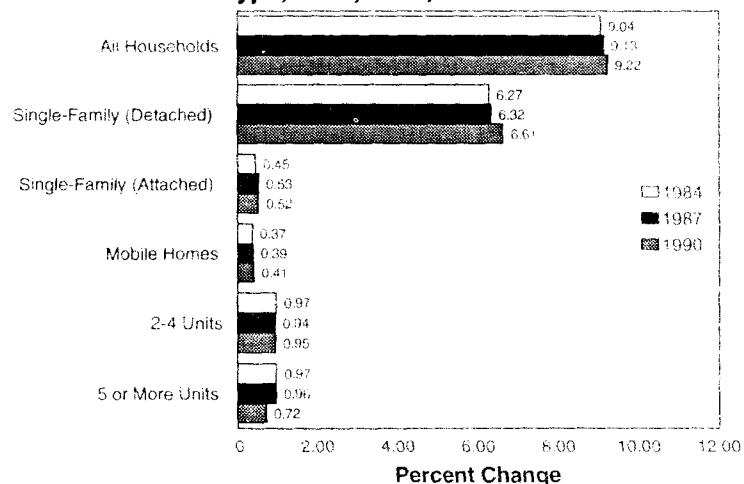
¹⁰The word "recession" is used to describe a period of slow or no economic growth. A recession is officially defined as two consecutive quarters of falling Gross National Product.

¹¹RECS does not collect data on vacant or seasonal housing units.

The weather was mild in the years studied (1984, 1989, and 1990) compared to 30-year averages. In 1990, the weather was 14 percent warmer than the average. In 1987, the weather was 8 percent warmer than the average while in 1984, the weather was 2 percent colder than the average. When weather effects like these are not considered, reductions in total energy consumption due to milder weather, could be regarded as increases in energy efficiency when indeed, they are not.

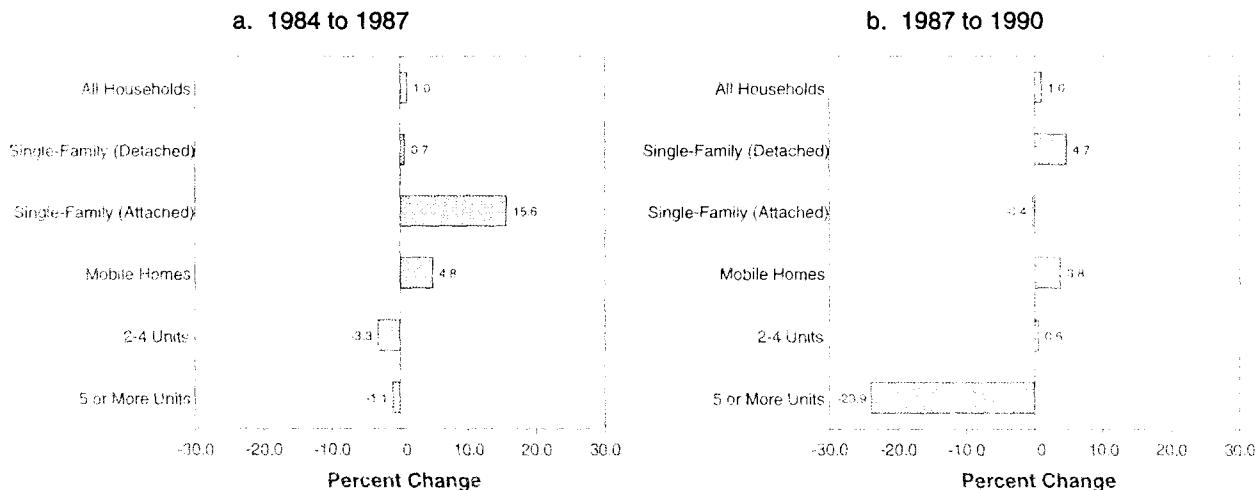
Total residential site energy increased by 2 percent from 1984 to 1990, but adjusting for weather suggests that if the weather had been average, total energy consumption would have grown by 9 percent during 1984-1990. Comparison of weather-adjusted trends against the unadjusted total energy consumption trends suggests that the weather-induced "conservation" should be removed before any attempt is made to develop energy-intensity indicators.

Figure 3.5. Total Site Energy Consumption by Housing Unit Type, 1984, 1987, and 1990



Sources: Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files.

Figure 3.6. Change in Total Site Energy Consumption by Housing Unit Type



Sources: Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files.

In this chapter, total site energy consumption is weather-adjusted before any attempt is made to present energy-intensity indicators. Weather-adjusted total site energy consumption is calculated for each Census region. For 1984, 1987 and 1990, space-heating energy consumption is adjusted by a heating-degree day (HDD) factor and the air-conditioning demand is adjusted by a cooling-degree day (CDD) factor, to which was added unadjusted demand for all other end uses. The methodology used to develop the HDD and CDD factors and adjusted total site energy consumption estimates is presented along with examples in the residential section of Appendix A under "Degree-Day-Adjusted Estimates."

As seen in Figure 3.7 covering intervals of growth/growth and growth/recession, if total site energy consumption is not adjusted for the mild weather, growth in total site energy consumption is underestimated.

Demand Indicators

The main demand indicators or drivers for energy services in the residential sector are the number of households, population, buildings, and the amount of floorspace (Figure 3.8).

Trends in Demand Indicators

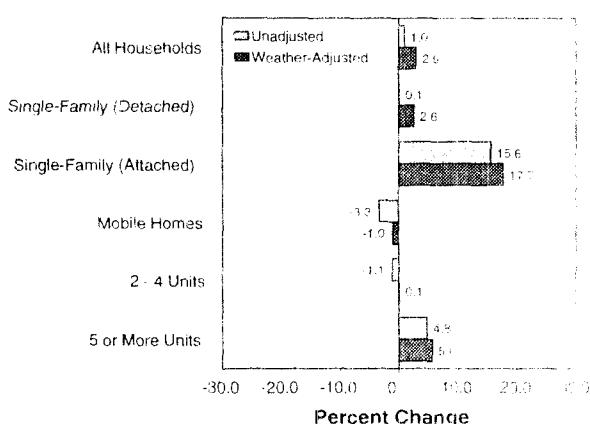
Households

The housing stock has changed significantly since 1984. The number of households grew by 4.9 percent during the growth/growth interval and 3.8 percent during the growth/recession interval.

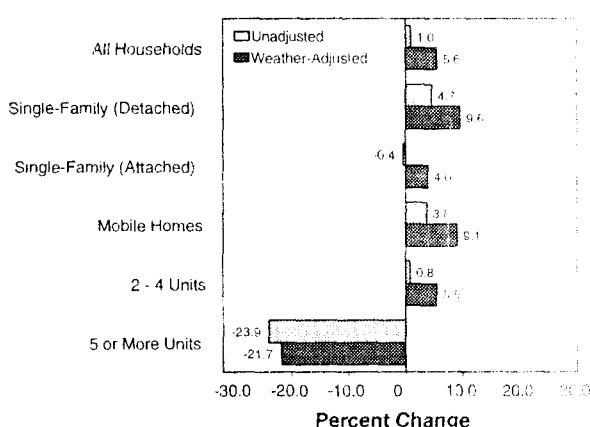
Much of this growth was in the South. Figure 3.9 shows that the greatest percentage of older households (at least 10 years old) is largest in the Northeast and smallest in the South. The growth in the construction of new housing units in the South is also one reason for the increase in households with air-conditioning. New housing units are more apt to have central air-conditioning. Between 1984 and 1990, the number of air-conditioned households throughout the country increased by almost 24 percent (Table 3.1). Throughout the period, the fuel mix also changed in United States households. The increased use of the electric heat pump, especially in the South, drove the 48 percent increase in the use of electricity as the main heating fuel.

Figure 3.7. Change in Unadjusted and Weather-Adjusted Site Energy Consumption by Housing Unit Type

a. 1984 to 1987



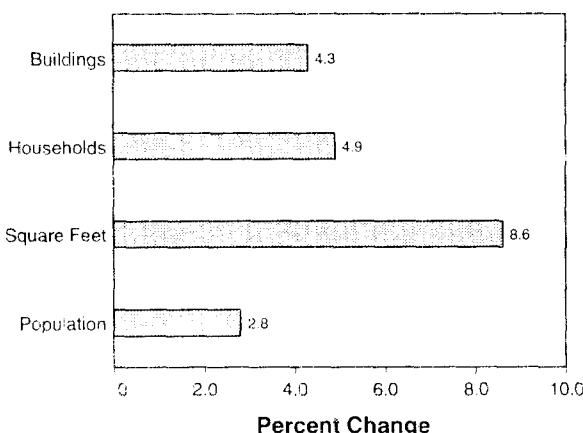
b. 1987 to 1990



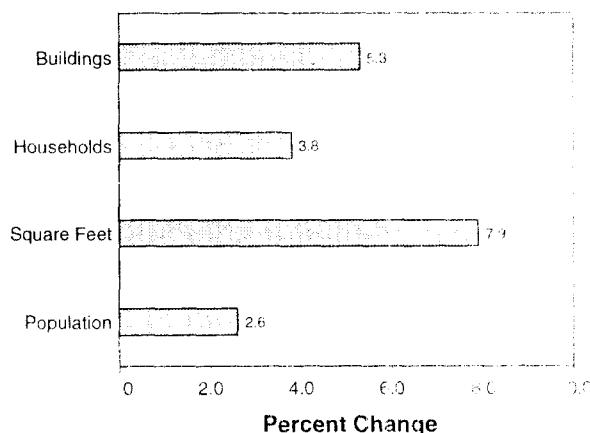
Sources: Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files.

Figure 3.8. Change in Demand Indicators in the Residential Sector

a. 1984 to 1987



b. 1987 to 1990



Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files. •U.S. Department of Commerce, Bureau of the Census, *Current Population Reports*, p. 25.

Population

The number of households is growing faster than the U.S. population. The population grew by only 6 percent during 1984-1990, whereas the number of households grew by 9 percent. This led to a decline in household size from 2.73 members per household in 1984 to 2.65 members per household in 1990.

Furthermore, in 1990, 25 percent of the households had only one member—in 1984 this percent was 23.6.¹²

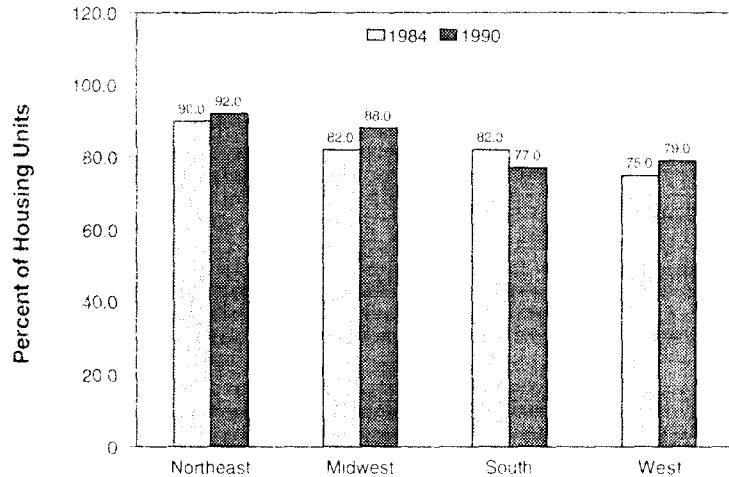
Floorspace

Total residential floorspace increased by 17 percent between 1984 and 1990, much faster than the growth in the number of households. The size of housing units has grown over time from 1,673 square feet per household in 1984 to 1,800 square feet per household in 1990.¹³

Buildings

The number of residential buildings between 1984 and 1990 grew faster than the number of households (9.8 percent growth for buildings and 8.9 percent for households), indicating greater construction of single-family homes. This was the case during the growth/recession interval but less strong during the growth/growth interval between 1984 and 1987 (Table 3.1).

Figure 3.9. Percent of Housing Units at Least 10 Years Old by Census Region, 1984 and 1990



Sources: Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files.

Box 3.1.

Demand Indicators in the Residential Sector

- Number of Households
- Number of Household Members
- Number of Buildings
- Amount of Floorspace

Table 3.1. Demand Indicators in the Residential Sector, 1984, 1987, and 1990

Demand Indicator	Units		
	1984	1987	1990
Million Buildings	67.6	70.5	74.2
Million Households	86.3	90.5	94.0
With Air-Conditioning	51.4	57.5	63.6
With Electricity as the Main Heat Source	14.5	17.9	21.5
Single-Family Detached	53.5	55.2	58.4
Billion Square Feet	144.4	156.9	169.2
Heated	124.3	135.0	147.5
Cooled	89.1	104.0	118.8
Million Residents	235.8	242.3	248.7

Sources: ●Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files. ●U.S. Department of Commerce, Bureau of the Census, *Current Population Reports*, p. 25.

¹²Energy Information Administration, *Housing Characteristics 1990*, DOE/EIA-0314(90), Table 11; *Housing Characteristics 1984*, DOE/EIA-0314(84), Table 17.

¹³Energy Information Administration, *Housing Characteristics 1990*, DOE/EIA-0314(90), Table 15; *Housing Characteristics 1984*, DOE/EIA-0314(84), Table 20.

Demand-Indicator Adjustments

Demand indicators in the residential sector are influenced by behavioral and structural effects that can mask the effects of energy-efficiency changes. The major behavioral influences on residential energy consumption include changes in family size, income, average length of daily occupancy, age of household members, thermostat setting, and the number of employed members of household.¹⁴ Structural changes include household size (floorspace), building age, location (region), and fuel mix used.

These behavioral and structural effects must be taken into account in comparisons of energy-intensity indicators over time. For example, increases in floorspace per household member (612 square feet per household member in 1984 to 680 square feet in 1990) increase the demand for space heating and air conditioning, lighting, and convenience appliances such as dishwashers.

A behavioral change affecting energy consumption is the growing number of single-member households. Declines in household size also result in more floorspace per person, higher heating demand, and lower water heating demand per person. Households with fewer members will often acquire the same number and size of major appliances, and consume more energy per household member than a larger household. At the same time, though, single persons may spend less time at home than families, resulting in fewer hours demanding energy.

Over the whole population, disposable income per capita has increased. During the growth/growth interval, disposable income in constant dollars increased 16 percent whereas during the growth/recession interval, this growth was limited to 4 percent.¹⁵ While single-member and two-person households may spend less time at home, thereby using less energy, they and larger households may also increase the demand for energy services if disposable incomes have increased. Purchase of such energy-using equipment as computers, hot tubs, home theater systems, and swimming pools increase residential energy consumption.

Illustrated are only a few of the behavioral and structural influences that affect the demand for energy services in the residential sector. The next section presents choices of energy-intensity indicators for the residential sector. The behavioral and structural influences described in this section need to be considered when the comparisons of the energy-intensity indicators are presented over time.

Energy-Intensity Indicators for the Residential Sector

Energy consumption and the drivers of the demand for energy in the residential sector, the demand indicators, have been presented in detail. The next step is to construct energy-intensity indicators for the residential sector. Box 3.2 lists the indicator choices presented in this section. Each of the indicators have their own strengths and limitations, which will be discussed in the next section. Additionally, although the indicators presented in this chapter are based only on site energy consumption, the indicators may also be presented based on end-use site energy consumption such as space heating. However, not all of the demand indicators are suitable to use in the development of end-use intensity indicators. For example, the energy used for space heating may be presented as space-heating energy per square foot, but it would not make sense to use the square foot demand indicator to develop a water-heating intensity indicator. A more suitable energy-intensity indicator would be water-heating energy per household member.

Box 3.2.

Energy-Intensity Indicators for the Residential Sector

- Million Btu per Building
- Million Btu per Household
- Thousand Btu per Square Foot
- Million Btu per Household Member

¹⁴U.S. Congress, Office of Technology Assessment, *Building Energy Efficiency*, OTA-E-518, May 1992, p. 20.

¹⁵U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business Patterns*, August issues.

Table 3.2. Unadjusted and Weather-Adjusted Residential Site Energy-Intensity Indicators, 1984, 1987, and 1990

Energy-Intensity Indicator	Units					
	1984		1987		1990	
	Unadjusted	Weather Adjusted	Unadjusted	Weather Adjusted	Unadjusted	Weather Adjusted
Million Btu/Building	134	135	130	133	124	133
Million Btu/Household	105	106	101	104	98	105
Thousand Btu/Square Foot	63	63	58	60	55	59
Million Btu/Person	38	39	38	39	37	40

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, 1990 Residential Energy Consumption Surveys, Public-Use Data Files. •U.S. Department of Commerce, Bureau of the Census, *Current Population Reports*, p.25.

Energy-Intensity Indicator Trends

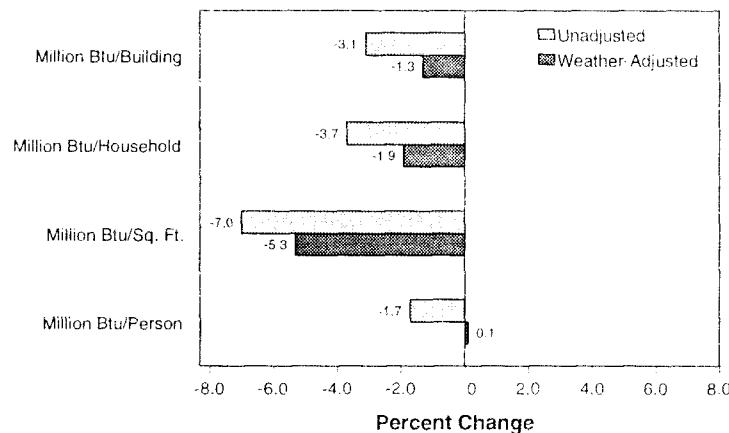
Table 3.2 shows estimates for the various energy-intensity indicators for 3 of the RECS years. Two sets of estimates are presented: unadjusted and weather-adjusted. Given the variety of indicators available, caution is warranted in the interpretation of residential energy-intensity indicators since the magnitude and direction of the energy-intensity indicator changes are dependent on the choice of the demand indicator. Figure 3.10a shows the changes in these indicators over the growth/growth interval. In the absence of adjusting consumption for weather deviations from the normal average, energy-intensity appears to fall during the growth/growth interval, and energy efficiency may have increased, no matter which indicator is used.

When weather adjustments are made, the decreases in energy-intensity are less pronounced. The story is slightly different when comparing changes in these energy-intensity indicators over the growth/recession interval (Figure 3.10b). All of the energy-intensity indicators registered a decrease in intensity, suggesting an increase in energy efficiency. Weather-adjusted energy-intensity indicators, with the exception of million Btu per square foot, actually registered increases in energy-intensity suggesting decreases in energy efficiency over the growth/recession interval.

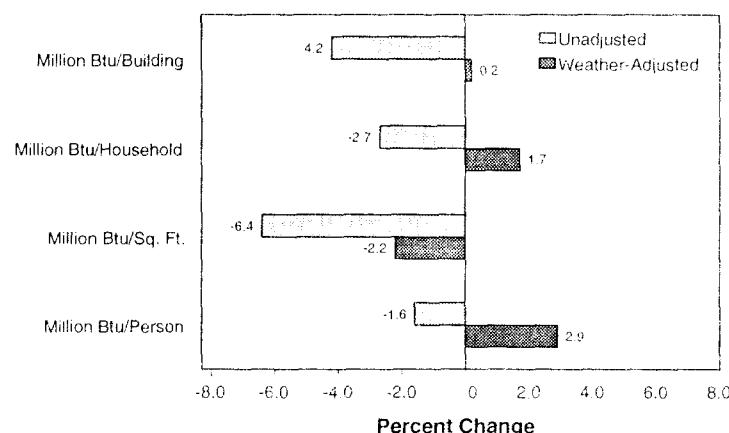
Individually, the demand indicator, square feet, registered the largest percent increase over the growth/growth interval, partially causing the energy-intensity indicator, million Btu per square foot, to register the largest percentage decrease in energy-intensity. Underlying this was the growth in the average size of the housing units, a structural change. Conversely, the smallest decrease in an energy-intensity indicator, million Btu per person, reflected the fact that the growth in population registered the slowest percent change of all of the demand indicators. When adjustments were made for weather effects, this intensity indicator actually increased.

Figure 3.10. Change in Energy-Intensity Indicators for the Residential Sector

a. 1984 to 1987



b. 1987 to 1990



Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Survey, Public-Use Data Files. •U.S. Department of Commerce, Bureau of the Census, *Current Population Report*, p. 25.

Some of the decreases in the intensity indicators during both the growth/growth and growth/recession intervals may be a reflection of energy-efficiency increases. However, the above discussion gives the reader a clearer understanding of the difficulties in trying to assess energy-intensity changes as a reflection of changes in energy efficiency. Efficiency gains or reductions are taking place along with structural and behavioral changes. To unbundle the intensity indicators and obtain "true" or "pure" energy efficiency is impractical if not impossible. Adjustments such as the degree-day adjustments and awareness of the behavioral and structural influences are about the most that may be done, especially in an environment of limited data, time, and resources. Standardizations can be done to take care of the structural changes such as: changing distribution of the household by household type.

Another aspect in the development of energy-intensity indicators is the ability to make comparisons within a particular indicator, such as million Btu per household, but over characteristics such as type of housing unit. These comparisons may be more fruitful. The million Btu per household is not a particularly robust indicator in that energy use per household incorporates changing household member compositions, size, and housing type distributions. The energy-intensity indicators may become more robust if the indicator is decomposed by characteristics, such as housing type.

Table 3.3 does just that for two characteristics, type of housing unit and Census region. One can see the differences in the energy-intensity indicator across a particular characteristic, whether the energy-intensity indicator was unadjusted or weather adjusted. Taking the characteristic, type of housing unit as an example, will demonstrate the advantages of comparing within an energy-intensity indicator and across the characteristic. The more detailed "micro-residential" energy-intensity indicator is more robust.

**Table 3.3. Unadjusted and Weather-Adjusted Residential Energy-Intensity Indicator,
1984, 1987, and 1990
(Million Btu per Household)**

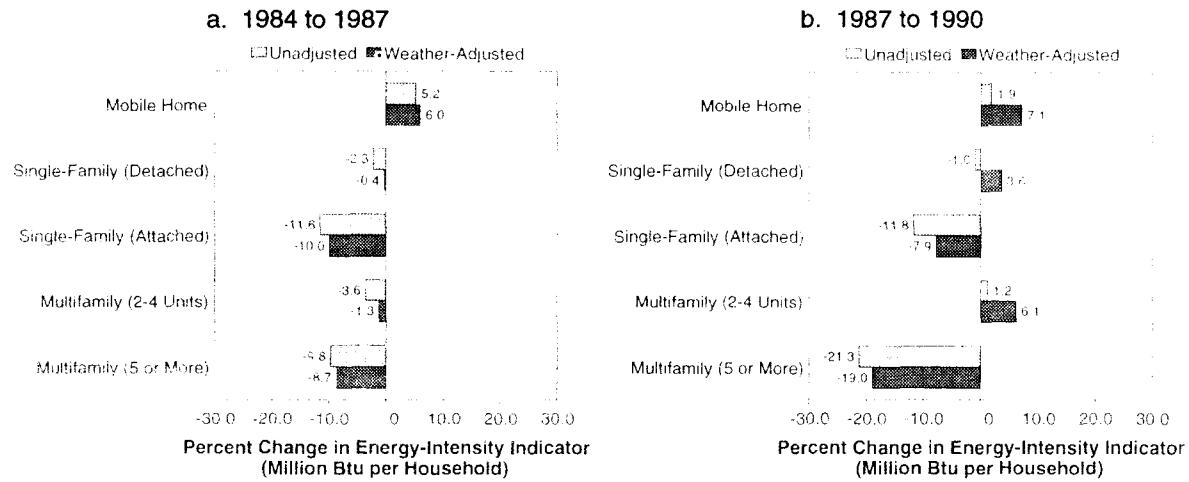
Characteristic	Million Btu/Household					
	1984		1987		1990	
	Unadjusted	Weather Adjusted	Unadjusted	Weather Adjusted	Unadjusted	Weather Adjusted
All Households	105	106	101	104	98	105
Census Region						
Northeast	125	127	124	126	120	131
Midwest	129	130	123	131	122	131
South	85	87	84	84	81	87
West	85	85	78	80	78	79
Type of Housing Unit						
Mobile Home	73	74	76	78	78	84
Single-Family Detached ..	117	118	114	118	113	122
Single-Family Attached ...	112	113	99	101	87	93
Multifamily (2-4 Units)	97	98	93	96	95	102
Multifamily (5 or More) ...	71	72	64	66	51	53

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, 1990 Residential Energy Consumption Surveys; Public-Use Data Files.

The largest decreases in the intensity indicator, million Btu per household, was in the single-family attached and large multifamily housing units (Figure 3.11). Since 1984, the number of occupied large multifamily housing units declined by almost a half-million units in 1990 as well as total consumption for all large multifamily units.

After weather adjustments, intensity actually increased during the growth/recession interval in the single-family detached and smaller multifamily housing units.

Figure 3.11. Change in an Energy-Intensity Indicator by Housing Unit Type



Note: The percent changes were based on unrounded data.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1984, 1987, and 1990 Residential Energy Consumption Surveys, Public-Use Data Files.

Strengths and Limitations of the Energy-Intensity Indicators

Four energy-intensity indicators were presented in this chapter that may be used as the basis for the measurement of energy efficiency. All four indicators are imperfect. One imperfection can easily be addressed: the influence of changes in the weather. Adjusting the intensities for weather, especially since the recent years have been mild, can explain a considerable portion of the reductions in these energy-intensity indicators. Structural and behavioral influences affect all four indicators, some more than others. Energy use per person account for population growth but does not address other issues. Energy per household does not account for the expansion in household floorspace whereas energy per square foot does. Energy per square foot may be appropriate for some end uses, e.g., space-heating energy, but not for others such as water heating energy.

No single energy-intensity indicator for the residential sector stands out as clearly superior to the others. The choice of indicator depends on the questions asked and on data and resource availability.

4. Commercial Building Sector

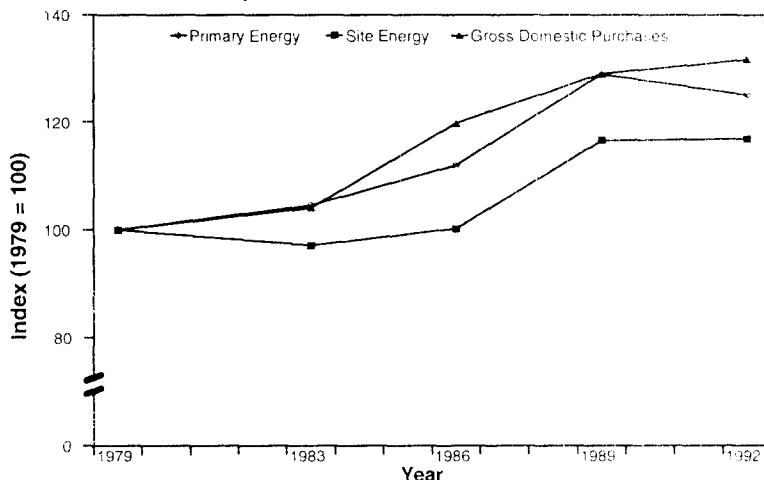
Introduction

The commercial building sector is extremely difficult to delineate. As generally covered by EIA, and for the purposes of this document, the commercial building sector consists of all buildings that meet the definition of a building and for which the majority of floorspace is dedicated to activities other than residential or industrial¹⁶ businesses. The vast majority of energy use associated with this sector occurs in buildings, to maintain the building environment, and provide building-based services. Commercial buildings encompass diverse kinds of structures with equally varied operations. Energy use in the commercial building sector is affected by the physical characteristics of the buildings, age of the buildings, efficiency of the equipment, occupants' energy-related behavior, location, and structural effects. Different principal building activities¹⁷ demand different energy services and various levels of a particular service. The energy used in commercial buildings range from the major energy sources—electricity, natural gas, fuel oil, and district heat—to the minor energy sources: propane, coal, and the renewable sources, wood and solar.¹⁸

The energy supply disruptions of 1973 and 1979, along with a growing concern for the environment, led to increased awareness of the need to reduce energy consumption. Commercial buildings built in the 1980's were designed for specific climates, were well-insulated, and included more efficient space conditioning and lighting systems. Nevertheless, an expanding economy and increases in energy service demand during the 1980's caused an increase in energy consumption in the commercial building sector. During that period energy demand grew by 1.0 percent a year.¹⁹

Between 1979 and 1983, the economy was growing at approximately the same rate as total primary energy consumption (Figure 4.1). In 1983 total energy consumption and Gross Domestic Purchases diverged, reflecting the growing concern for the environment and the building of more energy-efficient buildings.²⁰ This gap seems to narrow somewhat in 1989 only to reopen when the economy faced a slowdown before the recession in 1991. Between 1989 and 1992, total site energy consumption remained relatively stable while total primary energy fell slightly, reflecting a possible relative decline in electricity consumption. In 1989 electricity consumption was 48 percent of all commercial site energy consumption, but in 1992, this percentage fell to 45 percent.

Figure 4.1. Commercial Building Sector Total Energy Consumption and Gross Domestic Purchases Indices, 1978 to 1992



Notes: •U.S. Gross Domestic Purchases used to develop the index are in constant 1987 dollars. •Gross Domestic Purchases includes imports and excludes exports.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1979, 1983, 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files. •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, National Income and Product Accounts, Quantity series.

¹⁶Industrial businesses include manufacturers; agriculture, forestry, and fisheries; mining; and construction. These are excluded from the Commercial Building Sector.

¹⁷"Principal Building Activities" is defined in the commercial section of the Glossary.

¹⁸In this chapter, commercial site energy consumption includes only electricity, natural gas, fuel oil (distillate and residual), and district heat (hot water and steam).

¹⁹See EIA's *Energy End-Use Intensities in Commercial Buildings* (DOE/EIA-0555(94)/2), pp. 1 and 2.

²⁰Gross Domestic Purchases is a measure of U.S. gross domestic purchases of goods and services including imports and excluding exports. Whereas Gross Domestic Product (GDP) is a measure of U.S. gross domestic production of goods and services. Gross Domestic Product for only services is used later in the chapter. See "Gross Domestic Purchases" and "Gross Domestic Product" in the general terminology section of the Glossary.

Chapter Organization

In this chapter, the major data source, EIA's Commercial Buildings Energy Consumption Survey, is described first. A discussion of site energy consumption in the commercial building sector follows, along with a discussion of the necessity of adjusting energy consumption for weather and vacancy influences. Next, the demand indicators, buildings, floorspace, square-foot hours, number of employees, and gross domestic product for services are described along with the trends in and adjustments to these demand indicators. Five energy-intensity indicators will be presented followed by a discussion of the strengths and limitations of the energy-intensity indicators.

Major Data Sources

Energy Information Administration

Commercial Buildings Energy Consumption Survey (CBECS)

The CBECS is a national representation probability sample of commercial buildings. For the purposes of this survey, a commercial building is defined as one whose principal activity is not residential or industrial. The survey covers all commercial buildings over 1,000 square feet. For each of the roughly 6,000 buildings in the sample, the CBECS collects data on energy-related characteristics of the building through personal interviews with the buildings' owners or managers, and total energy consumption for all end uses from billing data provided by the buildings' energy suppliers.

EIA conducts this national sample survey of commercial buildings and their energy suppliers on a triennial basis. Previous surveys were conducted in 1979, 1983, and 1986 under the name Nonresidential Buildings Energy Consumption Survey (NBECs). In 1989, the survey name was changed to CBECS and for consistency, all the surveys will be referred to CBECS in this chapter. The latest CBECS was in 1992.

Energy Consumption in the Commercial Building Sector

Background

Energy is used in the commercial building sector to provide services such as lighting, space conditioning, ventilation, water heating, refrigeration, powering office equipment, and other uses. The amount of energy used to provide these services depends on the activities taking place in the commercial buildings; for example, health care, offices, food service, and so forth. EIA classifies commercial buildings by the activity occupying the most floorspace in the building. This classification is based on the premise that buildings within the same principal building activity have similar energy consumption patterns and that activity classification is useful to examine differences in energy use among various types of buildings.

In 1992, 27 percent of the 4.8 million commercial buildings in the United States were mercantile buildings used primarily for sale and/or distribution of goods and services. These buildings had 18 percent of the 67.9 billion square feet of commercial floorspace and used 15 percent of the 5.8 quadrillion Btu of site commercial energy to provide energy services. Office buildings accounted for only 16 percent of all buildings and floorspace, but commanded 22 percent of all the commercial site energy used in 1992 (Figures 4.2 and 4.3).²¹

In 1989, the largest proportion of the energy used for energy services in commercial buildings was for space heating (35 percent) followed by lighting (18 percent), water heating (9 percent), office equipment (7 percent), space cooling (5 percent), ventilation (5 percent), cooking (5 percent) and refrigeration (3 percent).²² Some building activities use more of a particular energy service than other building activities; for example, office buildings used only 30 percent of the total site energy for space heating, but educational buildings used 54 percent of total site energy for space heating.

²¹EIA's *Commercial Buildings Energy Consumption and Expenditures 1992* (DOE/EIA-0318(92)) presents a profile of energy consumption and expenditures in 1992.

²²At the present time, only the 1989 CBECS data have been used to estimate end-use estimates. Engineering estimates were derived for each building in the sample. These estimates were then statistically adjusted to match the total energy consumption for each building. This methodology is fully developed in *Energy End-Use Intensities in Commercial Buildings* (DOE/EIA-0555(94)/2), September 1994.

Additionally, regional differences affect the level of demand for energy services. For example, in 1989 the South Census Region, a very warm region, used 8 percent of its total site energy for space cooling, whereas the Northeast, a cooler region, used only 3 percent of total site energy for space cooling.

Energy Trends

Two intervals of time will be used for trends, similar to those used for the residential sector but following the years of the CBECS. The first is an interval of growth/growth (1986 to 1989) and the second of recession/recovery (1989 to 1992). Total site energy consumption grew by 16 percent in the first interval and by less than 1 percent during the second (Table 4.1 and Figure 4.4).

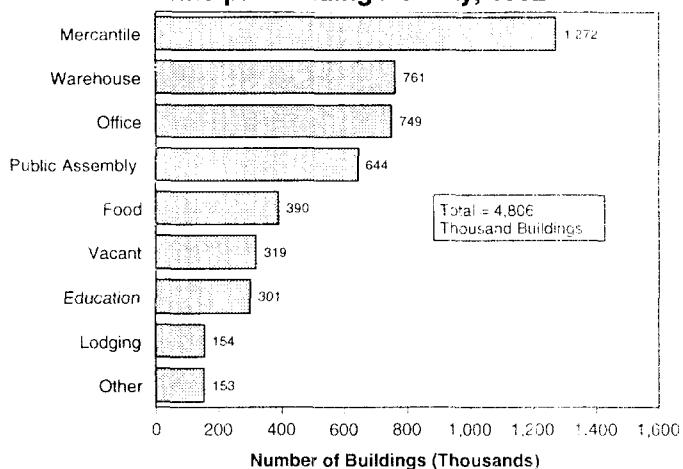
During the growth/growth interval, total site energy consumption increased for each building type except for food and health care, but total site consumption would have increased more if vacancy rates had not increased. During those years, new commercial buildings were constructed at a rapid rate, and the total floorspace of vacant buildings doubled, increasing from 2,090 million square feet in 1986 to 4,161 million square feet in 1989.

During the recession/recovery interval, changes in total site energy consumption varied by building activity (Table 4.1). Floorspace for vacant buildings continued to grow, but only by 6 percent. The decline in the rate of growth of vacant space was attributed to the decline in growth of commercial building construction and leasing costs.

Weather affects energy consumption in commercial buildings. During the intervals studied, the winters were warmer and the summers were hotter than the 30-year average. If the weather had been closer to the average, total site energy consumption would not have increased as much during the growth/growth interval, and would have grown instead of staying flat during the recession/recovery interval.²³

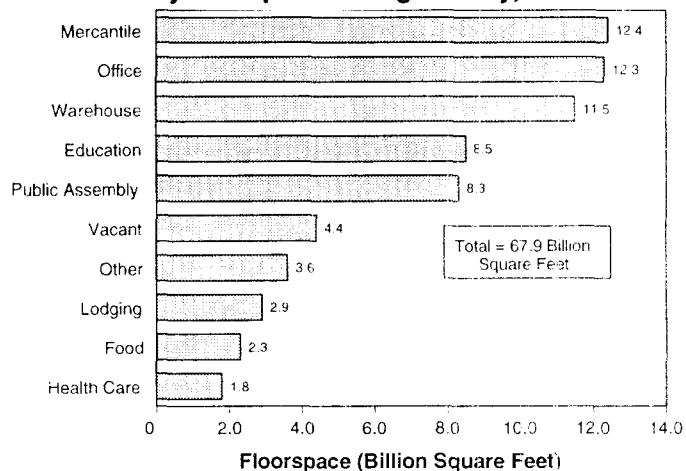
Total site energy consumption estimates can be adjusted not only for the weather effects, but also for vacancy effects. Adjusting estimates to omit vacant buildings, which use little energy, changed the trend in total site energy consumption during the intervals under study. During the growth/growth interval, the increase in adjusted consumption was less pronounced than the unadjusted trend, and the growth in total site energy consumption during the recession/recovery interval was even larger (Table 4.1 and Figure 4.4).²⁴

Figure 4.2. Number of Commercial Buildings by Principal Building Activity, 1992



Source: Energy Information Administration, Office of Energy Markets and End Use, 1992 Commercial Buildings Energy Consumption Survey, Public-Use Data Files.

Figure 4.3. Floorspace in Commercial Buildings by Principal Building Activity, 1992



Source: Energy Information Administration, Office of Energy Markets and End Use, 1992 Commercial Buildings Energy Consumption Survey, Public-Use Data Files.

²³See "Degree-Day Adjusted Estimates" in the commercial section of Appendix A for the methodology and an example.

²⁴See "Occupied Commercial Buildings Site Energy Consumption Adjustment" in the commercial section of Appendix A.

**Table 4.1. U.S. Commercial Total Site Energy Consumption by Principal Building Activity, 1986, 1989, and 1992
(Million Btu)**

Principal Building Activity	Unadjusted			Weather Adjusted			Weather and Vacancy Adjusted		
	1986	1989	1992	1986	1989	1992	1986	1989	1992
All Buildings	4,977	5,788	5,803	5,057	5,725	5,931	4,757	5,317	5,664
Principal Building Activity									
Public Assembly	394	441	419	405	433	429	397	419	415
Education	632	704	637	650	689	647	584	518	600
Food	394	394	584	393	393	594	375	378	587
Health Care	456	449	403	457	450	416	456	449	414
Lodging	299	425	463	303	421	471	289	393	459
Mercantile	985	1,048	892	1,001	1,035	905	984	1,014	892
Office	1,008	1,230	1,272	1,029	1,224	1,327	982	1,196	1,298
Warehouse	462	536	590	470	526	597	442	517	586
Vacant	91	98	131	93	96	131	--	--	--
Other	254	464	412	255	458	415	249	433	414

-- = Data not available.

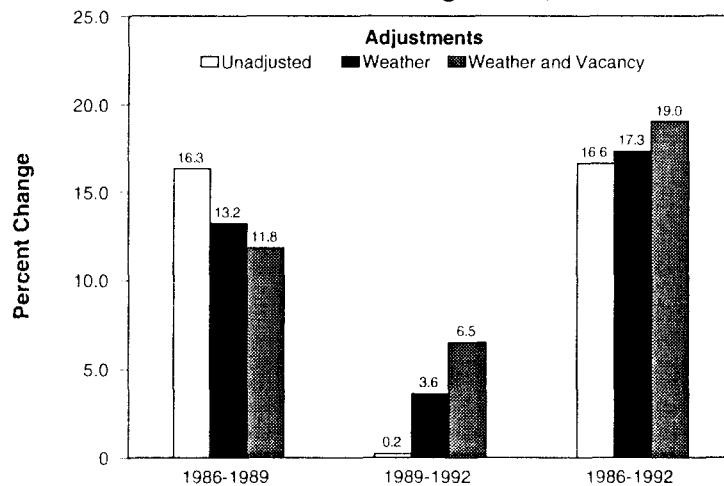
Sources: Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, 1992 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files.

Eliminating effects of extreme weather reduces the peaks and fills the valleys. By eliminating vacant building energy use, periods of high vacancy rates (e.g., 1989) are corrected to reflect occupied energy use. For almost all principal building activities, these adjustments reduced the magnitude of the decrease and augmented the increases in site energy consumption.

Demand Indicators

In the commercial building sector, some of the demand indicators for energy services are: number of buildings, operating hours, number of workers in a building, and size of a building by floorspace. The greater the floorspace (measured in square feet), number of buildings, and operating hours of buildings, the higher the energy required for heating, cooling, lighting, and ventilation and other end uses. Thus, the increases and decreases in unadjusted total site energy consumption shown in Table 4.1 and Figure 4.4, for instance, reflect commensurate increases and decreases in many of the commercial demand indicators (Figure 4.5).

Figure 4.4. Change in Total Site Energy Consumption in the Commercial Building Sector, 1986 to 1992



Sources: Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Buildings Energy Consumption Survey, Public-Use Data Files.

Trends in Demand Indicators

Number of Buildings

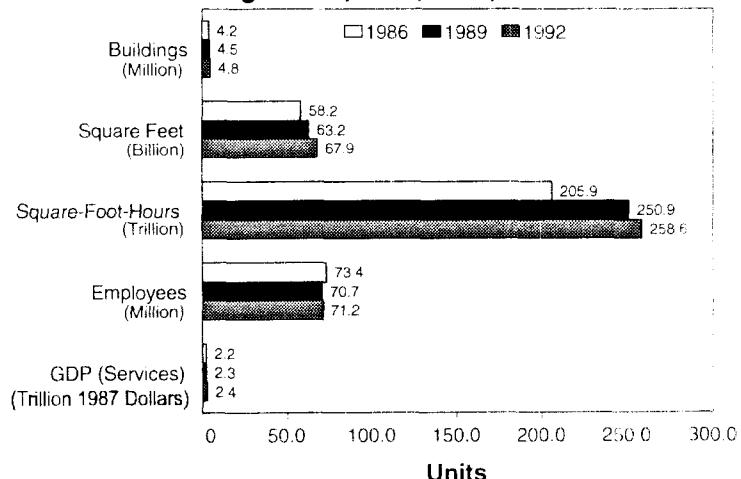
The number of commercial buildings increased by 9 percent during the growth/growth interval and by 6 percent during the recession/recovery interval (Figure 4.6). During both intervals construction of new buildings decreased dramatically, dropping by 25 percent over the growth/growth interval and by 40 percent over the recession/recovery interval.²⁵

²⁵Data obtained from EIA's 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys. Other undocumented data presented in this chapter were also obtained from the respective CBECS.

Total Floorspace

Patterns of growth in total floorspace were similar to those for number of buildings during both time intervals. Increases in total floorspace for new construction also followed the growth in the number of buildings over the growth years; however, during the recession/recovery interval, new total floorspace decreased by 23 percent although new construction fell by approximately 40 percent. In 1986, newly constructed buildings averaged 15.8 thousand square feet per building. This average did not change in 1989, but in 1992, the average square footage of a newly constructed building was 19.6 thousand square feet.

Figure 4.5. Demand Indicators in the Commercial Building Sector, 1986, 1989, and 1992

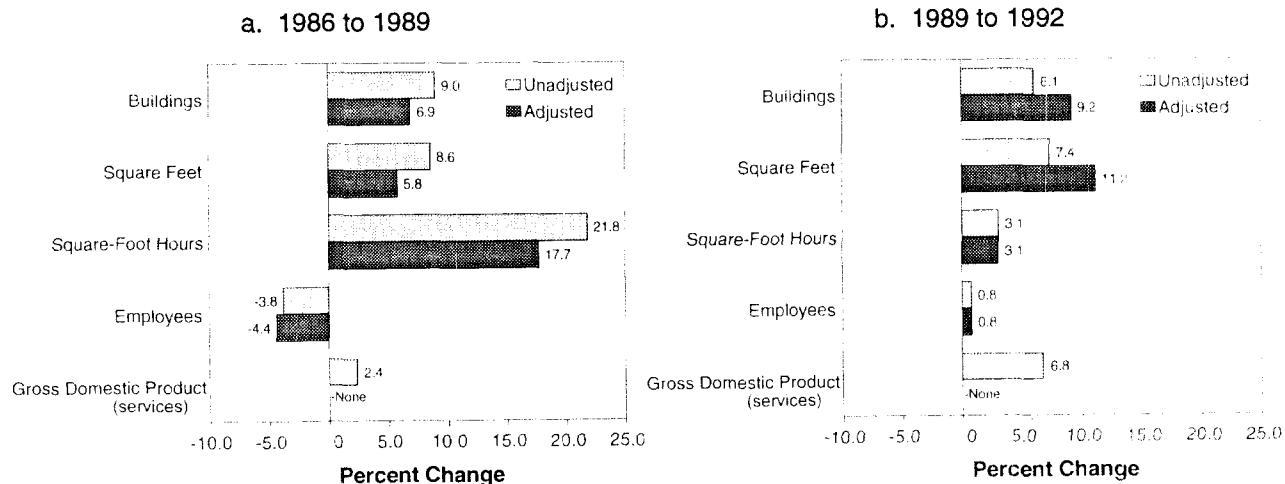


Square-Foot Hours

Square-foot hours are a surrogate measure of economic activity.²⁶ Square-foot hours grew rapidly during the growth/growth interval (22 percent). The increase in this indicator may be attributed to the growth of retail sales in mercantile and service buildings. Retail sales grew by almost 10 percent (constant 1987 dollars) during this time.²⁷ The rate of growth in square-foot hours as well as the rate of growth in retail sales slowed during the recession/recovery interval, resulting in an increase of only 2 percent for retail sales and 3 percent for square-foot hours. The percent of all commercial buildings open 48 hours or less per week increased from 40 percent in 1989 to 48 percent in 1992. Conversely, the percent of all commercial buildings open 85 hours or more per week decreased from 20 percent in 1989 to 17 percent in 1992. The reduction in operating hours follows the economic slowdown the country as a whole was facing during those years.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Building Energy Consumption Surveys, Public-Use Data Files. •U.S. Bureau of Economic Analysis, National Income and Product Accounts of the United States, Volume 2, 1959-1988; and Survey of Current Business, March 1993.

Figure 4.6. Change in the Demand Indicators for the Commercial Building Sector



Note: "Adjusted" is an adjustment for vacancies.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1986 and 1989 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files. •U.S. Bureau of Labor Statistics, Employment and Earnings, monthly March issues. •U.S. Bureau of the Census, Current Construction Report, series C30 and press release CB-92-14. •U.S. Bureau of Economic Analysis, National Income and Product Accounts of the United States, Volume 2, 1959-1988 and Survey of Current Business, March 1993.

²⁶For each principal building activity, the total building square footage is multiplied by the annual operating hours. The square-foot hours are summed over all principal building activities to obtain total square-foot hours.

²⁷U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, various March issues.

Number of Employees

The total number of employees fell during the growth years and was flat during the recession/recovery interval.

During the growth years, the number of buildings with fewer than 10 employees grew by 7 percent, whereas the number of buildings with 10 to 19 employees fell by 4 percent. The commercial building sector, perhaps following the manufacturing sector, may have downsized. Investigation into changes in the number of buildings in each principal building activity type may be warranted since some principal building activity types may be more apt to substitute equipment for employees than others (e.g., increased use of computers in office buildings to increase productivity).

Box 4.1.

Demand Indicators in the Commercial Building Sector

- Number of Buildings
- Floorspace
- Square-Foot Hours
- Number of Employees
- Gross Domestic Product for Services (Constant 1987 Dollar)

Gross Domestic Product (Services)

This estimate of economic activity appears to run counter to the results of changes in square-foot hours, a surrogate to economic activity. During the growth/growth interval, the growth in Gross Domestic Product (GDP) for services was far smaller than the growth in square-foot hours. One possible explanation is that commercial businesses may have kept their doors open longer to make the same profit that they made in fewer hours in better economic times.

Demand-Indicator Adjustments

Demand indicators, with the exception of GDP for services, can be adjusted by removing vacant buildings from the estimates in the same way as the consumption estimates were adjusted. The effects of these adjustments are depicted in Figure 4.6.

Energy-Intensity Indicators for the Commercial Building Sector

Energy-intensity indicators are used to measure the ratio of energy consumption to the demand for services using the demand indicators described in the previous section. The energy-intensity indicators may be applied across the entire sector, or conditionally for a specific building activity, building age, end use, or other limiting characteristics. A commonly used energy-intensity indicator for the commercial building sector is energy consumption per square foot. However, a variety of other popular indicators exist (see Box 4.2).

Box 4.2

Energy-Intensity Indicators for the Commercial Building Sector

- Million Btu per Building
- Thousand Btu per Square Foot
- Btu per Square-Foot-Hour
- Thousand Btu per Employee
- Thousand Btu per Dollar of Gross Domestic Product for Services (Constant 1987 Dollar)

Trends in Energy-Intensity Indicators

During the growth/growth interval, all the energy-intensity indicators—except thousand Btu per square-foot hour²⁸—registered increases in intensity, a trend suggesting that energy efficiency decreased.²⁹ During the recession/recovery interval, all of the energy-intensity indicators decreased, suggesting increases in energy efficiency (Figure 4.7). The results in the two different intervals suggest that influences other than only changes in energy efficiency may be affecting the results. If the time interval chosen were the entire period, 1986 to 1992, the energy-intensity indicators, million Btu per building and thousand Btu per square foot, showed no changes (Table 4.2).

Adjusting demand indicators in the development of the energy-intensity indicators begins to remove a few of those influences that affect energy-intensity that are not due to changes in energy efficiency (Table 4.2 and Figure 4.7). The adjustments seem to put a damping effect on the intensity indicators. The increases in intensity during the growth/growth interval are less pronounced, and the decreases during the recession/recovery interval are not as great as the unadjusted estimates.

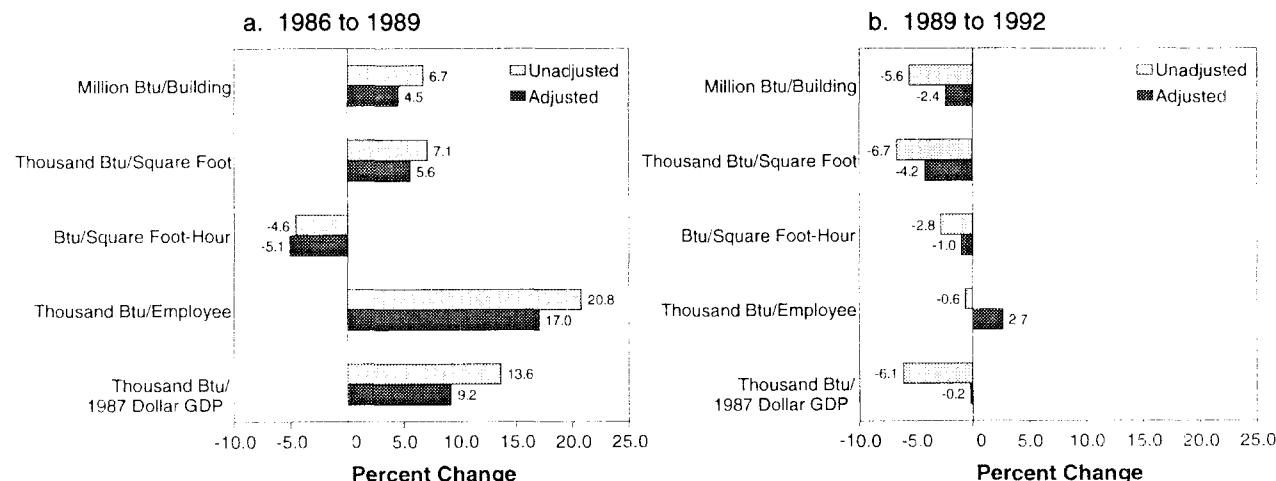
Table 4.2. Comparison of Commercial Site Energy-Intensity Indicators, 1986, 1989, and 1992

Energy-Intensity Indicators	Units					
	1986		1989		1992	
	Unadjusted	Weather and Vacancy Adjusted	Unadjusted	Weather and Vacancy Adjusted	Unadjusted	Weather and Vacancy Adjusted
Million Btu/Building	1,198	1,300	1,278	1,358	1,207	1,325
Thousand Btu/Square Foot ...	86	92	92	97	86	93
Btu/Square-Foot-Hour	24	25	23	24	22	23
Thousand Btu/Employee	68	69	82	81	82	83
Thousand Btu/Dollar GDP ...	2,231	2,132	2,534	2,328	2,379	2,332

Note: Service sector Gross Domestic Product estimates are in 1987 constant dollars.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Building Energy Consumption Surveys, Public-Use Data Files. •U.S. Bureau of Economic Analysis, *National Income and Product Accounts of the United States*, volume 2, 1959-1988, and *Survey of Current Business*, March 1993.

Figure 4.7. Change in Energy-Intensity Indicators in the Commercial Building Sector



Note: •"Adjusted" includes adjustments for weather and vacancy. •Percent changes were based on unrounded data.

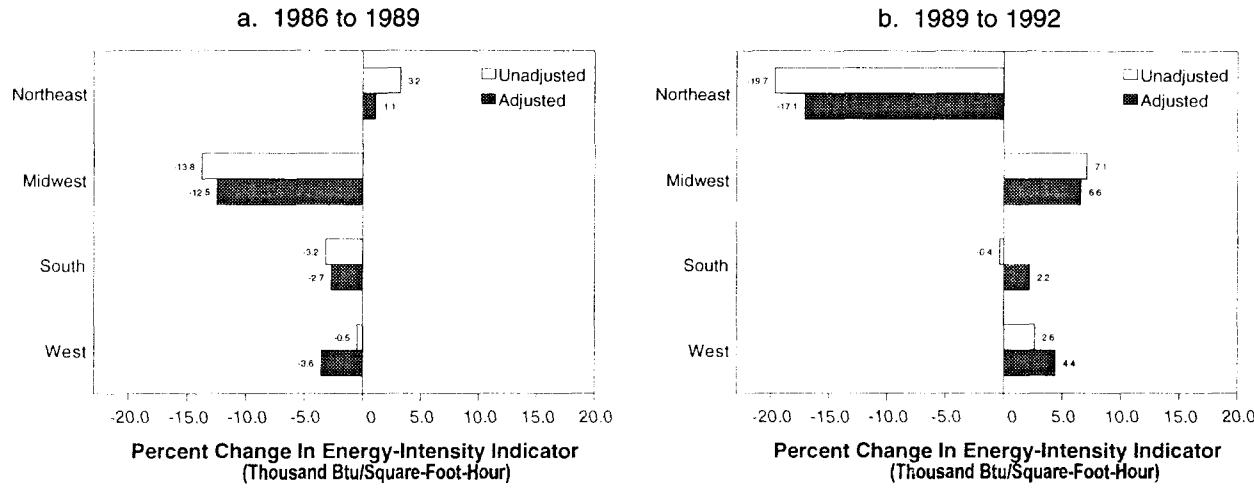
Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1986 and 1989 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files. •U.S. Bureau of Economic Analysis, *National Income and Product Accounts of the United States*, Volume 2, 1959-1988, and *Survey of Current Business*, March 1993.

²⁸In the last section it was shown that square-foot hours had increased during the growth/growth interval by approximately 18 to 22 percent depending on whether the indicator was adjusted for weather and vacancy. This rate of increased slowed dramatically over the recessionary/recovery interval.

²⁹Given the variety of energy-intensity indicators available, caution is warranted in attempting to compare indicators. The magnitude and direction of changes in the energy-intensity indicators are dependent on the choice of demand indicator used in the denominator. Additionally, structural or behavioral effects may intensify or diminish changes in energy-intensity.

Examination of estimates of the unadjusted and adjusted energy-intensity indicator (thousand Btu per square-foot-hour) across the four Census regions demonstrates regional differences (Figure 4.8). During the interval of growth/growth, the Northeast was the only Census region with increases in the intensity indicator, even after adjustments are made. During the recession/recovery interval, the Northeast experienced the largest decrease in the intensity indicator (-19.7 percent unadjusted and -17.1 percent adjusted). The Northeast was the only Census region to have a negative energy-intensity indicator. Most of the large decrease was in the mercantile and warehouse building activities (Figure 4.9).

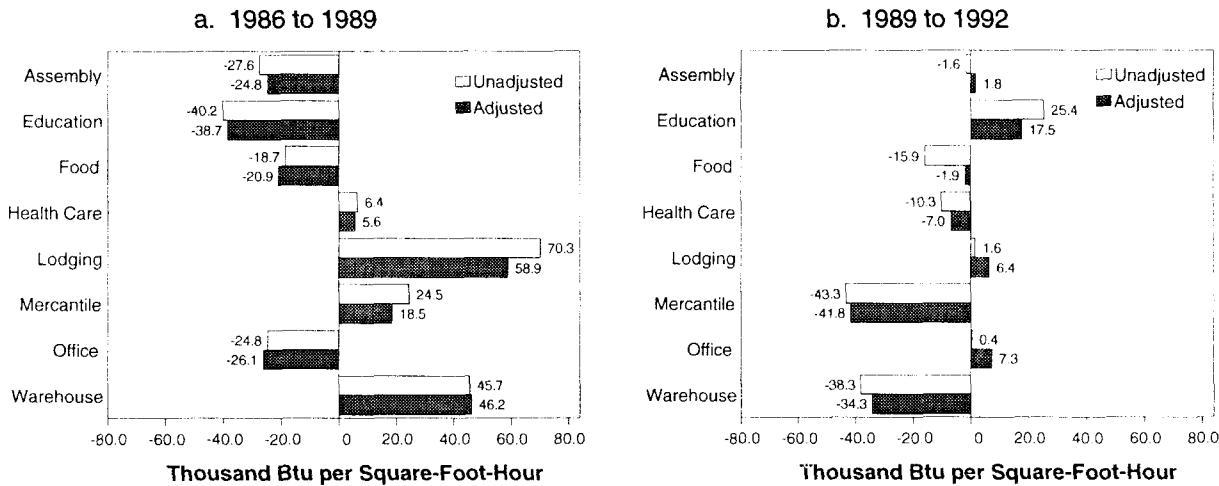
Figure 4.8. Change in the Energy-Intensity Indicator in the Commercial Building Sector by Census Region



Note: •"Adjusted" includes adjustments for weather and vacancy. •Percent changes were based on unrounded data.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files.

Figure 4.9. Change in Energy-Intensity for the Northeast by Principal Building Activity



Note: •"Adjusted" includes adjustments for weather and vacancy. •Percent changes were based on unrounded data.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys, Public-Use Data Files.

In the Northeast, in 1992, the demand for electricity was 38 percent of the demand for all major fuels. In the early 1990's, electric utilities aggressively promoted demand-side management (DSM) programs, especially in the Northeast to either reduce electricity demand at peak times or throughout the year. According to the electric utilities in the Northeast, 55 percent of the commercial buildings participated in some type of DSM. This may have been one of the contributing factors in the reduction of the energy-intensity indicator.

Going one step further is an examination of the estimates for an energy-intensity indicator, thousand Btu per square-foot-hour, by principal building activity in the Northeast. Figure 4.9a shows that lodging, mercantile, health care, and warehouse building types displayed increases in the energy-intensity indicator during the growth/growth interval while other activities posted reductions. These relationships remained even when the estimates were adjusted for weather and vacancy.³⁰

Other structural and behavioral effects need to be considered, such as new construction growth and changing business tax laws in addition to the weather, vacancy, regional, and economic effects discussed above. Such consideration is necessary to separate the effects that are related to energy efficiency from the effects that are unrelated. Standardizing could take place by basically keeping a characteristic such as floorspace at a certain level and examining the intensity indicators as if the amount of floorspace had remained the same. However, as more standardizations take place, a greater level of detailed data will be needed.

Strengths and Limitations of the Energy-Intensity Indicators

The CBECS contains sufficient detail that site energy consumption estimates can be adjusted for some of the major influences on changes in energy consumption such as weather and vacancy. The CBECS data, though, are available only every 3 years. However, this limitation may not be important because the measurement of energy-intensity may be feasible only every few years because of the availability of other data and limited resources.

Table 4.3 presents some of the strengths and limitations of the demand indicators that influence the amount of energy consumed in the commercial sector. One needs to remember that the greater the disaggregation of the energy-intensity indicator, e.g., a particular energy service such as space heating, the greater are the data needs and the lower the precision of the data due to sample-size limitations. The particular use of an indicator, such as for policy program evaluation, may dictate the type of indicator and the level of disaggregation needed.

Table 4.3. Strengths and Limitations of the Energy-Intensity Indicators

Energy-Intensity Indicator	Strength of Demand Indicator Used in the Energy-Intensity Indicator	Limitation of the Demand Indicator Used in the Energy-Intensity Indicator
Energy per Building	<ul style="list-style-type: none"> ● Collected by EIA as part of a detailed energy survey ● Vacancy adjustments are possible 	<ul style="list-style-type: none"> ● Data available every 3 years ● Data not available for buildings 1,000 square feet or less
Energy per Square Foot	<ul style="list-style-type: none"> ● Collected by EIA as part of a detailed energy survey ● Demand for major energy services such as space conditioning is influenced by the amount of floorspace ● Vacancy adjustments are possible 	<ul style="list-style-type: none"> ● Data available every 3 years ● Does not completely capture the operational profile of the building, e.g., water heating does not depend on floorspace in the building ● Data not available for buildings 1,000 square feet or less
Energy per Square-Foot Hour	<ul style="list-style-type: none"> ● Calculated from EIA CBECS data ● Surrogate for economic activity ● Demand for major energy services such as space conditioning is influenced by the amount of floorspace ● Vacancy adjustments are possible 	<ul style="list-style-type: none"> ● Data available every 3 years ● Does not completely capture the operational profile of the building, e.g., water heating does not depend on floorspace in the building ● Data not available for buildings 1,000 square feet or less
Energy per Employee	<ul style="list-style-type: none"> ● Available annually ● Capture the operational profile of the building for water heating for certain building activities, e.g., office buildings 	<ul style="list-style-type: none"> ● Not available by detailed characteristics
Energy per GDP Services (1987 Dollars)	<ul style="list-style-type: none"> ● Measure of economic activity ● Available annually 	<ul style="list-style-type: none"> ● Not available by detailed characteristics

³⁰ Adjustments are not uniform over the principal building activities since for each of the building activity types energy demand for different energy services and different levels of energy services are not the same.

5. Transportation Sector

Introduction

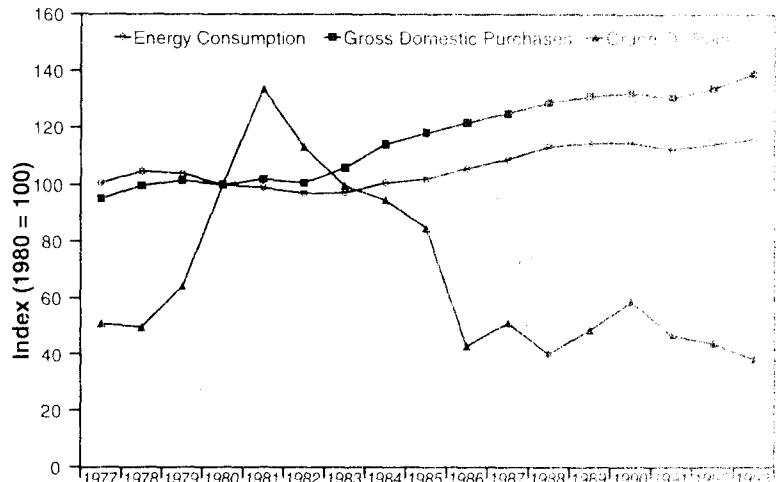
Energy use in the transportation sector is primarily for passenger travel and freight movements. Passenger travel vehicles consist of light-duty vehicles (automobiles, motorcycles, and light trucks) and heavy-duty vehicles (buses, airplanes, boats, and trains). The freight modes of transport include truck, air, rail, pipeline, and marine (domestic barge and cargo). Energy is also used for military operations and off-highway vehicles used for construction and farming.

Petroleum supplies the vehicles in the transportation sector in the forms of gasoline, diesel fuel, liquefied petroleum gas, jet fuel, and residual fuel oil. In 1992, more than 60 percent of petroleum products supplied was gasoline. The transportation sector uses very small amounts of other fuels such as natural gas and electricity.³¹

In the late 1970's total energy consumption (indexed to 1980) grew faster than Gross Domestic Purchases (GDP).³² This pattern reversed in the early 1980's and became even more pronounced as GDP grew at a faster rate than total energy consumption. However, total energy consumption increased as well, as Figure 5.1 shows. Passenger miles have increased 21 percent between 1977 and 1992. Populations have increased and people are traveling more as the distance between work and home has increased. More shipping is being done over greater distances.³³

The price of energy during this time was very volatile. Between 1977 and 1980, the real price of crude oil nearly doubled. It reached a peak in 1982 and then dived below the prices of the late 1970's.

Figure 5.1. Total Primary Transportation Energy, Gross Domestic Purchases, and Crude Oil Price Indices, 1977 to 1993



Notes: •Gross Domestic Purchases used to develop the index are in constant 1987 dollars. •Crude Oil Domestic First Purchase Price Index is in constant 1987 dollars per barrel, U.S. Average.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 2.1 and 5.17. •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, National Income and Product Accounts, Quantity series.

Chapter Organization

The first presentation will be a detailed discussion of the several data sources used for the analysis in this chapter. This will be followed by a discussion of energy consumption in the transportation sector as a whole.

The next sections will first discuss U.S. passenger transportation followed by a discussion on U.S. freight transportation the topics presented are: energy consumption, demand indicators, and the development of energy-intensity indicators. This presentation will be followed by the development of a composite energy-intensity indicator for the entire transportation sector. The chapter will end with a discussion of the strengths and limitations of the energy-intensity indicators presented in the chapter.

³¹ As of December 1992, there were 2,240 federal and over 248,000 nonfederal alternative-fuel vehicles. Almost 143 million automobiles and 43 million light trucks were operated on alternative fuels in the United States in 1991. These 250,240 alternative-fuel vehicles represent less than 0.2 percent of the passenger vehicles. See *Alternatives to Traditional Transportation Fuels: An Overview*, DOE/EIA-0585/O (June 1984) for more detailed information.

³² Gross Domestic Purchases includes imports and excludes exports.

³³ For more information, see "Transportation and its Costs" in *Transportation Statistics: Annual Report 1994*, U.S. Department of Transportation, Bureau of Transportation Statistics.

Major Data Sources

U.S. Department of Energy (DOE)

Energy Information Administration

Residential Transportation Energy Consumption Survey (RTECS). The RTECS is a national multistage probability sample survey conducted on personal vehicles from a subsample of households in the RECS sample from the previous year. The first annual RTECS was conducted in 1983 with subsequent surveys conducted in 1985 and triennially thereafter. Baseline information about the RTECS household and vehicle stock is collected during the RECS personal interview. Via telephone interviews, the data for the following year are collected at two points in time about vehicle stock, vehicle stock turnover, new purchases, and vehicle-miles traveled (VMT). A third interview takes place early the following year. The RTECS is designed to collect actual VMT for each vehicle in the household by obtaining the odometer reading at two points in time. The vehicle characteristic information is collected directly from the respondents and the decoded Vehicle Identification Number. Vehicle fuel consumption and expenditures are estimated using vehicle fuel efficiency, presented in miles per gallon from the U.S. Environmental Protection Agency and adjusted for in-road degradation, and motor fuel prices from the Department of Commerce, Bureau of Labor Statistics, and Lundberg, Inc.

Oak Ridge National Laboratory (ORNL)

Transportation Energy Data Book: *Transportation Energy Data Book*, Edition 14 and earlier reports. These reports are statistical compendiums prepared and published by ORNL under contract with the Office of Transportation Technologies in DOE. The data book presents statistics and information from diverse sources that characterize transportation activity and presents data on other factors that influence transportation energy use.

U.S. Department of Transportation (DOT)

Bureau of Transportation Statistics

Transportation Statistics: Annual Report 1993 and *Transportation Statistics: Annual Report 1994*. These two reports summarize the state of the transportation system as to : the transportation network, the use of the system, how well it works, costs of transportation, safety, and energy and the environment. The data presented are from various agencies, including the U.S. Department of Commerce-Bureau of the Census, U.S. Department of Labor-Bureau of Labor Statistics, Eno Transportation Foundation, Oak Ridge National Laboratory, and the Department of Transportation-Federal Aviation Administration and Federal Highway Administration.

Federal Highway Administration

Nationwide Personal Transportation Survey (NPTS) is a periodic survey of personal travel. The NTPS data are based on a nationally representative sample of households from which the amount and nature of personal travel by all modes is collected.

Energy Consumption in the Transportation Sector

Background

In 1992, 27 percent of total primary energy and 37 percent of total site energy was used by the transportation sector. Automobiles—both private and business—used 40 percent of the sector's energy, and trucks—light-duty and heavy-duty—used 32.7 percent (Figure 5.2).

In this chapter, only the conventional sources of energy used in the transportation sector are included in the analysis. These are gasoline, diesel fuel oil, jet fuel, residual fuel oil, and natural gas and electricity used for pipelines and light rail. Other energy sources used in the transportation sector are not included in this chapter—methanol, ethanol, liquefied petroleum gas, compressed natural gas, and other alternative fuels that are beginning to contribute to the transportation supply mix. The Energy Information Administration is just beginning to provide data related to these alternative fuels.³⁴

Choice of fuel varies by transportation mode, e.g., automobiles consume gasoline, diesel, and alternative fuels; trucks run on diesel fuel, gasoline, and liquefied petroleum gas; aircraft fly with jet fuel and aviation gasoline; and marine vessels burn distillate and residual fuel oil.

Energy Trends

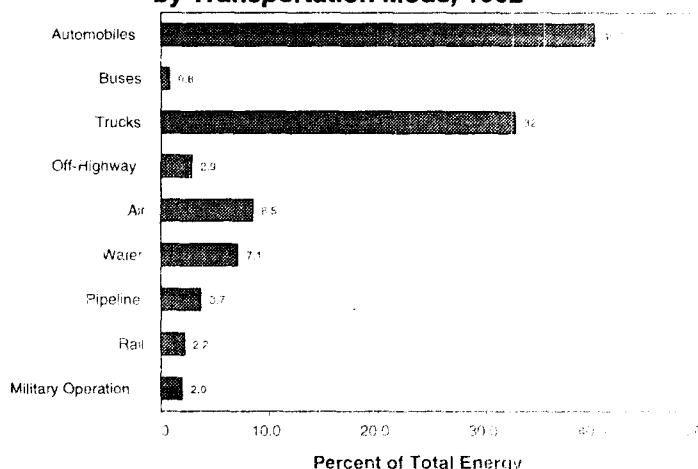
Almost 70 percent of the energy used in the transportation sector is used by passenger modes of travel. The smallest amount is used by the military and for off-highway vehicles such as those used in construction and farming (Figure 5.3).³⁵

The two time intervals used in this chapter are one of growth/growth (1985 to 1988) and one of growth/recession (1988 to 1991). Site energy consumption grew by 8.4 percent during the interval of growth/growth, but was essentially flat (actually, 0.4 percent decline), during the interval of growth/recession (Figure 5.4).

Although most of the energy used in this sector is for passenger travel, the energy used for freight transportation grew twice as fast as that for passenger travel during the interval of growth/growth.

The passenger and freight transportation sectors are very different. Each uses different energy sources and displays different reactions to price changes. The energy efficiency characteristics of each are treated separately in the next two sections.³⁶

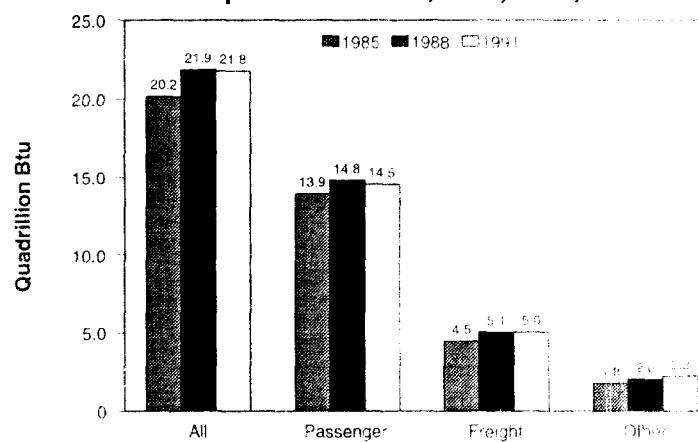
Figure 5.2. Percent of Total Primary Energy Consumption in the Transportation Sector by Transportation Mode, 1992



Notes: •Motorcycles account for less than .01 percent of total energy consumption in the transportation sector. •Off-Highway includes construction and farming. •Electricity losses are included.

Source: U.S. Department of Energy, Oak Ridge National Laboratory, *Transportation Energy Data Book* (ORNL-6798), Edition 14, Table 2.9.

Figure 5.3. Total Site Energy Consumption in the Transportation Sector, 1985, 1988, and 1991



Notes: •Other modes include military, off-highway (construction and farming), and recreational boats. •The methodologies used to separate air passenger and freight and to calculate site electricity for rail and pipeline are located in the transportation section in Appendix A.

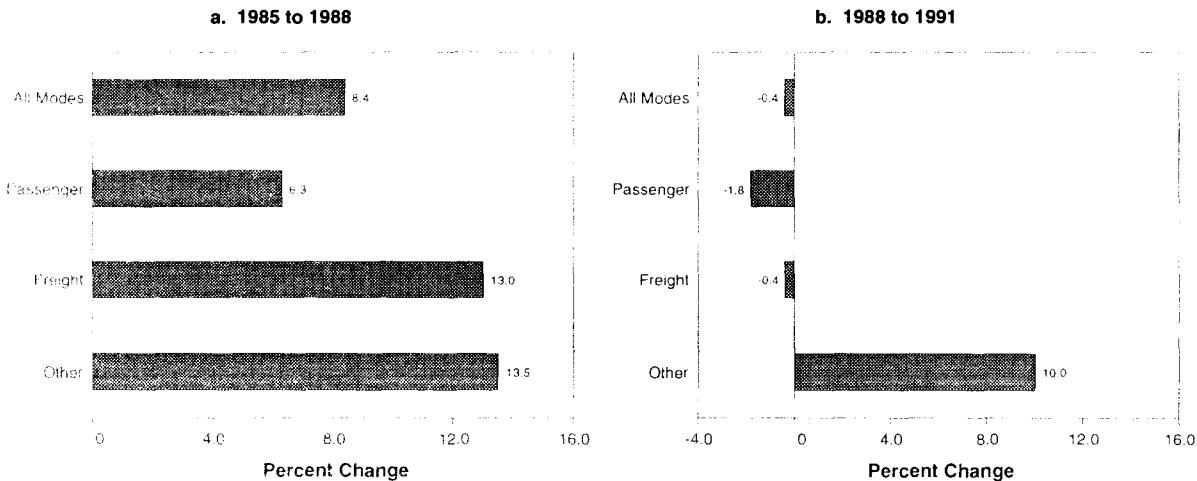
Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14 and unpublished 1985 data from ORNL. •Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, September 1993, Tables 1, 4, and 6. •Eno Transportation Foundation Inc., *Transportation in America* 1994, pp. 44 and 49.

³⁴The pilot study of alternative fuel vehicles in Atlanta is the first computer-assisted telephone interview survey of participants in the Clean Cities program co-sponsored by the U.S. Department of Energy and the U.S. Environmental Protection Agency.

³⁵In this chapter, passenger vehicles do not include recreational boats. Freight transportation modes do not include foreign air and marine cargo movements. Military transportation and other vehicles such as construction and farm vehicles are excluded as well. Marine freight does include domestic movements through canals, rivers, the Great Lakes, and along the coasts.

³⁶See Green, David L. And Yuehui Fan, *Transportation Energy Efficiency Trends, 1972-1992*, Oak Ridge National Laboratory (December 1994) for a detailed discussion of energy efficiency in the transportation sector.

Figure 5.4. Change in Total Site Energy Consumption in the Transportation Sector, by Transportation Mode



Notes: •Other modes include military, off-highway (construction and farming), and recreational boats. •The methodology used to separate air passenger and freight is presented in the transportation section in Appendix A.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14 and unpublished 1985 data from ORNL. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Tables 1, 4, and 6 (September 1993). •Eno Transportation Foundation Inc., *Transportation in America 1994*, pp. 44 and 49.

U.S. Domestic Passenger Transportation

Background

When the United States recognized the hazards of its dependency on foreign oil supplies in the aftermath of the first oil embargo in 1973, passenger automobile fuel economy averaged only 14 miles per gallon (mpg). Congress responded by passing the Energy Policy and Conservation Act of 1975 (Public Law 163), which established Corporate Average Fuel Economy (CAFE) standards for each automaker, with domestically produced and imported automobiles counted as separate fleets.³⁷ The uniform CAFE standard for automobiles began at 18 mpg with the 1978 model year, increasing to 27.5 mpg by 1985. For trucks, the CAFE standard began at 17.2 mpg in 1979, rising to 20.5 mpg by 1987.

Public agreement as to the success of the CAFE standards is still pending. During the time when most of the standards were coming into effect, the price of gasoline was sharply increasing. The price increases could have increased the public demand for more efficient automobiles. Nevertheless, vehicle fuel efficiencies have increased. Newer automobiles are more efficient than older cars, averaging 20.6 to 22.0 mpg for model year 1983 or later compared with 14.1 mpg or less for model year 1979 or earlier.³⁸

Passenger Transportation Energy Consumption

Site energy used for domestic passenger travel increased by 6 percent during the growth/growth interval and decreased by almost 2 percent during growth/recession interval (Figure 5.4). Automobiles and light trucks are responsible for most of the energy consumed in passenger transportation (Figure 5.5). The total site energy used in light trucks grew the most of any of the passenger modes during the growth/growth interval (13.2 percent) (Figure 5.6).

³⁷Fleet CAFE values are measured as the sales-weighted harmonic mean of individual model fuel economies. These standards are based on tests administered by the U.S. Environmental Protection Agency; actual on-road fuel economy is considerably less. CAFE standards for light trucks are lower than for passenger cars. See Office of Technology Assessment, *Improving Automobile Fuel Economy: New Standards, New Approaches*, OTA-E-504 (October 1991, for more information.

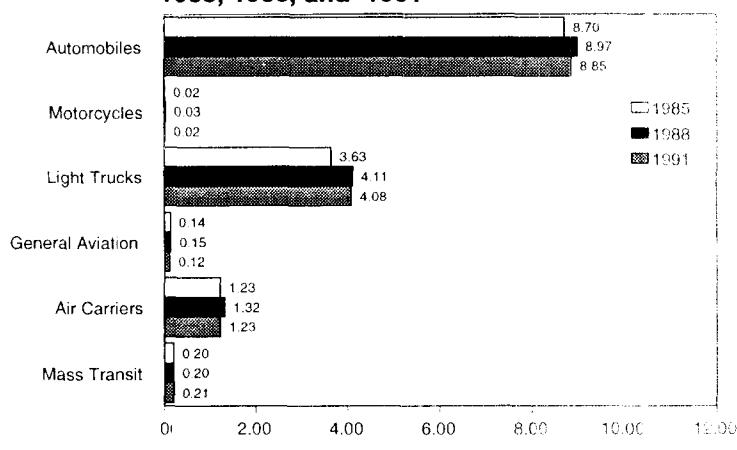
³⁸See Chapter 4, "Vehicle Fuel Efficiency and Consumption," in *Household Vehicles Energy Consumption 1991* (DOE/EIA-0464(91)) for further information.

All passenger transportation modes except mass transit sustained reductions in energy use during the growth/recession interval.³⁹ In fact, mass transit energy use, which accounted for no more than 1 percent of passenger site energy consumption in 1991, increased throughout both intervals of time, despite recent survey results showing increased preference for personal vehicles at the expense of mass transit.⁴⁰

The mode experiencing the smallest decline in site energy consumption during the growth/recession interval was light trucks. The increased penetration of light trucks with lower fuel economies than passenger automobiles may be responsible for this.⁴¹

Three modes—general aviation, air carriers, and motorcycles—experienced large percentage reductions in site energy use during the growth/recession interval; however, these three modes combined amount to about 10 percent of passenger site transportation energy use. Air carrier energy use grew by 7 percent during the growth/growth interval, only to shrink by an equivalent amount during the growth/recession interval.

Figure 5.5. Site Energy Consumption for Passenger Travel by Passenger Mode, 1985, 1988, and 1991

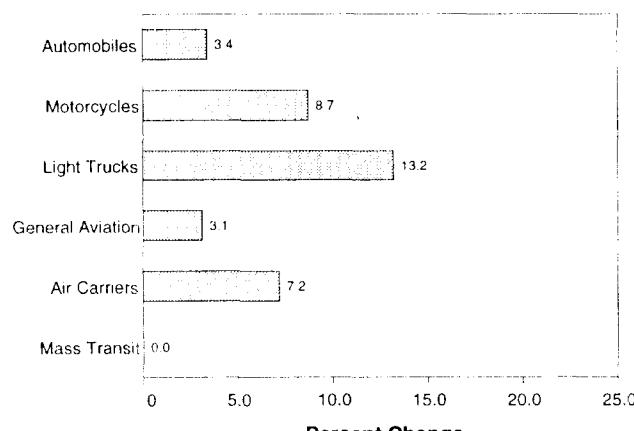


Notes: •Mass Transit includes buses and passenger rail. •Derivation of these numbers are described in the transportation section of Appendix A.

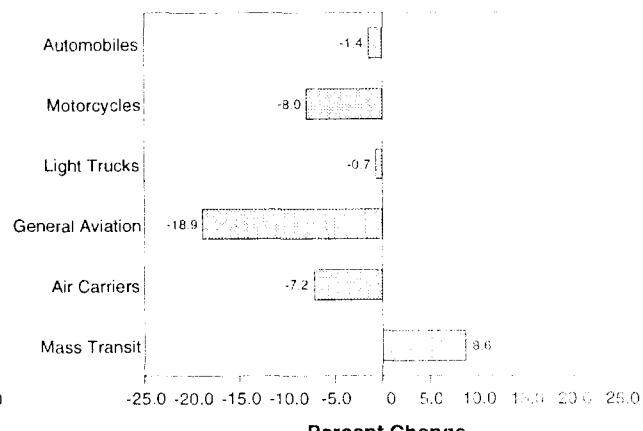
Sources: U.S. Department of Energy, Oak Ridge Nation Laboratory (ORNL), *Transportation Energy Data Book*, Edition 8, Table 1.5, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL.

Figure 5.6. Change in Site Energy Consumption for Passenger Travel, by Passenger Mode

a. 1985 to 1988



b. 1988 to 1991



Note: Mass transit includes buses and passenger rail.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14 and unpublished 1985 data from ORNL. •Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics* (September 1993), Tables 1, 4, and 6. •Eno Transportation Foundation Inc., *Transportation in America* 1994, pp. 44 and 49.

³⁹Since rail and bus transit vehicles consume energy whether people board them at full capacity or not, increases in energy use may not necessarily signify greater passenger occupancy aboard mass transit.

⁴⁰U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Survey: Travel Behavior Issues in the 90's*.

⁴¹Different CAFE standards apply to trucks and automobiles.

Demand Indicators

A number of possible demand indicators may be considered as drivers of the demand for energy services in the passenger transportation sector. None of these indicators is universally applicable to all passenger transport modes:

- **Population growth** is indicative of the demand for personal or household vehicles, and indirectly for nonresidential vehicles to support the economy
- **Number of persons working** may serve as a good indicator of the demand for business travel, either commuting daily by car, bus or rail, or extended business trips by rail or air
- **Number of vehicles** in each mode is useful for within modes perhaps, but not across modes. It severely restricts analysis of high-density vehicles (i.e., buses, trains, and planes carrying more people per vehicle)
- **Growth in personal income** is an important indicator because in the residential transportation sector, higher incomes are more likely to result in the purchase of a second or third car. In 1991, for every additional \$16,000 of income, vehicle miles traveled increased by approximately 3,000 miles.⁴²
- **Number, Frequency, and duration of trips** made by passenger vehicles vary significantly. For example, in 1991, the average car trip was 9 miles while buses averaged 143 miles and planes 806 miles per trip⁴³
- **Fuel cost** is considered to be a key determinant of transportation demand—the low price of gasoline, which contributes to low overall vehicle operating costs, currently does not appear to be as influential in consumers' choice of vehicle purchases in comparison with the 1970's and early 1980's⁴⁴
- **Vehicle-miles traveled** mask differences in vehicle occupancy across passenger transport modes and changes in occupancy over time—in 1991, automobiles carried on average 1.6 passengers per mile while buses and air carriers transported 16.4 and 87.7 passengers, respectively
- **Passenger-miles traveled** reflects vehicle occupancy within each passenger mode—in 1991 mass transit rail and buses traveled more than 12 billion vehicle-miles, compared with 153 billion passenger-miles over the same period.

Trends in Demand Indicators

While the vehicle may be the consuming unit, the energy-service demand is for movement from one point to another—distance traveled or a social interpretation would say, 1 trip. Only two of the above indicators include distance, Vehicle-Miles Traveled (VMT) and passenger-miles traveled (PMT).

Vehicle-Miles Traveled

VMT grew significantly during 1985-1991 (Figures 5.7 and 5.8), primarily because of the growth in VMT for light-duty vehicles (23 percent). Most of this growth took place during the growth/growth interval (Figure 5.8a). Of all of the light-duty vehicles, the light truck experienced the largest growth in VMT, not only for the growth/growth interval, but even larger growth during the growth/recession interval.

The mix of light-duty vehicles has changed substantially since 1985. Automobiles, while still dominant, lost a 6-percent share among all light-duty vehicles: 72 percent in 1991 compared with 78 percent of all light-duty vehicles in 1985. Minivans, which were just entering the market in 1985, have made substantial market penetration, exceeding 5 million vehicles in 1991, or a 3-percent market share. Sport-utility vehicles doubled within these 6 years, from 3.7 million to 7.3 million vehicles in 1991. Pickup trucks increased in number to almost 26 million vehicles in 1991.

⁴²See EIA's Household Vehicles Energy Consumption 1991, p. 19. (December 1993), (DOE/EIA-0464(91)).

⁴³U.S. Department of Transportation, Bureau of Transportation Statistics, *1990 Nationwide Personal Transportation Survey, Summary of Travel Trends*, p. 18; Enn Transportation Foundation, *Transportation in America 1994*, p. 70.

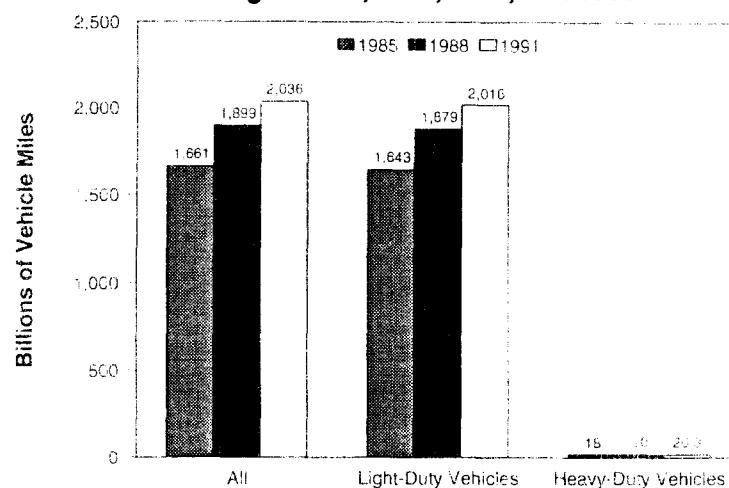
⁴⁴U.S. Congress, Office of Technology Assessment, *Improving Automobile Fuel Economy: New Standards, New Approaches*, OTA-E-504 (Washington, DC: U.S. Government Printing Office, October 1991), p. 2.

VMT for heavy-duty vehicles showed a 11-percent growth during the growth/growth interval and only a 3-percent growth during the growth/recession interval. Air carriers experienced the largest growth in VMT during the first interval (22 percent).

A number of factors are responsible for growth in VMT:

- Increasing driving-age population
- Growing working population, as more women enter the workforce and more families have two income-earners
- Rising real income levels, which make airfares and extended trips more affordable
- Rising demand for travel as lifestyles become more multi-dimensional
- Increasing average personal trip length (9-percent increase between 1983 and 1990) for almost all purposes⁴⁵
- Longer commutes as more homes are located outside of central cities.⁴⁶
- Lower vehicle occupancy, which increases vehicle miles relative to PMT (Figure 5.9).

Figure 5.7. Demand Indicator, Vehicle-Miles Traveled by Passenger Mode, 1985, 1988, and 1991

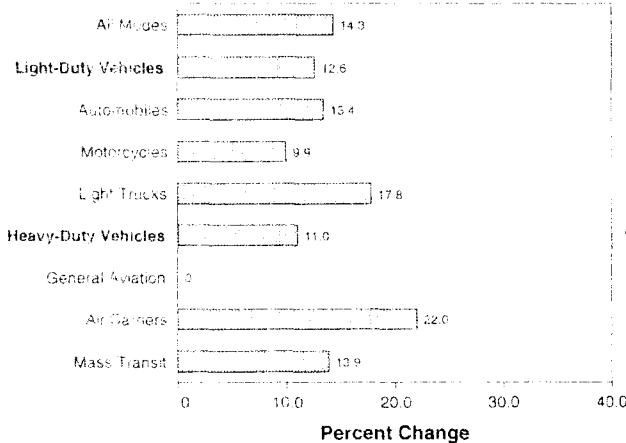


Notes: •No change was reported for General Aviation 1985-1988. •Mass transit includes buses and passenger rail.

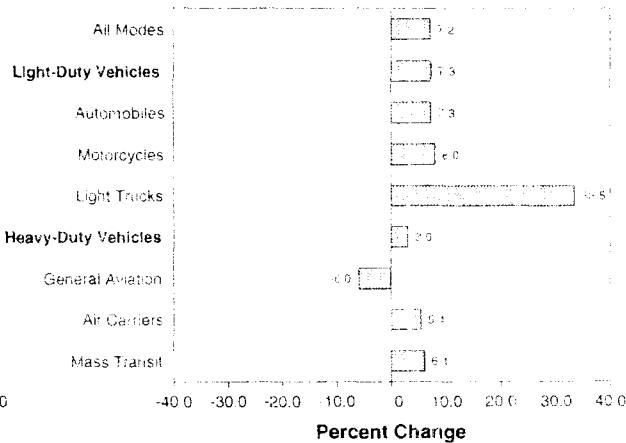
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Tables 5 and 6.

Figure 5.8. Change In Demand Indicator, Vehicle-Miles Traveled, by Passenger Mode

a. 1985 to 1988



b. 1988 to 1991



Notes: •No change was reported for General Aviation 1985-1988. •Mass transit includes buses and passenger rail.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report, September 1993, Tables 5 and 6.

⁴⁵U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Survey: Summary of Travel Trends*, pp. 33 and 42. The NPTS was conducted in 1983 and 1990.

⁴⁶This could be mitigated somewhat, by the growth of homes and businesses in the suburbs which would imply shorter commutes.

Passenger-Miles Traveled

Most of the growth in PMT can be attributed to light-duty vehicles (Figure 5.10). In 1991, there were 3.5 trillion passenger miles, of which 2.5 trillion were attributed to automobiles. The number of PMT has continually climbed over both the growth/growth interval (11.8 percent) and the growth/recession interval (5.4 percent). The increasing choice of consumers for light trucks and air travel is reflected in high increases in PMT by these two modes (Figure 5.11).⁴⁷

PMT by light trucks increased 17 percent during the growth/growth interval, almost twice the rate of increase for automobile passenger miles. Over the next 3 years, light-truck passenger miles grew by 6.9 percent, a rate of growth only slightly greater than automotive passenger mile growth. Passenger demand for automobiles and light trucks buoyed an otherwise flat recessionary period.

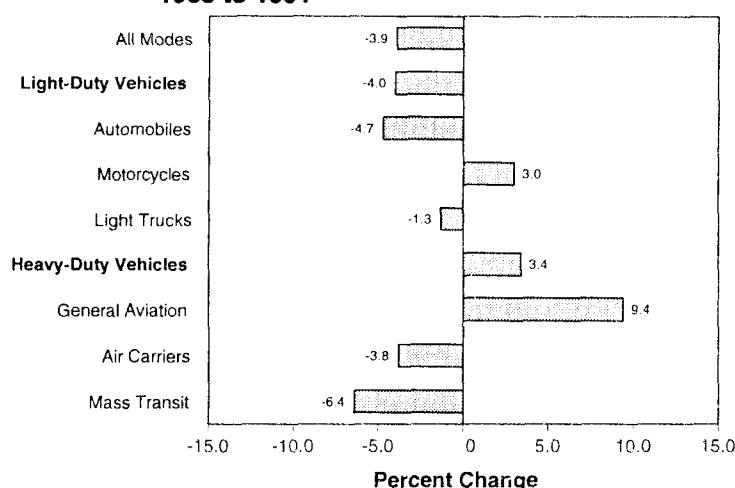
Most of the increases in heavy-duty vehicle use took place during the growth/growth interval. Passenger demand for air carriers and mass transit grew by 20 percent and 17 percent, respectively, during these two intervals. PMT by these three modes did not increase noticeably over the growth/recession interval.

Passenger Transportation Energy-Intensity Indicators

Two energy-intensity indicators are presented in this section: VMT and PMT. VMT does not take into account the number of passengers in a vehicle. Only detailed data on light-duty vehicles used by households, are available from the RTECS conducted by EIA.

PMT accounts for differences in vehicle use and occupancy. These indicators are presented separately so as not to encourage comparisons. The two different indicators are based on two different data sets and vehicle definitions. The RTECS data, the source for VMT, cover only household vehicles. The data set used for PMT (DOT) defines vehicles differently, e.g., light trucks are both household and commercial vehicles. Additionally, DOT defines light trucks as any 2-axle or 4-tire truck, whereas, EIA's definition is based on weight.

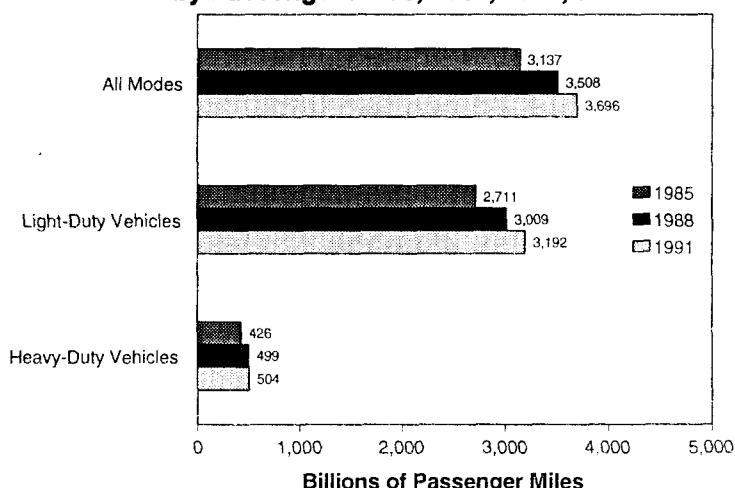
Figure 5.9. Change in Occupancy by Passenger Mode, 1985 to 1991



Notes: Mass transit includes buses and passenger rail.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Tables 5 and 6.

Figure 5.10. Demand Indicator, Passenger-Miles Traveled by Passenger Mode, 1985, 1988, and 1991

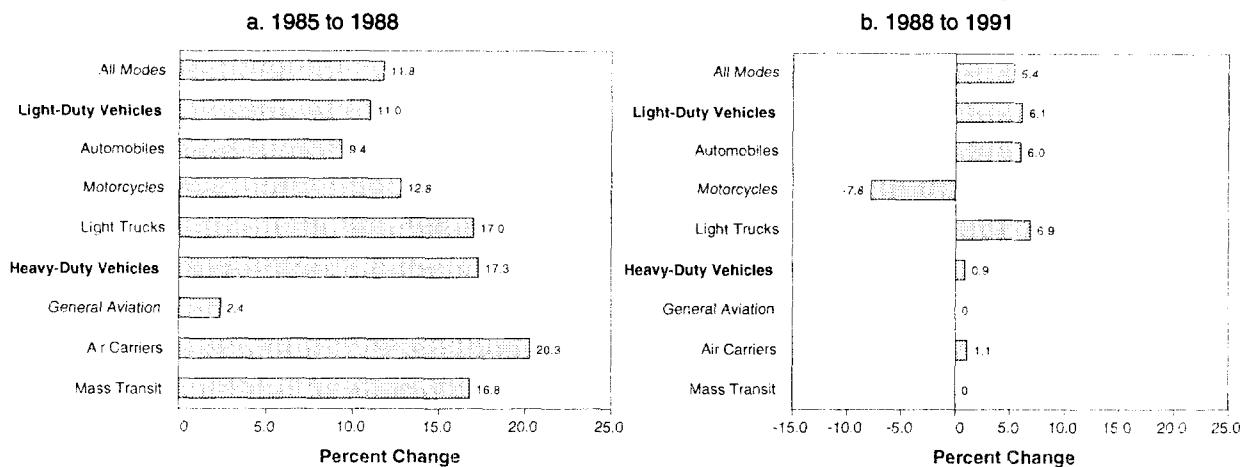


Note: Mass transit includes buses and passenger rail.

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6.

⁴⁷Light trucks include Minivans, sport-utility vehicles, and pickup trucks. See the definition of "Light Truck" in the transportation section of the Glossary.

Figure 5.11. Change in Demand Indicator, Passenger-Miles Traveled, by Passenger Mode



Notes: Mass transit includes buses and passenger rail.

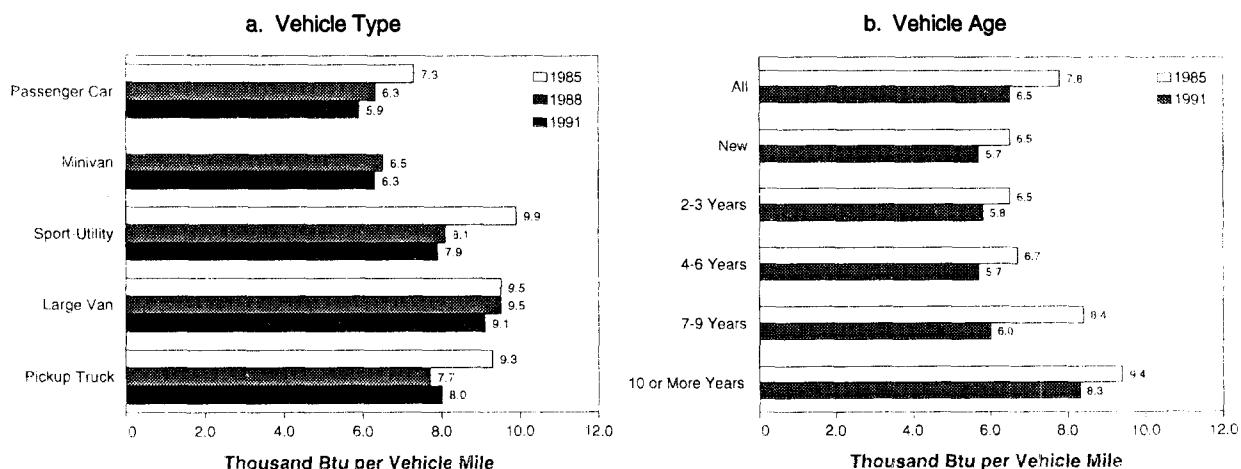
Source: •Energy Information Administration, Office of Energy Markets and End Use, 1991 Residential Transportation Energy Survey, Public-Use Data Files. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6.

Trends in Energy-Intensity Indicators

Energy per Vehicle-Mile Traveled

In 1991, the passenger car displayed the lowest energy-intensity indicator of all of the household vehicles, 5.9 thousand Btu per VMT. The largest was the large van (9.1 thousand Btu per VMT). In 1991 the sport-utility intensity indicator was 7.9 thousand Btu per VMT versus 5.9 thousand Btu per VMT for the passenger car (Figure 5.12a). The largest reduction in the energy-intensity indicator has been experienced by sport-utility vehicles, a 20-percent reduction in the energy-intensity indicator between 1985 and 1991 (Figure 5.13) with most of the reduction between 1985 and 1988, the growth/growth interval. However, even with such a large reduction in the intensity indicator, sport-utility vehicles intensity indicator is still much higher than the passenger car.

Figure 5.12. Energy-Intensity Indicator for Household Vehicles, by Vehicle Type and Age, 1985, 1988, and 1991



Note: Minivan classification not applicable in 1985.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988 and 1991 Residential Transportation Energy Consumption Surveys, Public-Use Data Files.

Overtime, each type of passenger vehicle has experienced reductions in energy-intensity. In fact, vehicle vintage is closely associated with household vehicle energy-intensity. Newer vehicles were, on average, 12 percent less energy intensive per VMT (Figure 5.13) in 1991 than in 1985. However, the energy-intensity indicator for 4-6 year-old vehicles in 1991 is no different than that of new cars, but substantially better than the energy-intensity indicator of 4-6 year-old vehicles in 1985 (Figure 5.12). There were 31 percent fewer new household vehicles on the road in 1991, a recession year, than in 1985. Vehicles were held longer in 1991 than in 1985. The share of vehicles 4 to 6 years old increased from 19.2 percent in 1985 to 25.8 percent in 1991 (Figure 5.14).

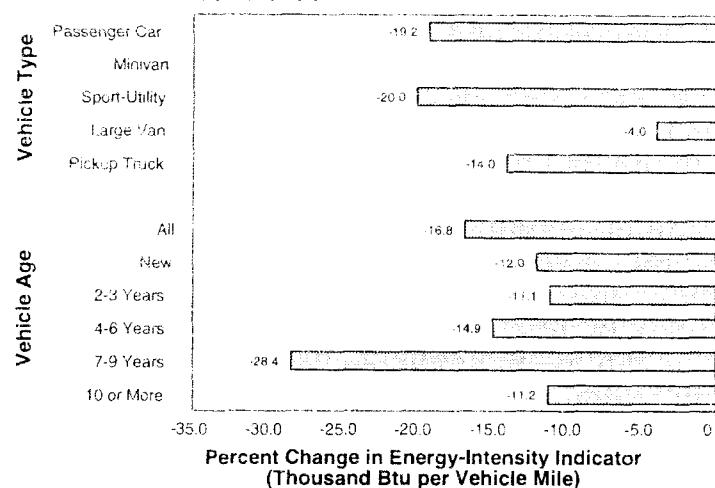
Figure 5.14 displaying the percent share of vehicles by vehicle type and vehicle age, shows a reduction in the share of the passenger car and an increase in the share of sport-utility, pickup truck, and the new Minivan. The gas mileage for these vehicles is less than the passenger car, thus dampening the reduction in energy-intensity indicator for household vehicles as a whole.

Energy per Passenger-Mile Traveled

Among light-duty vehicles, light trucks are the most energy intensive, consuming 5.9 thousand Btu per PMT in 1991, or two-thirds more energy than an automobile, to move one passenger 1 mile (Figure 5.15). Among the heavy-duty vehicles, general aviation vehicles are the most energy intensive, consuming 9.6 thousand Btu per PMT in 1991. Smaller general aviation planes consumed over two and one-half times more jet fuel than commercial air carriers to move one passenger 1 mile. Mass transit (buses and rail) are the least energy intensive of all modes.

During the growth/growth interval, all passenger modes except general aviation reduced their energy-intensity per PMT. Automobiles reduced their consumption of motor fuels per passenger mile by almost 6 percent (Figure 5.16). Automobile passenger miles increased far faster than automobile energy consumption during the interval, which may be correlated with stock turnovers.

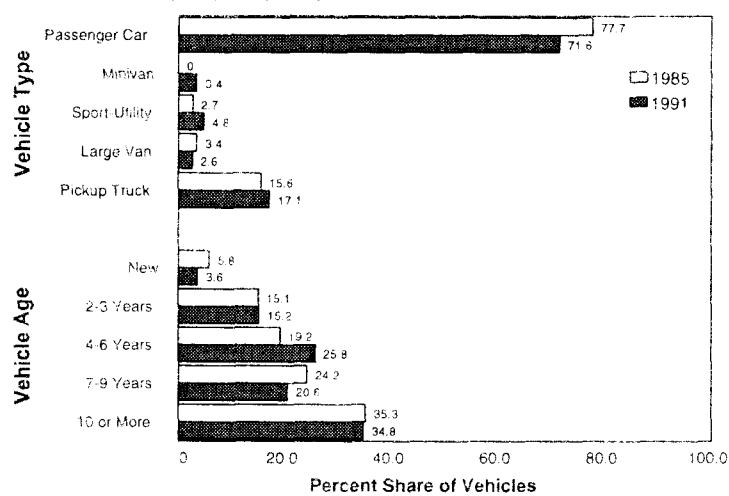
Figure 5.13. Change in the Energy-Intensity Indicator, 1985 to 1991



Notes: Minivan classification not applicable in 1985. •Percent changes are based on unrounded numbers.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985 and 1991 Residential Transportation Energy Consumption Surveys, Public-Use Data Files.

Figure 5.14. Characteristics of Household Vehicles, 1985 and 1991



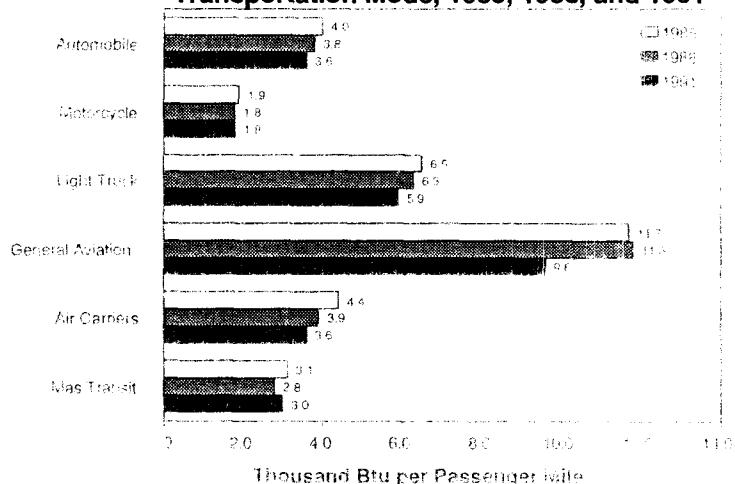
Notes: •Minivans were not available in 1985. •In 1985 all vans were considered large. •Sport-utility in 1991 applies to jeep-like in 1985.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985 and 1991 Residential Transportation Energy Consumption Surveys, Public-Use Data Files.

Although the energy-intensity indicator for mass transit was 8 percent less intensive over the growth/growth interval, this intensity indicator grew by almost 6 percent over the growth/recession interval. Several effects may explain these changes. Buses in the United States are aging. The federally recommended average of 12 years for a standard bus and 10 years for a medium-duty bus.⁴⁸ If age is considered a surrogate for physical condition, and if deteriorating condition adversely affect intensity then the energy-intensity of the aging bus fleet will increase. Mainly, though, ridership problems are causing these intensity changes. Fewer people are using buses for transportation.

Mass transit rail cars and locomotives, stations, track, and maintenance facilities are far newer than buses. Mass transit travel is most often used in the urban areas. Urban areas are most apt to have rapid rail systems. As shown in the 1990 *Nationwide Personal Transportation Survey*, ridership problems face both commuter and intercity rail.

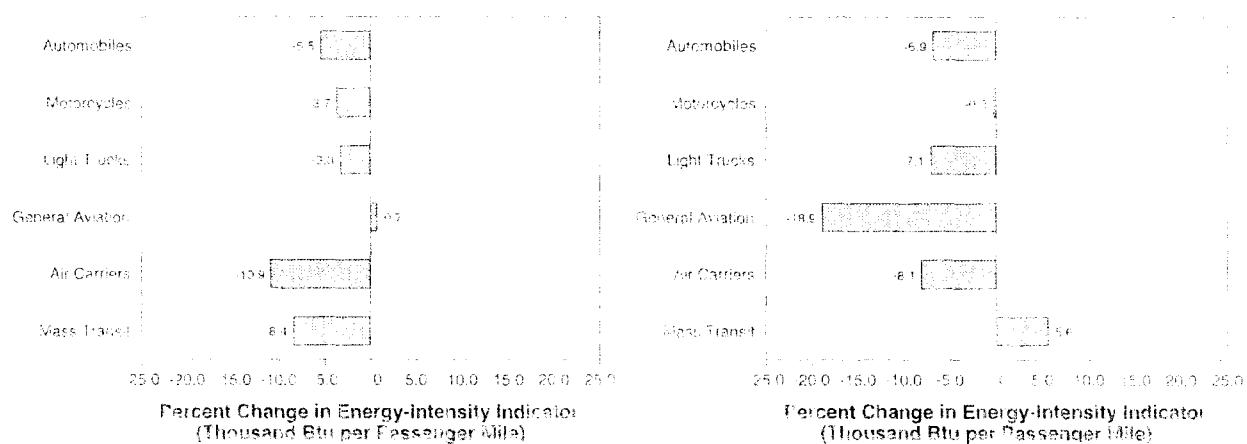
Figure 5.15. Energy-Intensity Indicator by Passenger Transportation Mode, 1985, 1988, and 1991



Notes: •Mass transit includes buses and passenger rail. •Derivation of these estimates are described in the transportation section of Appendix A.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6.

Figure 5.16. Change in the Energy-Intensity Indicator, by Passenger Transportation Mode
a. 1985 to 1988
b. 1988 to 1991



Notes: •Mass transit includes buses and passenger rail. •Derivation of these numbers are described in the Transportation section of Appendix A.

Source: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6.

The largest reductions in the energy-intensity indicator were registered in air travel. Commercial air carriers reduced the energy-intensity of their operations by 11 percent during the growth/growth interval and by another 8 percent during the growth/recession interval. This reduction was achieved by increasing passenger miles faster than jet fuel demand during the growth/growth interval and by reducing jet fuel demand by 7 percent during the growth/recession interval while moving the same number of passenger miles. Flight stage length is a key determinant of energy-intensity.

⁴⁸U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics, Annual Report 1994*, (January 1994), Tables 2-8, p. 30.

Increasing flight stage lengths increase the overall efficiency of the aircraft by:⁴⁹

- Reducing the fuel used for taxing, idling, climb-out, and approaches
- Using larger, more efficient aircraft
- Increasing load factors if frequency of service decreases.

Fewer, more efficient aircrafts, with increased passenger loads and traveling over longer distances directly reduces energy-intensity.

Between 1988 and 1992, the average flight-stage length has fluctuated between 563.2 miles and 588.4 miles with a slight upward trend.⁵⁰

U.S. Domestic Freight Transportation

Background: The Changing Regulatory Environment of Freight Transportation

Rail. Much of the growth in transportation energy consumption between 1973 and 1985 was due to freight energy use. Deregulation helped increase the demand for energy from freight carriers.

Rail freight transportation in the United States has a history of regulation and subsidization. Major federal legislation passed during the 1970's and 1980's partially deregulated portions of the freight system: The Regional Rail Reorganization Act (1973) and Railroad Revitalization and Regulatory Reform Act (1976) provided financial support for bankrupt train companies and relaxed some rate regulation by the Interstate Commerce Commission. But the railroads were still considered completely regulated until the passage of the Staggers Act in 1980, which removed regulatory control of markets in which train companies faced substantial competition, and streamlined regulations relating to company mergers and track abandonment.

Trucking. In 1980, only 44 percent of trucking industry movements were regulated,⁵¹ essentially that portion of travel under Interstate Commerce Commission control. The Motor Carrier Act of 1980 reduced restrictions on entry and expansion in the trucking industry and relaxed various regulations. The Surface Transportation Assistance Act (1982) superseded state requirements on size and weight limits for trucks.⁵² The number of businesses in highway freight transportation appears to have grown since partial deregulation in 1980. The Interstate Commerce Commission reports more than 50,000 for-hire motor carriers are currently operating. It has been estimated that 74 percent of all intercity freight was carried by regulated trucks in 1991.⁵³

Other freight modes. Congress deregulated domestic air cargo transport in 1978. However, the authority to block discriminatory and preferential rates was retained by the Civil Aeronautics Board until 1984, when the authority was transferred to the Department of Transportation. Oil pipelines remain 84 percent regulated by the Federal Energy Regulatory Commission. Domestic waterborne cargo is the least regulated portion of the freight industry, with only 8 percent of river and canal freight transport regulated in 1991.

⁴⁹A.B. Rose, *Energy-Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements*, ORNL-5506 (Oak Ridge, TN: Oak Ridge National Laboratory, January 1979), pp. 3 and 4.

⁵⁰U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics: Annual Report 1994*, pp. 83 and 84.

⁵¹The percentages are calculated from the portion of freight ton miles carried by the mode. See Eno Transportation Foundation, *Transportation in America 1994*, pp. 17 and 51.

⁵²U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, p. 50.

⁵³U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics: Annual Report 1994*, pp. 19 and 20.

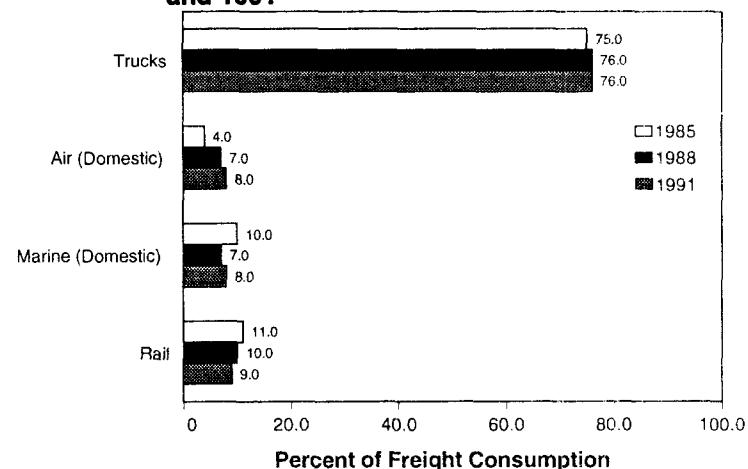
Freight Transportation Energy Consumption

Freight total site energy consumption totaled 5.0 quadrillion Btu in 1991, representing approximately 23 percent of total site transportation energy (Figure 5.3). Most of the energy was used by trucks, which have access to 3.9 million miles of roads and streets throughout the U.S. highway system (Figure 5.17). For nonbulk cargo—mail, perishable foods, packaged goods—trucks are the dominant transport mode.⁵⁴

The share of energy used by domestic air freight seems to be growing the most, but data collection for small package shipments such as Federal Express, or United Parcel Service did not begin until 1986. Therefore, the change in site energy consumption during the growth/growth interval is a reflection of this. The growth in site energy consumption during the growth/recession interval seems reasonable.

During the growth/growth interval, site energy consumption grew from 3.9 quadrillion Btu to 4.4 quadrillion Btu (12 percent).⁵⁵ Most of the growth was in the trucking industry (13 percent). Domestic marine transportation reduced site energy consumption by 19 percent during the interval. Rail energy consumption displayed very little growth (Figure 5.18).

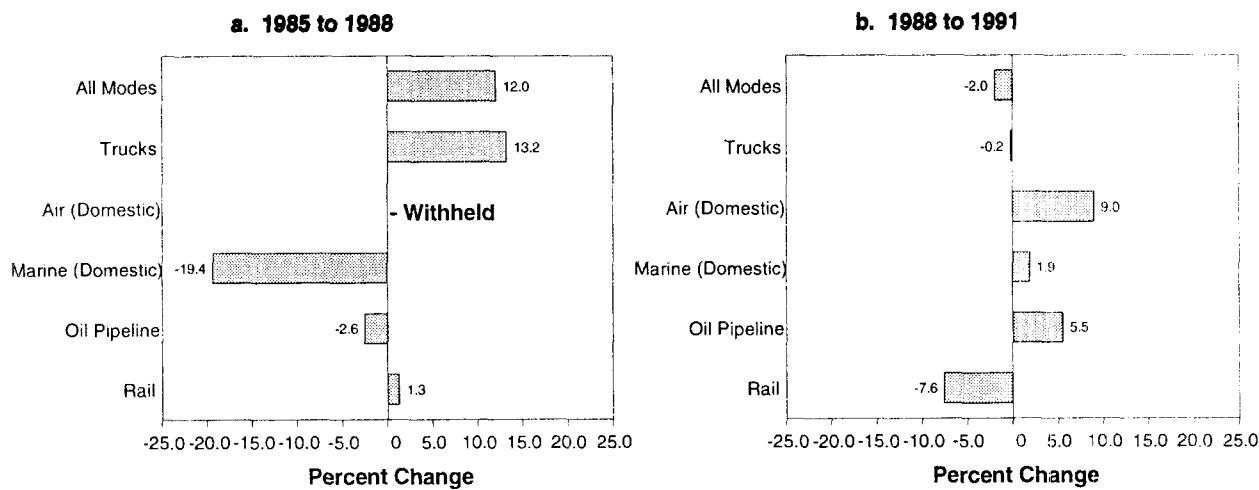
Figure 5.17. Freight Transportation Site Energy Consumption by Freight Mode, 1985, 1988, and 1991



Notes: •In this graph, the share of oil pipeline in total freight consumption was less than 1 percent. •Energy for moving water and natural gas is excluded. •Data collection for small package shipments such as Federal Express or United Parcel Service did not begin until 1986.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Edition 8, Table 1.5, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL.

Figure 5.18. Change in Freight Transportation Site Energy Consumption, by Freight Mode



Notes: •Percent change in domestic air freight transportation is not shown for 1985 to 1988. •Since data collection for small package carriers such as Federal Express did not begin until 1986. •In this graph, the share of oil pipeline in total freight consumption was less than 1 percent. •Energy for moving water and natural gas is excluded.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Edition 8, Table 1.5, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL.

⁵⁴U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 1991*, Tables MV-9 and MV-11.

⁵⁵Excluding energy for moving water and natural gas.

During the growth/recession interval, site energy consumption fell by almost 8 percent. Over both intervals of time, oil pipelines displayed a 3 percent growth in energy consumption.⁵⁶

The changing structure of the U.S. economy has played a major role in the changing nature of freight transport. The economy is providing more higher value-added products that weigh less per dollar of value added than raw materials.⁵⁷ Air and truck carriers are transporting a growing share of these high value added products, at the expense of rail and boat transport. Moreover, intermodal freight (carriage on trailers and containers by trains, barges and ships for final delivery by trucks) is the fastest growing segment of truck freight.

Freight Transportation Demand Indicators

The freight transportation sector is a very heterogenous sector, making it difficult to find one demand indicator that captures changes in demand for all of the various modes.

Using the **number of freight vehicles** as a demand indicator is inappropriate. Freight vehicles vary by size, weight, speed, age, and cost. For example, transport units include a variety of engines or self-propelled vessels (tractor trucks, locomotives, towboats, tugs, tankers, ships) and hauled or non-self-propelled vessels (rail cars and barges). In freight handling, one engine or self-propelled vessel will drag or push a number of flat hauling vehicles that by themselves do not consume energy.

Employment in rail, marine, truck, or air freight is not a perfect indicator. Employment has stayed constant or fallen since 1985.⁵⁸ Freight handling is very labor intensive at the points of origin and destination, but the need for workers during very long hauls varies by type of mode. Increasing employment in any particular freight mode would not necessarily be considered as the cause of greater energy demands, because the employee is not the consuming unit.

Economic activity is also an imperfect indicator. When the economy is growing, freight revenues increase. The opposite is true in times of economic contraction. One way of capturing economic activity is to use the industrial production index as a proxy for the demand for freight movements. This index is based on the value of output but freight energy consumption is not necessarily a function of the dollar value of manufacturing shipments or value added. Tonnage of freight hauled or miles traveled do not necessarily move in tandem with increases in the industrial production index, value of manufacturing shipments, or manufacturing value added. Shifts in the product mix that alter the industrial production index, for instance, are structural shifts in the manufacturing sector, not the source of efficiency improvements in freight transportation.

The **weight of goods moved** is more closely associated with the amount of energy consumed than with the value of the product transported. If more tons of cargo are moved, independent of the value of the cargo, then more energy is expended. Measuring freight movements purely in terms of weight is misleading, given the changing structure of the economy towards more lighter, higher value-added products and their domination of freight transport.

The distance the freight travels and the weight of the cargo being hauled measured in miles and tons, respectively, is correlated with energy consumption. The demand indicator, **ton miles**, captures both the weight of the freight and the distance it travels. Data available on intercity freight movements most likely underestimates the total amount of miles traveled since short hauls within city borders are not included.

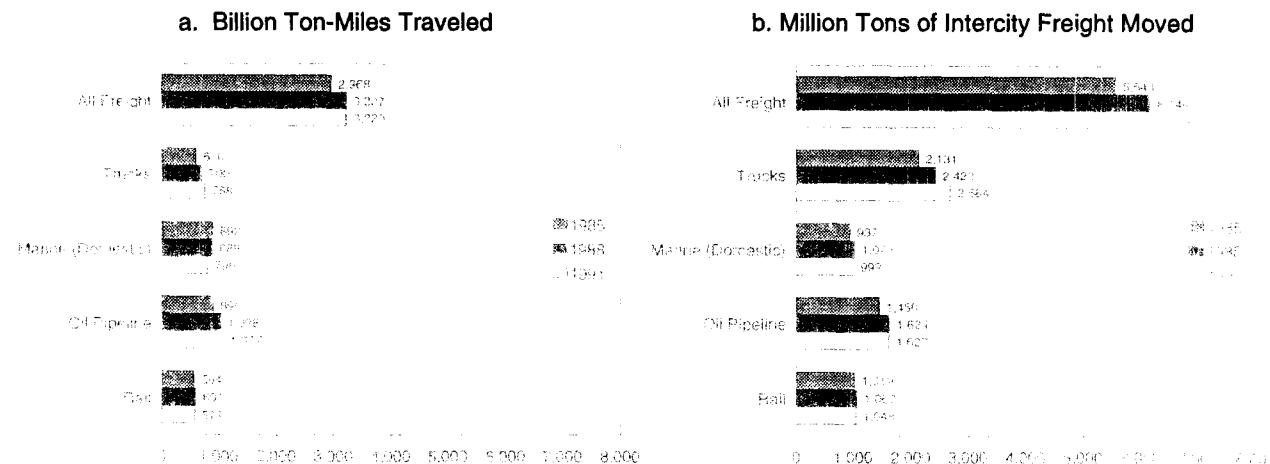
Figure 5.19 presents a comparison of the composition of domestic freight by ton-miles traveled and transported for 1985, 1988, and 1991. In 1991 trucks hauled 42 percent of the weight but only 24 percent of the ton miles. Trucks haul primarily lighter, high-value added products shorter distances than other freight modes.

⁵⁶Pipelines include those moving crude oil, petroleum product, coal slurry, natural gas, and water. This chapter is limited to oil pipelines, since comparable demand indicator data are not available for natural gas.

⁵⁷U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington DC: U.S. Government Printing Office, July 1994), p. 50.

⁵⁸U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 57, p. 144.

Figure 5.19. Domestic Freight Weight and Miles Traveled by Freight Mode, 1985, 1988, and 1991



Notes: •Figure a: Air mode was 7, 9, 9 ton miles, respectively, for 1985, 1988, and 1991. •Figure b: Air mode was 6, 8, 7 ton miles, respectively, for 1985, 1988 and 1991. •Energy for moving water and natural gas is excluded. •Marine ton miles include freight transported in rivers, canals, Great Lakes and ocean. •Intercity freight ton miles only are included. •Truck ton miles include both Interstate Commerce Commission (ICC) and non-ICC trucks. •Pipeline ton miles represent movement of crude oil and other petroleum products (excludes movement of water and natural gas). •Air freight volumes include Federal Express and UPS small package shipments only after 1985 since a data collection for small package shipments such as Federal Express or, United Parcel Service did not begin until 1986.

Source: Eno Transportation Foundation, Inc., *Transportation in America 1994*, 12th Edition, pp. 44 and 46.

The opposite situation faces domestic marine and rail freight modes. In 1991, waterborne carriers haul only 16 percent of the total intercity freight but account for almost 25 percent of the ton-miles traveled. Rail freight moves 16 percent of the tons but accounts for over 18 percent of the ton-miles traveled. Air freight tons and ton miles are comparable. Air freight represents less than 0.1 percent of the tons transported.

Trends in Freight Transportation Demand Indicator

During the growth/growth interval, ton miles grew by almost 9 percent while the growth/recessionary interval basically showed no growth. Trucks and rail both registered 15-percent gains in ton miles during the growth years with fewer gains during the growth/recession interval (Figure 5.20). Rail relies on coal and farm products for at least half of its business. For trucks, no single commodity accounts for more than 16 percent of revenues; agriculture, food, and other manufactured goods accounted for 29 percent of the 1991 revenues in the trucking industry.⁵⁹

During the growth/growth interval, data as mentioned previously, were not collected on the small package carriers until 1986, but this mode seems to be doing well as ton miles grew by almost 7 percent in the growth/recession interval. Air freight focuses on high-value goods with high-time demands, either perishables or high-value technical goods.

The largest reduction in ton miles was experienced by the domestic marine freight mode. Growth in this mode was flat during the growth/growth interval and fell by almost 11 percent during the growth/recession interval. Marine transport has traditionally hauled lower value-added, heavy cargo. An important factor that may have contributed to a reduction in domestic marine ton miles is the rise of imported goods.⁶⁰ Waterborne carriers rely on petroleum and coal for at least half of their revenue.

⁵⁹U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994), pp. 43-46. These pages present a discussion on the types of goods each of the freight modes carry.

⁶⁰U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994), p. 50.

Oil pipeline ton miles track movements in the petroleum industry. While domestic crude oil production fell 9 percent during the growth/growth interval, imports of crude oil grew by 60 percent.⁶¹ Refinery output increased by 9 percent during this time.⁶² Ton miles grew by 7 percent since most of the refinery output is delivered to end users via the product pipeline system. During the growth/recession interval, domestic crude oil production fell by 9 percent, imported crude increased by only 13 percent, and refinery output showed very little growth. As a result, ton miles decreased by nearly 4 percent.

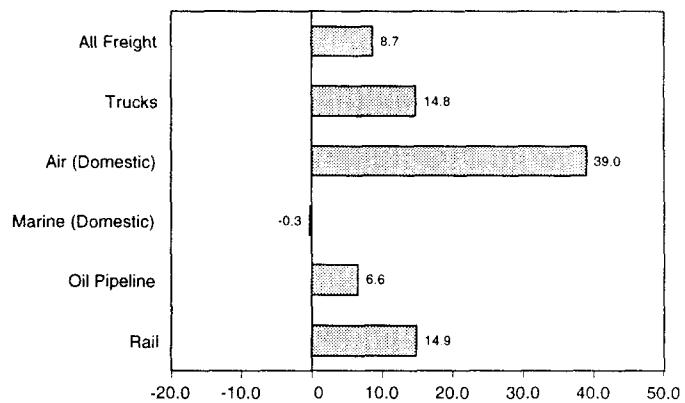
Freight Transportation Energy-Intensity Indicators

Only one energy-intensity indicator is presented for the freight transportation sector, energy per ton miles. The heavier the freight, and the more miles this freight is carried, the more energy is needed. If less energy is used for the same level of weight and miles or if more weight is carried and/or more miles are traveled for the same amount of energy, then gains in energy efficiency may occur depending on the level of any structural or behavioral effects that may have taken place.

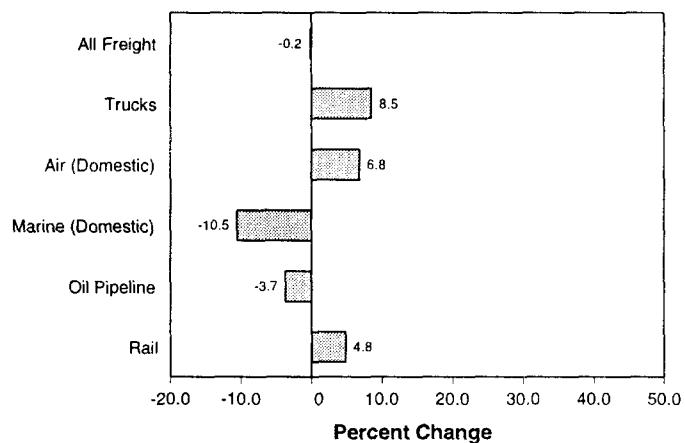
When comparing the energy-intensity indicator for freight transportation, energy used for nonhauling purposes is included. For freight modes, a significant portion of the energy expended is attributed to nonhauling purposes, e.g., almost half of the energy consumed by freight rail is not used to move freight:

- More than 30 percent is used for empty backhaul
- About 4 percent is reported lost or spilled each year
- About 4 percent is consumed in idling
- Ten percent is used by yard locomotives assembling and switching cars.⁶³

Figure 5.20. Change in Ton Miles by Freight Mode
a. 1985 to 1988



b. 1988 to 1991



Notes: ● In this graph, the share of oil pipeline in total freight consumption was less than 1 percent. ● Energy for moving water and natural gas is excluded. ● Data collection for small package shipments such as Federal Express or United Parcel Service did not begin until 1986.

Source: Eno Transportation Foundation, Inc., *Transportation in America* 1994, 12th Edition, p. 44.

⁶¹U.S. Department of Energy, Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 5.2 and 5.3, pp. 143 and 145.

⁶²U.S. Department of Energy, Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Table 5.8, p. 155.

⁶³A.B. Rose, *Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements*, ORNL-5554 (Oak Ridge, TN: Oak Ridge National Laboratory, June 1979), pp. S-10 and 5-4.

Trends In Freight Transportation Energy-Intensity Indicators

Air freight continues to be the most energy-intensive mode of freight transportation (Figure 5.21). In 1985, air freight required 20 thousand Btu to move 1 ton 1 mile. By 1988, during an interval of growth/growth, this had climbed to 31 thousand Btu per ton mile. During the growth/recession interval, this grew more slowly to 32 thousand Btu per ton mile (Figure 5.21).

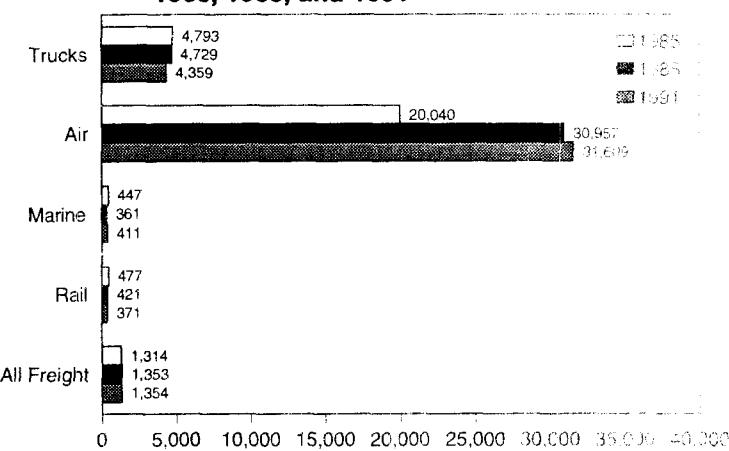
Trucks were the second most energy-intensive freight mode, requiring 4.8 thousand Btu per ton mile in 1985. During the growth/growth interval, energy consumption increases were close to that of increases in ton miles leading to approximately a 1-percent reduction in the energy-intensity indicator (Figure 5.22a). During the growth/recession interval, energy consumption growth fell slightly while ton miles increased by 8.3-percent causing a 7.9-percent decrease in the energy-intensity indicator (Figure 5.22b). Throughout the 1970's and early 1980's, there has been only modest improvement in truck-fleet economy, with combination trucks averaging 5.5 mpg and larger single-unit trucks at 7.3 mpg in 1990. Heavy single-unit trucks are twice as energy intensive as light trucks used for passenger travel. On average, a combination truck requires 3.1 thousand Btu to haul 1 ton of cargo 1 mile in 1991.⁶⁴

Countervailing factors may have yielded small gains in truck fuel economy. Factors that may have contributed to improved fuel economy include:

- Increased trip lengths
- Technical improvements in electronic engine controls
- Demand-actuated cooling fans
- Intercoolers
- Low-profile radial tires
- Multiple trailers.⁶⁵

The energy-intensity indicator for marine freight transportation decreased by 19 percent during the growth/growth interval, only to reverse this improvement during the growth/recession interval with a 14-percent increase in the energy-intensity indicator. During the growth/growth interval, much of the decrease resulted from a substantial reduction in consumption (19.4 percent) while the energy-intensity increase during the growth/recession interval was due to a large decrease in ton miles (10.5 percent). Increased imports reduced the distances that domestic marine freight has to travel. The hauling of raw materials and manufactured products, which has traditionally been the domain of rail and marine freight, and any intermodal competition has significantly been reduced.

Figure 5.21. Energy-Intensity Indicator by Freight Mode, 1985, 1988, and 1991



Notes: •The share of oil pipeline in total freight consumption was less than 1 percent. •Energy for moving water and natural gas is excluded. •Data collection for small package shipments such as Federal Express or United Parcel Service did not begin until 1986.

Sources: •U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Edition 11 and 14, Table 2.6 and unpublished 1985 data from ORNL.

⁶⁴Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics: Annual Report 1994*, p. 153.

⁶⁵U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994), p. 51.

The following improvements in technology and engineering may lead to reductions in the marine freight energy-intensity indicator:

- Improved engines, with greater use of fuel management computer systems
- Improved matching of barges and tugs
- Improved computer-aided operations
- Improved channels and locks
- Use of larger barges and tugs.⁶⁶

Marine carriers are more energy intensive per ton mile than **freight-train carriers** because the density and viscosity of the water are greater than those of air. A 10-percent reduction in marine operating speeds will yield a 20-percent reduction in energy use.⁶⁷

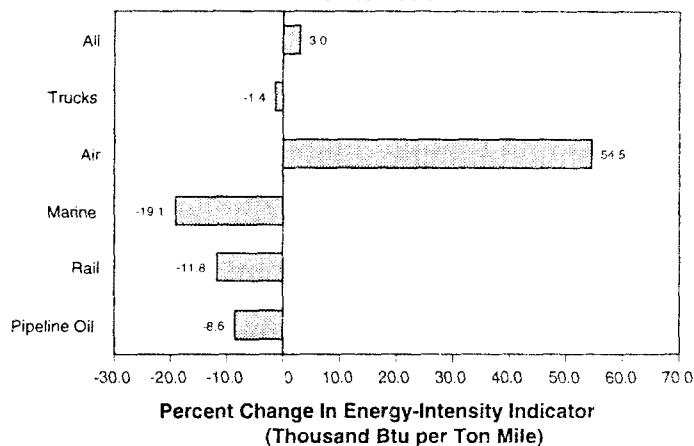
The energy-intensity indicator for **freight trains** decreased by 12 percent for each of the two intervals, growth/growth and growth/recession. In both cases, the decreases in the energy-intensity indicator were due to growth in ton miles. At the same time, energy consumption experienced slow growth (1.3 percent) during the growth years and energy consumption fell (7.6 percent) during the growth/recession interval.

Several rail efficiency improvements may be responsible for this reduction:

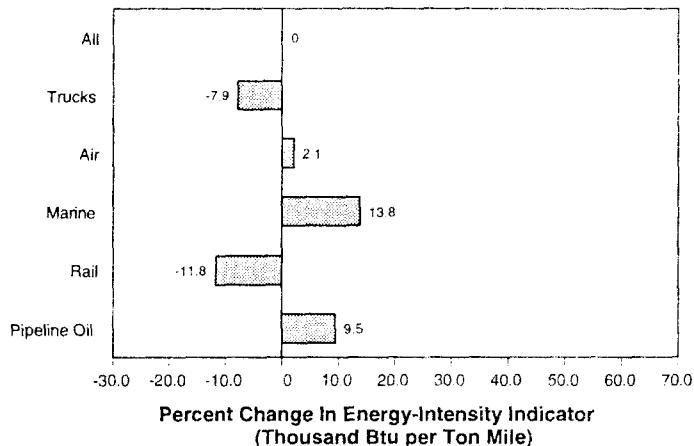
- Increased average trip length with fewer stops and greater sustained speeds
- Improved operations and communications—routing, scheduling, reduced empty car-miles, minimized starts and stops, and better matched locomotives and loads
- Technical improvements—reduced locomotive idling speeds, improved sizing of auxiliary loads, improved wheel-slip detection, greater use of flange lubricators, weight reduction, and aerodynamic improvements.⁶⁸

Figure 5.22. Change in the Energy-Intensity Indicator, by Freight Mode

a. 1985 to 1988



b. 1988 to 1991



Notes: ● In this graph, the share of oil pipeline in total freight consumption was less than 1 percent. ● Energy for moving water and natural gas is excluded. ● Data collection for small package shipments such as Federal Express or United Parcel Service did not begin until 1986.

Sources: ● U.S. Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*, Edition 8, Table 1.5, Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. ● Eno Transportation Foundation, Inc., *Transportation in America 1994*, 12th Edition, p. 44.

⁶⁶U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994), pp. 52 and 53.

⁶⁷A.B. Rose, *Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements*, ORNL-5554 (Oak Ridge, TN: Oak Ridge National Laboratory, June 1979), pp. 4-2 and 4-3.

⁶⁸U.S. Congress, Office of Technology Assessment, *Saving Energy in U.S. Transportation*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994), p. 52 cites Abacus Technology report without full citation.

The oil pipeline energy-intensity indicator decreased during the growth/growth interval (increase in ton miles larger than increase in consumption), only to increase during the growth/recession interval (energy consumption increased while ton miles fell). In most cases, there are no cheap alternatives to pipeline freight. Consequently, pipelines have encountered relatively little competition from other freight modes.

Transportation Energy-Intensity Composite Indicator

It is very difficult to make meaningful comparisons across passenger and freight modes. While both modes are petroleum dependent, passenger modes are dominated by gasoline-fueled internal combustion engines, and freight modes are dominated by diesel engines. Since there is no common demand indicator that may be used for the entire transportation sector, the percent change in the energy-intensity indicators from both passenger and freight travel is used in a transportation sector energy-intensity composite indicator. A multiplying factor is used that takes into account the relative share of site energy consumption of both passenger and freight modes.⁶⁹ Two composite energy-intensity indicators are presented. The first composite is a "bottom-up" approach that is built up from the individual passenger and freight modes. The second composite is a "macro" approach calculated from macro passenger and freight sums.⁷⁰

Table 5.1 shows the shares of each mode as a percent of total site transportation energy. In both cases, appropriate energy shares for the later year in any time interval were used. In this analysis, both composite energy-intensity indicators produce similar results, whether the methodology was macro or micro. Over the interval of growth/growth, energy-intensity composites show a decrease of 3.4 percent for the macro-transportation composite and 3.6 percent for the micro-transportation composite, suggesting that there may be an overall increase in energy efficiency. For the interval of growth/recession, the energy-intensity composites also suggest that there may be an overall increase in energy efficiency, keeping in mind possible other structural and behavioral effect that could be affecting the results.

Table 5.1. Building up a Composite Energy-Intensity Indicator for the Transportation Sector

Passenger and Freight Modes	Percent Share of Energy		Percent Change In Intensity		
	1988	1991	1985 to 1988	1988 to 1991	1985 to 1991
Automobiles	41.0	40.6	-5.5	-6.9	-12.0
Motorcycles	0.1	0.1	-3.7	-0.3	-3.9
Light Trucks	18.8	18.7	-3.3	-7.1	-10.1
General Aviation	0.7	0.6	0.7	-18.9	-18.4
Air Carriers	6.0	5.6	-10.9	-8.1	-18.1
Buses	0.7	0.8	-12.4	9.2	-4.4
Passenger Rail	0.2	0.2	-4.9	2.7	-2.3
Freight Trucks	15.1	15.2	-1.4	-7.9	-9.1
Air Freight*	1.3	1.4	54.5	2.1	57.7
Marine Freight	1.5	1.5	-19.1	13.8	-7.9
Rail Freight	2.0	1.8	-11.8	-11.8	-22.3
Oil Pipeline	0.1	0.1	-8.6	9.5	0.1
Micro-Transportation Composite	100.0	100.0	-3.6	-5.8	-9.0
Light-Duty Passenger Vehicles	60.0	59.5	4.2	-6.9	-10.8
Heavy-Duty Passenger Vehicles	7.6	7.2	-9.7	-7.1	-16.1
Freight Trucks	15.1	15.2	-1.4	-7.9	-9.1
Non-Highway Freight	4.8	4.9	1.1	2.7	3.8
Macro-Transportation Composite	100.0	100.0	-3.4	-5.7	-8.8

*Air Freight estimate increased after 1985 because data collection of small packages shipments did not begin until 1986.

Sources: •Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book*: Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Annual Report (September 1993), Table 6, and earlier publications.

⁶⁹In Chapter 7, "Economy," the methodology for the economy composite is presented. The methodology is basically the same as presented here.

⁷⁰The more detailed "Micro-Transportation" indicator is the more robust of the two indicators. This is because the more structural and behavioral effects that could be included before the build up of to the composite, the greater the chance that such effects will be removed.

Strengths and Limitations of the Energy-Intensity Indicators

A strength of the indicators for both passenger and freight transportation modes is that they depend on the energy content of the fuel being used. This allows all types of fuel to be evaluated and compared. When alternative fuels develop a significant presence in the fuel mix, the analysis used will still apply.

The analysis excluded several modes of both passenger and freight transportation. Off-highway energy use, recreational boats, cruise ships, military energy use, natural gas pipelines, and foreign air travel and water cargo were not analyzed because of lack of available demand indicators.

Data on the miles traveled and energy used to move passengers and freight are at times imprecise and contradictory. The Office of Technology Assessment identified two main reasons for the discrepancies: (1) inconsistent definitions on weight class, personal use, intercity movements, and inclusion of government and military vehicles; and (2) inconsistent data collection and quality (critical data are extrapolated from limited sample surveys or added from questionable State estimates).

In the study, *Transportation Energy Efficiency Trends 1972-1992*, limitations of the data are presented including:

- Truck freight ton miles are not reported for all types of trucks
- Pipeline ton miles are not reported annually for natural gas
- Domestic waterborne transport data fluctuate
- Passenger-mile data are interpolated from infrequent surveys.

Data are weak in assessing significant changes in the trucking industry since deregulation. The Motor Freight and Warehousing Census tracks trucking performed only by firms engaged in trucking services, excluding the majority of the trucking industry: owner-operator trucking, and corporate truck fleets that haul their own goods.⁷¹ Since deregulation, private fleets provide for-hire services, freight forwarders own their own fleets, and railroads and air carriers increasingly own and operate their own trucking fleets.

EIA's definition of light trucks may have affected the estimate of energy usage for this category. The definition of light trucks as used by the Eno Transportation Foundation is consistent with the Department of Transportation definition—all 2-axle, 4-tire single-unit trucks. However, EIA defines light trucks as trucks weighing up to 8,500 pounds. About 99.9 percent of the light trucks in the RTECS weighs 8,500 pounds or less. Since some 2-axle 4-tire trucks weigh substantially more than 8,500 pounds, the energy used for light trucks may have been overestimated.

⁷¹U.S. Department of Transportation, Bureau of Transportation Statistics, *Transportation Statistics: Annual Report 1994*, p. 61.

**U.S. Energy Information Administration
Transportation Sector Energy-Efficiency Workshop
Workshop Program**

U.S. Department of Energy, Washington, D.C.

March 19, 1996

8:30 a.m.	Registration (Room 6E-069)
9:00 a.m.	Opening Remarks (Room 6E-069) - Jay Hakes, Administrator, U.S. Energy Information Administration
9:05 a.m.	Energy-Efficiency Project - Lynda T. Carlson, Director, Energy End Use and Integrated Statistics Division, U.S. Energy Information Administration
9:15 a.m.	Chapter 5. Transportation Sector Overview and Workshop Format - Stephanie J. Battles, Project Manager, Energy End Use and Integrated Statistics Division
9:30-10:30 a.m.	I. Expert Reviews (Room 6E-069) - Steve Plotkin, Argonne National Laboratory; K.G. Duleep, Energy and Environmental Analysis, Inc. (Facilitator: Energetics; EIA Observer: Christy Hall)
10:30 a.m.	Break
10:45 a.m.	II. Panel Discussion (Room 6E-069): Energy Efficiency-What is it?; How Should EIA Measure It?; How are the Measurements Used? - Phillip Patterson, Office of Transportation Technologies, U.S. Department of Energy; David Chien, U.S. Energy Information Administration; Joanne Sedor, Bureau of Transportation Statistics, U.S. Department of Transportation; Lee Schipper, Lawrence Berkeley National Laboratory (Facilitator: Energetics; EIA Observer: Ron Lambrecht)
12:30-1:30 p.m.	Lunch Break
1:30-3:00 p.m.	Parallel Afternoon Sessions
	III A. Nontechnical (Room BE-069): Definition of Energy Efficiency; Usage of Energy Efficiency Indicators - Barry McNutt, Office of Energy Efficiency and Alternative Fuels Policy, U.S. Department of Energy (Facilitator: Energetics; EIA Observer: Leigh Carleton)
	III B. Technical (Room 6E-069): Other Approaches and Techniques - David L. Greene, Center for Transportation, Oak Ridge National Laboratory (Facilitator: Energetics; EIA Observer: Ivy Harrison)
3:00 p.m.	Break
3:15 p.m.	IV. Plenary Session (Room 6E-069): What Have We Learned? - Dwight French, Chief, Transportation and Industrial Branch, U.S. Energy Information Administration; EIA Observers: Christy Hall, Ron Lambrecht, Leigh Carleton, and Ivy Harrison (Facilitator: Energetics)
4:15 p.m.	Closing Remarks: Where Do We Go from Here? - Lynda T. Carlson, Director, Energy End Use and Integrated Statistics Division
4:30 p.m.	Adjourn

For Workshop Information, Contact: Stephanie J. Battles, U.S. Energy Information Administration
Telephone: (202)586-7237 or E-Mail: sbattles@eia.doe.gov



Guidelines for Expert Reviewers

Transportation Sector Energy-Efficiency Workshop

March 19, 1996

General Guidelines:

- Length of Review: 20 minutes

The Review Should Include But Not Limited To The Following Criteria:

- Identification of strengths
- Identification of technical deficiencies
- Specific remedial suggestions which would bring the measurements into compliance with professionally accepted standards
- Specific suggestions to improve usefulness of the energy-efficiency indicators
- Rank ordering of the importance of your suggestions for improvements—both technical and usefulness.

Please Send To:

Energetics
501 School Street S.W.,
Washington, D.C., 20024
ATTN: Andrea Lachenmayr

By March 8, 1996:

- One hard copy of your presentation
- Biographical sketch
- Audio-visual equipment needs

Questions Relating to Your Presentation Contact:

Andrea Lachenmayr (Energetics)
Telephone: (202) 479-2748

Questions Relating to Other Matters Pertaining to the Workshop Contact:

Stephanie J. Battles (Energy Information Administration)
Telephone: (202) 586-7237
E-mail: sbattles@eia.doe.gov

1 **Measuring U.S. Energy Efficiency**

Steve Plotkin

Argonne National Laboratory

2 **My Point of View**

- ◆ Data User, Policy Analyst
- ◆ NOT involved in data collection

3 **Who is the Customer?**

- ◆ Report doesn't explicitly identify customer
 - ◆ "One of the Department of Energy's missions is to promote energy efficiency to help the Nation manage its energy resources."
- ◆ Presumably, customers are Department of Energy officials
- ◆ But report doesn't really talk about customers and their needs

4 **Despite This, Does the Report Know its Audience?**

- ◆ Choices about level of detail appear random
- ◆ "Interesting stuff, but why did they choose to tell that to me?"
- ◆ Language ranges from nontechnical to "jargon"

5 **Is This Subject Important?**

- ◆ How debate the future without understanding the past?
- ◆ What does "understand" mean, and does the report help?
- ◆ What are the specific impacts of government actions and other factors?
- ◆ The report avoids delving into underlying causes
- ◆ Why not use the existing literature, e.g. Pisaradi, Green?

6 **Some Examples Where "Fleshing Out" Would Be Useful**

- ◆ CAFE standards – did they play any role in improving fuel economy?
 - ◆ Is there really any doubt they had some positive impact on fuel economy?
 - ◆ EIA could at least separate out the "junk science" from the legitimate analysis
- ◆ Role of light trucks on fleet fuel economy
 - ◆ What types of autos are replaced?
 - ◆ Role of technology vs. role of creating new market niches

7 **Some Comparisons are Apples and Oranges**

- ◆ Energy intensity of mass transit buses shouldn't be compared to intensity of all automobiles
- ◆ "Heavy single-unit trucks are twice as energy intensive as light trucks used for passenger travel." Why should we care?

8 **Avoiding Naive Comparisons: Energy Intensity of Mass Transit Vs. Autos**

- ◆ Energy used in accessing transit
- ◆ Trip Circuity
- ◆ Embodied energy

- ◆ Travel conditions - mostly city driving, weighted to peaks
- ◆ Not your average auto driver (what are you analysing?)
- ◆ Dominance of New York City

9 *Measuring Freight Intensity*

- ◆ One indicator is presented - energy per ton-miles
- ◆ Growing importance of high value cargo -- less about moving "tons" and more about moving "dollars of value."

10 *How Should We Deal With Differences Among Data Sets?*

- ◆ Make a determined effort to understand differences, resolve them
- ◆ Careful about reporting results that are contradicted in another data set
- ◆ Example: mass transit reported as the least energy intensive mode - but not according to the Oak Ridge Transportation Data Book.

11 *The Flagship Graph Compares Total Primary Transportation Energy, Crude Prices, and GDP*

- ◆ Does this make sense????
- ◆ Never mentioned again
- ◆ May be OK for freight
- ◆ Personal travel does vary with income, but with lots of other things as well

12 *Why Did You Choose These Time Periods?*

- ◆ Short periods don't provide stable trends
- ◆ Things change slowly (in all sectors, not just transportation!)

6. The Industrial Sector

Introduction

The industrial sector encompasses more than 3 million establishments engaged in manufacturing, agriculture, forestry, fishing, construction, and mining. These industries require energy to light, heat, cool, and ventilate facilities (end uses 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. Some industries require additional energy fuels for use as raw materials (feedstocks) in their production processes. Many industries use byproduct fuels⁷² to satisfy part or most of their energy requirements. In the more energy-intensive manufacturing and nonmanufacturing industries, energy used by processes dwarfs the energy demand for comfort.

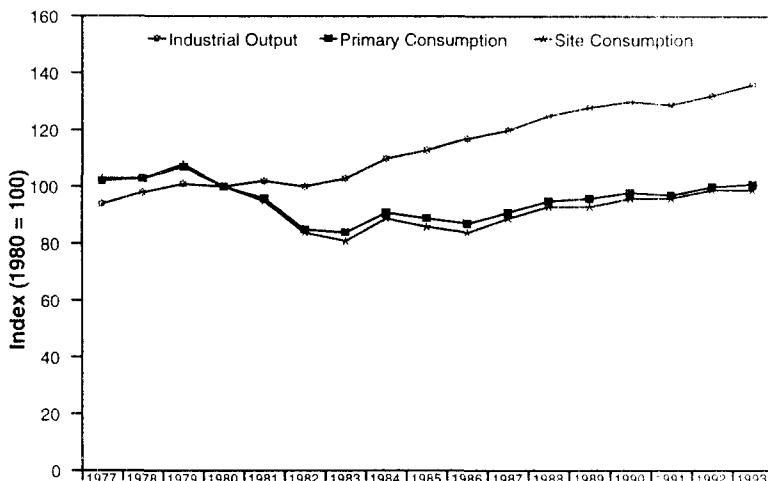
The value of industrial output has continued to increase, while total energy consumed by the industrial sector has fallen. This relationship is shown in Figure 6.1, where the consumption index for both primary and site energy is greater than the output index before 1980 and less afterward, with the gap consistently widening in the late 1980's. New energy-efficient technology and the changing production mix from the manufacture of energy-intensive products to less intensive products account for much of this difference.⁷³

In the industrial sector, manufacturing establishments consume the majority of the energy (Figure 6.2), even though they are far outnumbered by nonmanufacturing establishments (Figure 6.3).

In this chapter, only the manufacturing sector is considered in the development of energy-intensity indicators. Data are insufficient to permit the development of robust energy-efficiency indicators for the nonmanufacturing sector.⁷⁴

Historically, data on the manufacturing sector's energy use has also been scarce. This lack of data has made 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 more important and 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.

Figure 6.1. Output and Energy Consumption Indices for the Industrial Sector, 1977 to 1993



Note: Gross Product Originating by Industry used to develop the Industrial output Index is in constant 1987 dollars.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Table 2.1. •U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, May 1994, October 1994, and March 1995.

⁷²A byproduct fuel is a secondary or additional product resulting from the use of feedstocks or the processing of nonenergy materials.

⁷³As an interesting note, both primary and site energy were presented in Figure 6.1 to show the effects of a change in the energy mix over time. Around 1982, a gap develops between primary and site consumption, reflecting a change in the energy mix to the use of more electricity with its inherent losses that occur in the generation and transmission of electricity.

⁷⁴Agriculture, mining, and construction are 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.

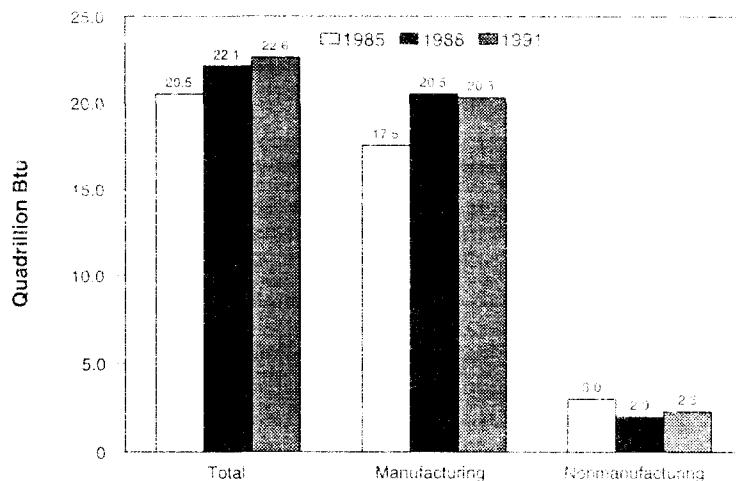
Industrial energy consumption and associated output data are classified by Standard Industrial Classification (SIC) in most surveys of establishments.⁷⁵ After the transportation sector, the manufacturing sector consumes the most energy in the United States. In 1991, 20.3 quadrillion Btu of energy for all purposes including use as feedstocks, or about one-third of the total end-use energy was consumed in the manufacturing sector (Figure 6.4).

Of the 20 major industry groups in the manufacturing sector, in 1991, 6 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 value for manufacturing, and as a result, are very energy intensive in their production, the exception being the Food and Kindred Products major group. This SIC industry is a high-energy consumer, but not very energy intensive as we will see later in this chapter.

Box 6.1.

Standard Industrial Classification (SIC) groups establishments according to their primary economic activity. Each major industrial group is assigned a two-digit SIC code. The SIC system, which serves as a framework for the collection of energy consumption and output data, divides manufacturing into 20 major industry groups and nonmanufacturing into 12 major industry groups. Each major industry group is further divided into three-digit groups and four-digit industries.

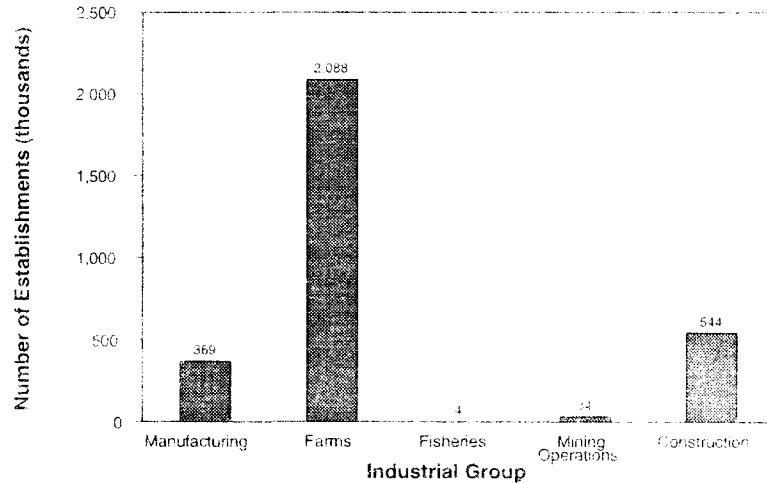
Figure 6.2. U.S. Industrial Total Site Energy Consumption, 1985, 1988, and 1991



Notes: •Total manufacturing estimates includes raw materials (feedstocks) but not by product fuels. •Nonmanufacturing estimates were obtained by subtracting MECS estimates from the industrial estimates presented in the *Annual Energy Review 1993*. •Due to this method, the nonmanufacturing estimates may be too low.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys, and *Annual Energy Review 1993*, Table 2.1.

Figure 6.3. Industrial Sector Establishments, 1987



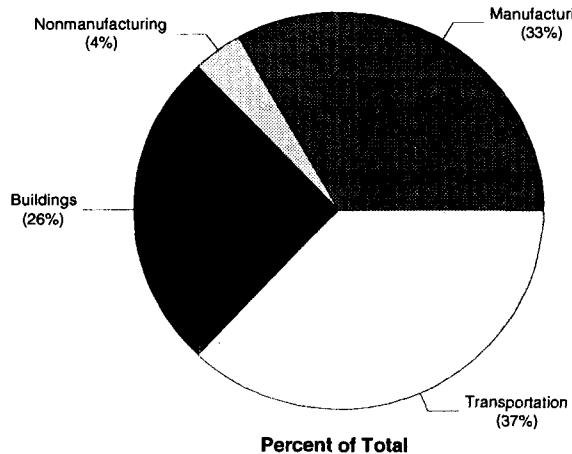
Sources: U.S. Department of Commerce, Bureau of the Census, 1987 *Census of Agriculture*, 1987 *Census of Mineral Industries*, 1987 *Census of Construction Industries*, and 1987 *Census of Manufactures*.

Chapter Organization

For the purpose of this analysis, the manufacturing sector is divided into three major groups; high-energy consumers; high-value-added consumers; and low-energy consumers. These are summarized in Table 6.1. The most important group, high-energy users, is presented in detail.

⁷⁵The Office of Management and Budget derived this hierarchical system. Wherever possible, data presented correspond to the 1987 SIC reclassification. As a result, 1985 and 1988 data may not be comparable with previously published data.

Figure 6.4. Sector Shares of Site Energy Consumption in the United States, 1991



Notes: •The residential and commercial building sectors are combined into the buildings sector. •Nonmanufacturing estimates were obtained by subtracting MECS estimates from the industrial estimates, presented in the *Annual Energy Review 1993*. •Due to this method, the nonmanufacturing estimates may be too low.

Source: Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 2.1 and 2.4.

First, the major data sources are described in detail. As in the previous chapters, 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. The most frequently used energy-intensity indicators will be compared, followed by a comparison of capacity and inventory-adjusted intensity indicators as a form of "closing in on energy-efficiency indicators." Last, the strengths and limitations of these energy-intensity indicators will be explored.

Table 6.1. Type of Manufacturing Industry Group

Standard Industrial Code	Major Industry Group	Description
High-Energy Consumers		
20	Food and Kindred Product	
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	The high-energy consumers convert raw materials into finished goods primarily by chemical (not physical) means. Heat is essential to their production, 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.
High-Value Added Consumers		
34	Fabricated Metal Products	
35	Industrial Machinery and Equipment	
36	Electronic and Other Electric Equipment	
37	Transportation Equipment	
38	Instruments and Related Products	
39	Miscellaneous Manufacturing Industries	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.
Low-Energy Consumers		
21	Tobacco Manufactures	
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	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.

Source: Energy Information Administration, Office of Energy Markets and End Use, *Manufacturing Consumption of Energy 1991*, DOE/EIA-0512(91).

Major Data Sources

U.S. Department of Commerce: Bureau of Census

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.

Between 1974 and 1981, the ASM collected data on the amounts of individual fuels and electric energy produced offsite, and expenditures for those fuels by SIC. Since 1981, the only energy data provided by the ASM are total expenditures for offsite-produced fuels, expenditures for electricity, and the amount of electricity produced offsite. The ASM continues to provide information on employment, value of shipments, and other important economic characteristics.

Energy Information Administration

Manufacturing Energy Consumption Survey: Current Triennial Series

The Manufacturing Energy Consumption Survey (MECS), conducted by the Energy Information Administration (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 provided three different measures of manufacturing energy consumption. These measures differ in terms of how offsite-produced energy, feedstocks, and byproduct energy are accounted for. The MECS measure of offsite-produced energy corresponds to the ASM "purchased fuels" definition.

The MECS is a sample of approximately 12,000 (increased to 16,000 for 1991) 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.

MECS data are available for data years 1985, 1988, and 1991. The next MECS will provide data for 1994.

U.S. 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 SIC manufacturing groups. For SIC 23 (Apparel) and SIC 39 (Miscellaneous), however, no FRB production index is defined.⁷⁶

⁷⁶See "Industrial Production" in the industrial section of the Glossary for a detailed description of the conversion of this index into constant dollars for analysis purposes in this report.

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.⁷⁷

Energy Consumption in the Manufacturing Sector

Measures of Consumption

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 use. Box 6.2 describes the three general measures of energy consumption used by EIA. According to the 1991 MECS, the amount of Total 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 does not include byproduct fuels produced from previously counted energy inputs. 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. It measures only the energy used for its energy content and not as an input into a manufacturing process. Therefore, the Total Inputs measure is the measure that will be used in the development of energy-intensity indicators in this chapter. As in the other end-use sectors, the energy consumption measures used in this analysis do not include the energy lost in the transmission and generation of electricity. These losses are dealt with in Chapter 7, "The U. S. Economy."

Box 6.2.

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 produced onsite from previously-counted energy inputs.
- **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. All nonfuel uses of energy and all byproduct energy are excluded.

Energy Trends

An ideal trend analysis would include 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 Annual Survey of Manufactures.⁷⁸ Since at least 70 percent of Total Inputs of Energy is made of energy sources produced offsite, the Offsite-Produced Energy measure does provide some insight into changes in energy consumption in the manufacturing sector from 1977 to 1991.

⁷⁷These sources of data are described in the industrial section of the Glossary.

⁷⁸Since the MECS does not collect annual data, EIA developed a method to derive estimates of offsite-produced energy 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).

As mentioned previously, the 20 SIC's have been grouped into three groups: High-Energy Consumers, High-Value Added Energy Consumers, and Low-Energy Consumers. Figure 6.5 shows the consumption trends for each of these groups from 1977 to 1991 for Offsite-Produced Energy. The High-Energy 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-Energy 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 U.S. manufacturers.⁷⁹

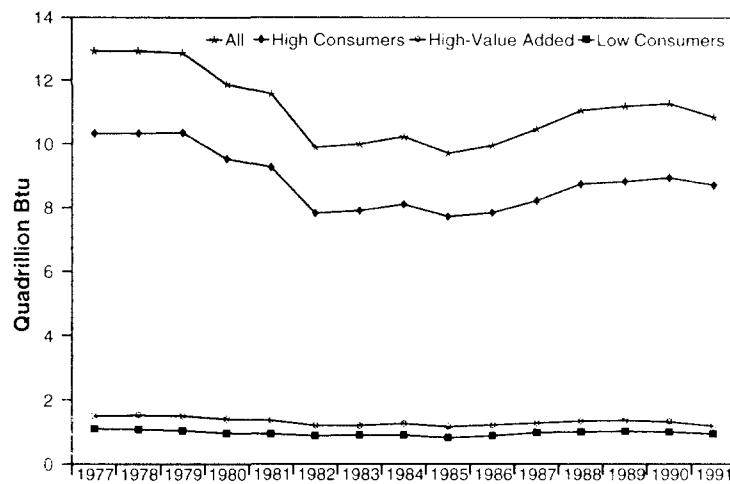
Although this percentage does increase to 3.5 percent for the High-Energy Consumers, it still is a very small portion of all of the costs of production that manufacturers face. However, in 1991, the costs of energy totaled \$32.9 billion (constant 1987 dollars) for the High-Energy Consumers.

As in the past chapters, the most recent trends of energy consumption in manufacturing are placed into two intervals, 1985 to 1988 and 1988 to 1991, the intervals of growth/growth and growth/recession. Using these intervals in the analysis in the remaining portion of this chapter will allow comparisons of Total Inputs of Energy for heat and power and electricity generation (including Offsite-Produced Energy) between the intervals of growth/growth and growth/recession. This will allow the usage of the most comprehensive data available, the MECS, in the actual development and discussion of energy-intensity indicators in the manufacturing sector.

Total Inputs of Energy for heat, power and electricity generation is shown in Figure 6.6 for each of the three manufacturing groups. The High-Energy Consumers consume most of the energy used in the manufacturing sector. All three groups are consistent in that during the interval of growth/growth, their energy consumption increased but, during the growth/recession interval, it declined (Figure 6.6a). The largest percentage decline of Total Inputs of Energy was experienced by the High-Value Added consumers. These consumers' energy consumption declined by 10.4 percent (0.1 quadrillion Btu). During the growth/recession interval, the greatest decrease in energy demand was experienced by firms engaged in producing goods that fluctuate with changes in personal income, such as jewelry, bicycles, computers, apparel, and leather.

During this interval, High-Energy Consumers faced a 0.4 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 growth/recession interval.

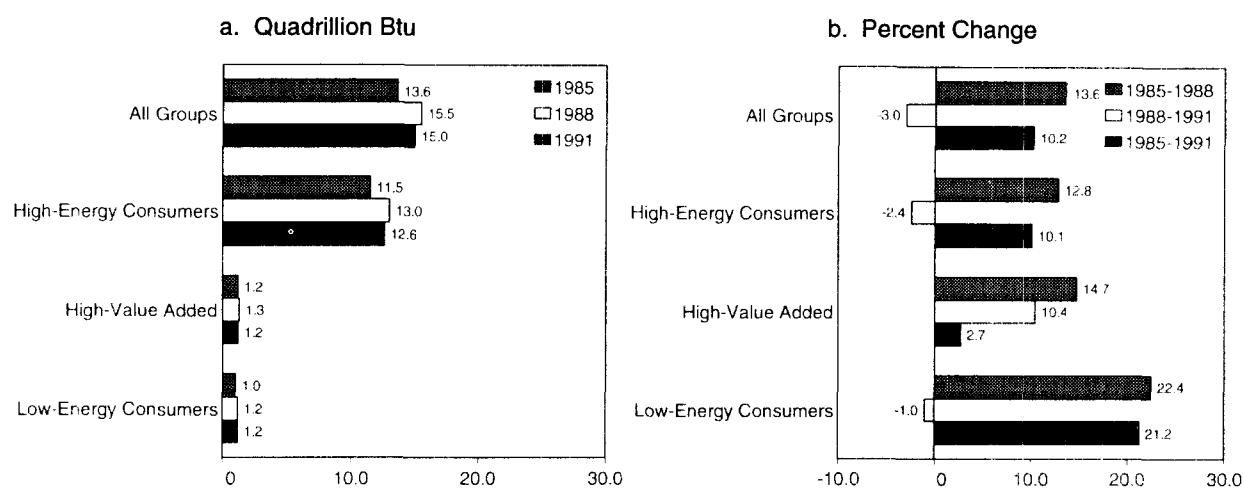
Figure 6.5. Offsite-Produced Energy Consumed for Heat and Power and Electricity Generation, 1977 to 1991



Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Derived Annual Estimates of Manufacturing Energy Consumption, 1977-1988* (August 1992), Table 1; and 1989-forward—EIA, Form EIA-846, 1991 Manufacturing Energy Consumption Survey.

⁷⁹See 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.

Figure 6.6. Total Inputs of Energy for Heat and Power and Electricity Generation by Manufacturing Group, 1985 to 1991



Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys.

Chemicals manufacturers exhibited the fastest growth in energy inputs throughout the entire 1985 to 1991. (24 percent) (Table 6.2) Petroleum and Coal Products industries were responsible for almost 30 percent of the 1.4 quadrillion Btu increase in Total Inputs of Energy despite the extent of the consolidation and plant closings that occurred. During the 1980's, mergers and acquisitions contributed to a 15-percent reduction in the total capacity of operable refineries in the United States.⁸⁰ Seventeen less sophisticated refiners (i.e., with older, less energy-intensive capital equipment in place) were put out of business in the aftermath of the 1986 oil price crash. Additionally, refiners have increased capacity utilization as plants were upgraded to meet additional environmental regulations governing gasoline and diesel fuel.

Table 6.2. Total Inputs of Energy for High Consumers in the Manufacturing Sector, 1985 to 1991

Manufacturing Groups	Trillion Btu			Percent Change		
	1985	1988	1991	1985-1988	1988-1991	1985-1991
High 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

Note: Total Inputs of Energy do not include energy used as feedstocks.

Sources: Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys.

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, e.g., tons could be used in the steel industry, but horsepower may be used in another industry. The demand indicators that are presented in detail in this chapter 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).

⁸⁰Calculated from EIA, *The U.S. Petroleum Refining Industry in the 1980's*, October 1990, Table S7.

All five are presented in constant 1987 dollars to compensate for inflation-induced price fluctuations. However, 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 Box 6.3 and also described in the industrial sector section of the glossary in this report.

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 the reasons why each of the three potential demand indicators may not be suitable and thus not presented further in this chapter:

Box 6.3.

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 weighted 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** - 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)** - 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. Surveyed by the Bureau of the Census only once every 5 years
- c. Establishment data not used to benchmark MECS

(2) Number of Employees⁸¹:

- a. Large variation in plant size and automation
- b. No relationship between labor intensity and energy-intensity

(3) Weight of the Manufactured Goods:

- a. Data not collected across all industries
- b. Would tilt demand towards industries producing heavier materials (e.g., cement and steel) and machinery.

Trends in Demand Indicators

As can be seen in Figure 6.7a, increases in each of the demand indicators occurred during the growth/growth interval of 1985 to 1988. Earlier, energy consumption also increased during this interval (Figure 6.6).

The demand indicator experiencing the largest increase in the growth/growth interval 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 growth/recession interval of 1988 to 1991 (Figure 6.7b).

⁸¹Includes production and nonproduction workers.

Figure 6.7. Demand Indicators in the Manufacturing Sector, 1985 to 1991



Note: Confidentiality does not allow EIA to display value of shipments estimates.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •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, and Table D4, "GPO Deflator," Table D3, "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 10/25/94. •U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, and 1991, Table 2.

High-Energy Consumers

During the growth/recession interval, the growth in the various demand indicators for High-Energy Consumers was either minimal or negative (Figure 6.8a). With the exception of GPO, most of the slow or negative growth during the growth/recession interval can be attributed to the Stone, Clay and Glass Products and the Primary Metals industries. However, the Primary Metals industries posted an 8.7- percent increase in 1988 to 1991 in GPO. The Primary Metals industries also posted the largest increase in value added during the growth/growth interval, 1985 to 1988.

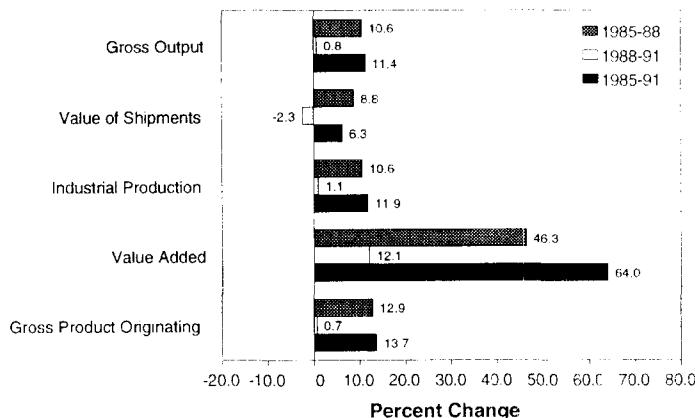
High-Value Added Consumer

The High-Value Added Energy Consumers accounted for 47 percent of value added in 1985. The share of value added for this group decreased to 41 percent by 1991 because industrial machinery and electronic products both lost out to cost-competitive imported products.

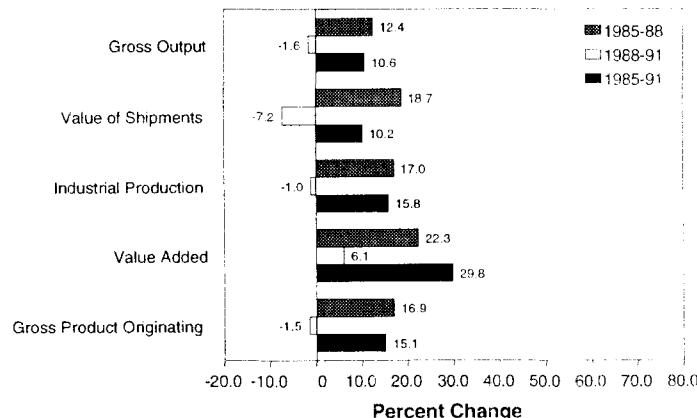
The High-Value Added Energy Consumers also were the largest contributors to industrial production and GPO, accounting for 45 percent and 47 percent, respectively, in 1991. With the exception of value added, all of the other demand indicators, as shown in Figure 6.8b, decreased during the growth/recession interval.

Figure 6.8. Change in Demand Indicators, 1985 to 1991

a. High-Energy Consumer



b. High-Value Added Energy Consumer



Low-Energy Consumers

The Low-Energy Consumers faced reductions in each of the demand indicators, the exception being value added (Figure 6.8c). These reductions seem to be greater than reductions in the other two groups. Most of the industry groups within the Low-Energy Consumers seemed to have fared poorly during the growth/recession interval. One apparent exception was the Rubber and Miscellaneous Plastics industry, which posted increases in all of the demand indicators.

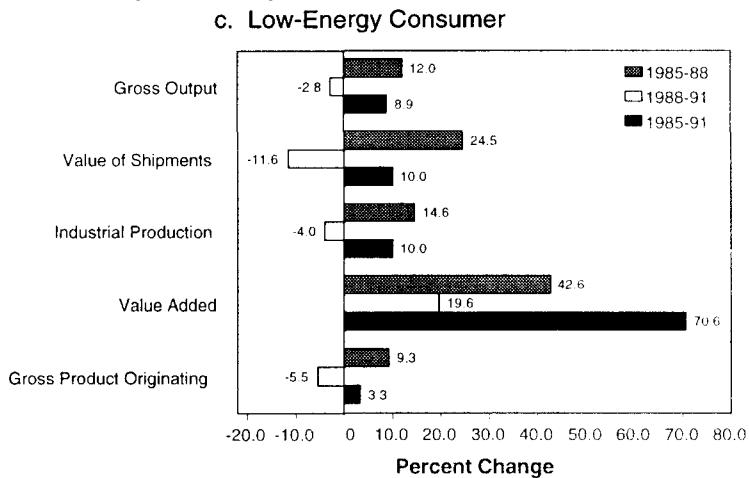
Demand Indicator Adjustments

As is demonstrated in the previous discussion, the economic environment may have major impacts on the levels of the demand indicators that drive energy consumption. These effects are, however, structural effects that need to be considered when measuring changes in energy-intensity indicators in the manufacturing sector.

The key drawback for the shipments-based demand indicator that it measures the product shipped from industries, whether manufactured this year or taken from inventory. Stock changes can obscure production activity in the manufacturing 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/growth interval and built up some inventories during the growth/recession interval (Figure 6.9). These movements in inventory need to be considered when choosing a "best" indicator of energy-intensity in the manufacturing sector.

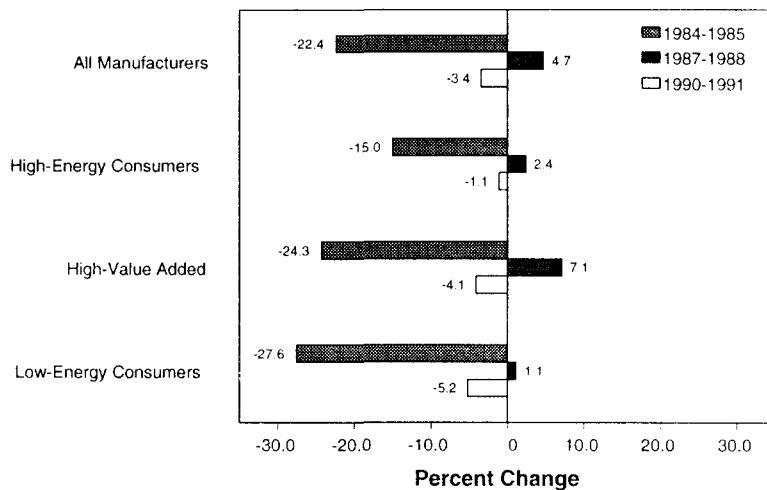
The best demand indicator that considers inventory changes is gross output. The problem is that, with the exception of value of shipments demand indicator, gross output and the other demand indicators presented in this chapter have not been corrected for the SIC reclassification in 1987 from a 1972 base.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

**Figure 6.8. Change in Demand Indicators, 1985 to 1991
(Continued)**



Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •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 Table D4, "GPO Deflators." •Federal Reserve Board, Industrial Production, provided by Charles Gilbert 10/25/94. •U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, and 1991, Table 2.

Figure 6.9. Changes in Inventory, U.S. Manufacturing Sector by Manufacturing Group, 1984 to 1991



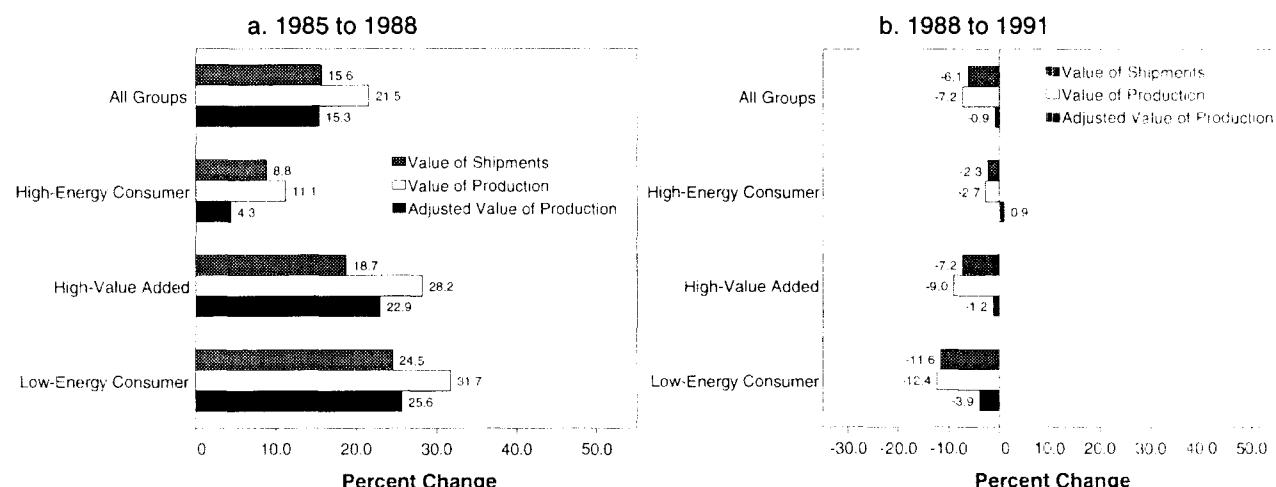
Sources: U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, and 1991, Table 2.

Although the value of shipments demand indicator does not take inventory changes into account, it can be revised to reflect these changes.⁸² Inventory-adjusted value of shipments, also called value of production estimates, act much like weather 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.

During the growth/growth interval, as inventories were being drawn down, the percentage increase in the value of shipments was more than the percentage increase in the value of production, which reflects the levels of production more accurately for all three energy-consuming groups (Figure 6.10a). Without inventory adjustments, decreases in energy-intensity indicators and potential increases in energy efficiency during these years might be overestimated.

During the growth/recession interval, inventories increased. The value of shipments was less than the value of production, reflecting a lower level of production than actually occurred (Figure 6.10b). 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. Decreases in energy-intensity indicators and potential increases in energy efficiency might be underestimated if inventory changes are not considered.

Figure 6.10. Changes in Value of Shipments, Value of Production, and Adjusted Value of Production by Manufacturing Group



Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •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 Table D4, GPO Deflators. •Federal Reserve Board, Industrial Production, provided by Charles Gilbert 10/25/94. •U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, and 1991, Table 2.

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, such as unscheduled outages, labor strikes or slowdowns, and materials supply bottlenecks, may alter utilization rates. If an establishment is not operating at full 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.

⁸²This methodology is described under "Inventory-Adjusted Value of Shipments" in the industrial section of Appendix A.

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.⁸³ 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 smooths 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 to years of low capacity utilization along with 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 6.10 shows the resulting percent changes in capacity-adjusted value of production for all the consuming groups for both the growth/growth and growth/recession intervals. These are smaller than the percent changes in the value of production for both periods. These reflect the adjustments on the value of production estimates upward in 1985 and 1991 where capacity utilization rates were lower than the 26-year average and adjustments downward in 1988 when actual capacity utilization rates were higher than the 26-year average.

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 be 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 may reflect increases in energy efficiency, these reflections also contain some structural and behavioral influences. A general indicator of energy-intensity used in the manufacturing sector is energy (thousand Btu) per demand indicator (in 1987 dollars). Box 6.4 lists the various potential indicators of energy-intensity in the manufacturing sector. There are choices, though, as to which indicator of energy-intensity to use. Table 6.3 shows 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 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.

Box 6.4

Energy-Intensity Indicators for the Manufacturing Sector (Thousand Btu/1987 Dollar)

- Energy / Gross Output
- Energy / Industrial Production
- Energy / Value Added
- Energy / Gross Product Originating
- Energy / Value of Shipments
- Energy / Value of Production
- Energy / Adjusted-Capacity Value of Production

The energy-intensity indicators using gross output, value of shipments, value of production, and adjusted value of production are comparable while the remaining three indicators 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 does not, implying that gross output and value of production are very comparable. One can see the difficulties in selecting an energy-intensity measure when measuring the impacts of a particular energy program.

⁸³The methodology is presented in the industrial section of Appendix A under "Capacity-Adjusted Value of Production Method."

Table 6.3. Energy-Intensity Indicators in the Manufacturing Sector, 1985, 1988, and 1991

Type of Manufacturing Group	Energy-Intensity Indicator: 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

Note: Total Input Energy for heat and power and electricity generation is used to compute the intensity indicators.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •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;" Table D4, "GPO Deflators." •Federal Reserve Board, Industrial Production, provided by Charles Gilbert 10/25/94. •U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures*, 1985, 1988, and 1991, Table 2.

Energy-Intensity Indicator Trends

Figure 6.11 adds to the choice dilemma when looking at the changes in the various energy-intensity indicators for all manufacturing and High-Energy Consumers. The outlier by far is value added. The problem with using an energy-intensity indicator based on value added, 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 has been standardized to the 1987 SIC classification.

Figure 6.11a shows the changes in the energy-intensity indicators over the growth/growth interval. There seem 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 have been very slight changes in energy-intensity and thus energy-efficiency changes seem to have been minimal for both the manufacturing sector and the high consumers of energy. When looking at the interval of growth/recession as shown in Figure 6.11b, the intensity picture changes. It seems that for the most part, energy indicators fell implying possible increases in energy efficiency. Again, the reader must be aware that structural change could be the influential factor. A huge price increase or other market fluctuation could augment a measure such as 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 indicator will always be susceptible to such market changes.

Other Structural Adjustment Considerations

In addition to the effects economic influences may have on the measurement of energy-intensity, changes in the relative market share of major industry groups (in terms of constant dollar value added, value of shipments, etc.) can be used to indicate changes in industry structure. EIA has developed a method for examining structural changes by holding the relative market share constant (percent share of the value of shipments within each two-digit SIC group) and revising four-digit SIC industry data in order to build up a structurally-adjusted intensity measure at the two-digit SIC level.⁸⁴

⁸⁴See Energy Information Administration, "Energy Efficiency in the Manufacturing Sector, *Monthly Energy Review*, December 1992, for a fuller treatment of this topic.

Examination of the components affecting intensity measures offers some insight into the structural changes of U.S. manufacturing and their impact on the efficiency of energy use.

If five of the High-Energy Consumers⁸⁵ are the most energy intensive per value of shipments or value of production, then reducing their share of demand could contribute to an overall reduction in energy-intensity for U.S. manufacturing. Likewise, the less energy-intensive categories—High-Value Added and Low-Energy Consumers—could increase their share of shipments or production and contribute to reduced energy-intensity for the manufacturing sector as a whole. For further discussion and detailed analysis using this methodology, see EIA's publication *Changes in Energy-Intensity in the Manufacturing Sector 1985 - 1991* (DOE/EIA-0552(85-91)).

Strengths and Limitations of the Energy-Intensity Indicators

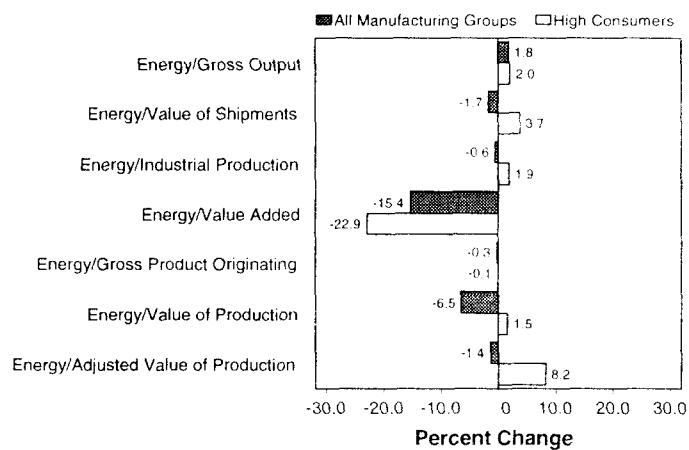
In this chapter, energy-intensive indicators were developed only for the manufacturing sector. Most of the energy used in the industrial sector is used in the manufacturing sector. This does not lessen the importance attached to the development of nonmanufacturing energy-intensive indicators. Future 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 chapter are varied. Each have certain strengths and limitations or weaknesses. The demand indicators used in the energy-intensity indicators are compared in Table 6.4.

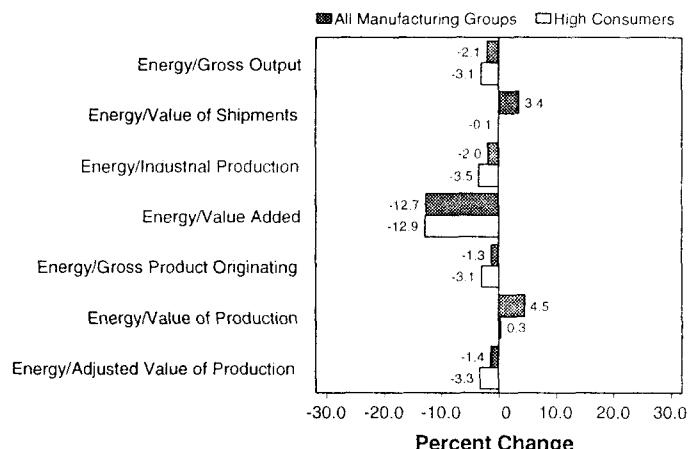
These are all dollar-denominated surrogates for actual output and as such, a huge price change or other market fluctuation could augment or distort the value of shipments and make energy-intensity indicators appear higher or lower than the actual change in intensity. Such distortion may cause underestimation and overestimation of energy-efficiency improvements.

Figure 6.11. Changes in Energy-Intensity Indicators for the Manufacturing Sector

a. 1985 to 1988



b. 1988 to 1991



Note: The ratio of the energy-intensity indicator represents changes in thousand Btu/1987 dollar.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •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 Table D4, "GPO Deflators." •Federal Reserve Board, Industrial Production, provided by Charles Gilbert 10/25/94. •U.S. Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1985, 1988, and 1991, Table 2.

⁸⁵The exception is the Food and Kindred Products industry group. Although establishments in this group are high-energy users, they are not energy intensive.

Table 6.4. Strengths and Limitations of Demand Indicators Used in the Energy-Intensity Indicators

Energy-Intensity Indicator (Thousand Btu/1987 Constant Dollar)	Strength of Demand Indicator Used in the Energy-Intensity Indicator	Limitation of Demand Indicator Used in the Energy-Intensity Indicator
Energy/Gross Output	<ul style="list-style-type: none">● Most comprehensive measure of production—includes inventory change● Available annually	<ul style="list-style-type: none">● Pre-1987 data are based on the 1972 SIC classification● Establishment data not available
Energy/Industrial Production	<ul style="list-style-type: none">● Available annually	<ul style="list-style-type: none">● Pre-1987 data are based on the 1972 SIC classification● Establishment data not available● Only two-digit SIC classification
Energy/Value Added	<ul style="list-style-type: none">● 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	<ul style="list-style-type: none">● 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	<ul style="list-style-type: none">● Includes inventory change● Available annually● Provides a better approximation of value added	<ul style="list-style-type: none">● Pre-1987 data are based on the 1972 SIC classification● Establishment data not available
Energy/Value of Shipments	<ul style="list-style-type: none">● Consistent 1987 SIC classifications● Collected by EIA as part of a detailed energy survey	<ul style="list-style-type: none">● Data available every 3 years● Does not consider inventory changes● Industry value of shipments data are confidential
Energy/Value of Production	<ul style="list-style-type: none">● Consistent 1987 SIC classifications● Collected by EIA as part of a detailed energy survey● Includes adjustments for changes in inventory	<ul style="list-style-type: none">● Data available every 3 years● MECS value of shipments data are confidential
Energy/Adjusted-Capacity Value of Production	<ul style="list-style-type: none">● Consistent 1987 SIC classifications● Collected by EIA as part of a detailed energy survey● Includes adjustments for changes in inventory and capacity.	<ul style="list-style-type: none">● Data available every 3 years● MECS value of shipments data are confidential.

7. United States Economy

Introduction

The information detailed in the past chapters demonstrates the difficulties of developing energy-intensity indicators. For sectors such as manufacturing, the choices of energy-intensity indicators are many. For transportation, the choices are few. Data are limited in some sectors and abundant in others. As was demonstrated, every sector, especially transportation, has complexities.

There are even more complexities across sectors. Energy is consumed differently for different reasons. Structural and behavioral effects manifest themselves in different ways. In spite of the difficulties, why is it important to attempt to develop an economy-wide energy-intensity indicator?

Environmental concerns and concerns about energy supply require knowledge as to how well we are doing in reducing the growth of energy consumption for the Nation as a whole. Basically, households, establishments, etc., change consumption patterns that, in turn, affect the amount of energy that flows or is delivered to them. Developing site energy-intensity indicators is appropriate at this sectoral level. Primary energy used to generate energy, including all of the losses in production, transmission and distribution of energy, must be included in the measurement of changes in energy-intensity for the economy as a whole.

Chapter Organization

This chapter first discusses primary or "total embodied" energy in definitional terms. Included is a discussion of the trends in energy consumption and the losses associated with energy production, transmission and distribution, and how these losses have grown over time. A proposed methodology for the development of economy-wide energy-intensity indicators and the limitations of such indicators are presented next. This presentation is followed by the development of economy-wide energy-intensity indicators using the methodology, including the development of conversion factors to adjust site energy estimates upward to account for losses. Finally, several economy-wide energy-intensity indicators are presented and compared.⁸⁶

Primary Energy

Background

Primary energy includes direct use by end users of fossil fuels (petroleum products, natural gas, and coal) and renewable energy (biomass and waste products) and the indirect use of fossil fuels, nuclear, hydropower, geothermal, and other renewable inputs in the form of electricity.

Two economy energy-intensity indicators, energy per capita and energy per Gross Domestic Purchases⁸⁷ are shown in index form in terms of primary and site energy (Figure 7.1). Indices of energy per capita rose in the early 1980's and remained higher than indices of energy per Gross Domestic Purchases, as economic growth outpaced population growth during the sustained economic expansion of the 1980's.

The difference between the estimates of primary energy and site energy has grown overtime (Figure 7.1). The indices using primary energy were slightly below their site energy counterparts in the 1970's, but were higher by the mid-1980's. The indirect consumption of energy as the inputs into electricity generation has grown over time as electricity consumption to end users has grown by 47 percent from 1977 to 1993.⁸⁸ This suggests increases in aggregate losses associated with time generation, transmission, and the distribution of energy.

⁸⁶A more detailed but similar approach is described under "Energy-Weighted Index" in the economy section of Appendix A.

⁸⁷Gross Domestic Purchases is used instead of Gross Domestic Product since it includes all personal consumption, gross private- domestic investment, and government purchases (Federal, State, and local) including imports, but not exports.

⁸⁸See Table 8.1 in EIA's *Annual Energy Review 1993*.

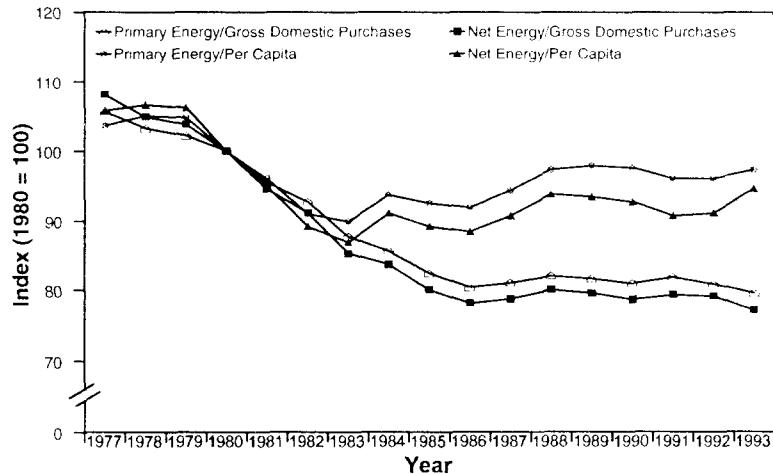
Production, transmission, and distribution losses occur among all energy sources, but the magnitude differs widely. The next two sections describe these losses for natural gas and electricity.

Energy Production Losses

Natural Gas. The energy losses in the production of natural gas include losses from repressuring gas into the wells, removing nonhydrocarbon gasses, venting and flaring certain amounts of gas during the extraction process, "extraction losses" or the removal of liquid constituents from the dry gas. Losses also occur in the inter- and intrastate pipeline distribution system. Operation of today's processing and pipeline systems were significantly modernized in the late 1980's through utilization of remote-terminal units, microwave communications, and computerized-control systems.⁸⁹ This modernization has reduced losses.

Electricity. Losses in the production of electricity are much higher than those from the production of natural gas. Electricity is generated by several different processes, each using different raw resources and each involving different amounts of energy losses. Most of the energy losses in the generation of electricity occur when heat is converted into mechanical energy for turning electric generators. Other losses include power plant use of electricity and losses due to transmission and distribution of electricity from the power plant to the end user. The system losses do change from year to year due to changes in the mix of inputs used to generate the electricity: coal, natural gas, petroleum products, hydropower, nuclear power, wind, sunlight, and geothermal heat. Therefore, for each year, there is a different multiplication conversion factor.

Figure 7.1. U.S. Economy Indices of Energy-Intensity Indicators, 1977 to 1993



Note: Gross Domestic Purchases used to develop the indices is in constant 1987 dollars.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 1.5 and 2.1; •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, National Income and Products Accounts, Quality Series.

Economy-Wide Energy-Intensity Indicator: Methodology

As demonstrated in the previous sections, primary energy estimates including losses should be used when developing an energy-intensity indicator for the economy as a whole. Additionally, estimating primary energy consumption, sector by sector, provides more insight than simply using total primary energy data for the economy as a whole. Regional and sectoral differences can help explain changes in energy demand.

Methodology

The first step in the development of economy-wide energy-intensity indicators is to develop energy-consumption estimates for each of the sectors. This methodology may be used to develop primary, unadjusted site, or adjusted site economy-wide energy-intensity indicators.⁹⁰

Next, for each sector, develop sector-specific energy-intensity indicators.

Finally, as a last step, add each of the sector energy-intensity indicators together into one economy-wide composite.

⁸⁹National Petroleum Council, *The Potential for Natural Gas in the United States*, December 1992, p. 113.

⁹⁰Adjusted site energy includes adjustments for weather, structural, and behavioral effects where possible. Primary energy estimates can also be adjusted, but was not done in this analysis.

Changes in energy-intensity overtime could be estimated using the economy-wide indicators. This would provide insight into changes in energy efficiency. Three composites can be created, based on primary energy, unadjusted site, and adjusted-site energy.

The next sections discuss each of the individual steps listed above using this methodology to develop such energy-intensity composite indicators for the U.S. economy. The section also discusses obstacles associated with the third step of the methodology and how they may be overcome.

Step 1: Development of Energy Estimates, Primary and Site Adjusted

Primary Energy Estimates. Primary conversion factors are calculated. These vary regionally according to the mix of fuels used directly or indirectly for electricity generation. For each of the sectors, these conversion factors convert site-adjusted estimates of energy consumption into primary energy estimates.

Adjusted-Site Estimates. Using a sectoral approach site energy is adjusted by weather, behavioral, or other structural effects that may increase or reduce actual energy consumption.

In the residential sector, site energy is adjusted by heating and cooling fluctuations relative to a normal 30-year average expectation for weather, in order to compare what energy demand might have been had the weather been normal. In this way, excess demand could be explained in terms of unusual weather patterns.

In the commercial sector, site energy is adjusted by both weather and occupancy, taking into account the fact that energy demand is nominal in a vacant building. By eliminating vacant buildings, commercial energy data more realistically reflects actual per building usage.

In the industrial sector, manufacturing value of shipments is adjusted by inventory changes and capacity utilization. By eliminating stock build-ups or depletions in any year, industrial production can be more realistically measured. By considering capacity utilization, periods of low or excessive product demand can help explain variations in energy demand.

In the transportation sector, the demand for passenger travel (vehicle miles traveled) is adjusted by occupancy. A vehicle traveling 100 miles with four passengers represents twice as much demand as a vehicle traveling 100 miles with two passengers.

Using adjusted site energy in the development of energy-intensity indicators as a basis for evaluating changes in energy efficiency is only one concept of energy efficiency based on the effects they adjust for.

Step 2: Develop Sector-Specific Energy-Intensity Indicators

Activity in each sector of the economy is measured uniquely. The demand indicators for each sector are parameters that influence energy consumption such as: the number of buildings, operating hours, the number of workers in a building, and the size of a building as measured by its floorspace. For instance, the residential sector measures its activity in terms of the number of households owned and rented, whereas the freight transportation sector measures activity in terms of ton miles traveled. There is no demand indicator common to all sectors, so sectoral energy-intensity indicators will be unique to each sector.⁹¹ This leads to the major obstacle in Step 3—adding unique sectoral-intensity indicators together to obtain an economy indicator of energy-intensity.

⁹¹Sectors, in this report are defined by the standard energy convention: residential, commercial, industrial, and transportation. This is a different accounting framework than reflected in the National Income and Product Accounts and the Input-Output Accounts, where sectors reflect SIC categories. Creative use of the Gross Output by SIC sector may provide the common denominator for the residential, commercial, industrial, and transportation sectors.

Step 3: Adding the Sectoral Energy-Intensities

The actual sectoral energy-intensity indicators cannot be added together, but an alternative is changes in an economy-wide energy-intensity built up from the changes in the sectoral energy-intensity indicators. For any given period of time, an economy composite energy-intensity indicator can be developed by weighing each of the sectoral changes in each of the indicators by the percent share of total consumption that each sector holds.

Box 7.1 provides an example of the development of such an economy-wide energy-intensity composite. The advantage of this methodology is that this single economy-wide energy-intensity indicator reflects the uniqueness of each sector, and can be adjusted for some of the weather, structural, and behavioral effects that can affect measures of energy-intensity such as those listed in Step 1 above. The next section attempts to develop economy energy-intensity composites using the methodology presented in this section.

Box 7.1

Economy Energy-Intensity Composite Example (1980-1990)

Sectors	Share of Total Consumption (1990)	Change in Intensity (1980-1990)
Residential	.15	-2
Commercial	.11	-2
Industrial	.37	-4
Transportation	.37	-3

Economy Composite (Percent Change) = multiplicative sum of percent share by percent intensity change

$$\text{Composite} = .15(-2) + .11 (-2) + .37 (-4) + .37 (-3) = -2.8$$

Notes: •The example is for illustrative purposes only. •Three composites may be developed using different measures of energy: primary, unadjusted site, and adjusted site. •The composite could be developed starting at a lower level than sector, e.g., housing unit, SIC, transportation mode, or building activity depending on the available data.

Energy-Intensity Composite: A Measure of Change in the U.S. Economy

This section will demonstrate the use of the methodology presented above. An economy energy-intensity composite (hereafter called economy composite) will be developed using changes in energy-intensity indicators based on adjusted site energy reflecting weather, behavioral, and structural changes. This economy composite will be compared to an economy composite developed based on changes in energy-intensity indicators using unadjusted site energy. Although an energy composite will be developed based on changes in intensity indicators using primary energy, adjustments to reflect behavioral and structural changes will not be developed in this report.

Obstacles to Overcome

Two major obstacles must be overcome in the development of economy composites. The first is the limited availability of comprehensive energy consumption data for the two comparison years. This is an obstacle whether the economy composite uses changes in intensity-indicators based on primary or site energy (unadjusted or adjusted). The second major obstacle is the necessity of developing primary conversion factors. These are needed to convert site energy into primary energy so that losses in production, transmission, and distribution can be included in an economy primary energy composite.

Available Comprehensive Data for Consistent Time Periods

The best consumption data available are from EIA's consumption surveys for the manufacturing, commercial, residential, and residential transportation sectors. Transportation sector data are available Oak Ridge National Laboratory for other modes of transportation. The major obstacle is time coverage. EIA's consumption surveys do not cover the same years. Therefore, the only solution is to create an, e.g., "1985-1988" economy composite instead of a true 1985-1988 economy composite. This solution is not perfect, but it is the best solution until further research detects another solution.

Development of Primary Conversion Factors

Information on losses is not available for all energy sources.⁹² Primary conversion factors are available or can be developed for natural gas and electricity.

Electricity. Electric utilities, and by association, nonutility generators,⁹³ can fully measure their generation and transmission and distribution (T&D) losses by fuel input (i.e., fossil fuel, nuclear, hydropower, and geothermal). In the development of an economy composite using changes in energy-intensity indicators based on primary energy, annual primary conversion factors for electricity by region are developed from the losses. These standard, useful measures of the efficiency of electricity generation and T&D are multiplied by regional site electricity requirements for each sector of the economy in order to estimate primary electricity consumption. The primary conversion factors developed for electricity vary by year and Census region (Table 7.1).⁹⁴

Table 7.1. Regional Primary Conversion Factors for Electricity, 1984 to 1992

Year	Primary Conversion Factor			
	Census Region			
	Northeast	Midwest	South	West
1984	3.241	3.390	3.597	3.692
1985	3.353	3.396	3.632	3.687
1986	3.641	3.518	3.570	3.772
1987	3.649	3.513	3.538	3.731
1988	3.599	3.524	3.518	3.670
1989	3.592	3.547	3.516	3.669
1990	3.618	3.535	3.435	3.678
1991	3.647	3.577	3.456	3.648
1992	3.639	3.544	3.452	3.636

Note: See "Primary Electricity Conversion Factors for Site Electricity" in the U.S. Economy section of Appendix A, "Methodology."

Natural Gas. Natural gas T&D losses are more difficult to measure since they are pipeline specific. Losses on the total amount of natural gas passing through the entire system vary with the volume of gas and distance traveled in the pipeline. Industry experts within EIA and the American Gas Association came to the conclusion that 1.02 was a reasonable estimate to be used as a primary conversion factor in the development of primary energy estimates. This conversion factor for primary natural gas used in this chapter is less sophisticated than the one developed for electricity. It is a single multiplier, regardless of year or region.

Other Energy Sources. Energy losses in pipeline, marine, and truck transportation as well as in bulk storage and distribution facilities have not been quantified for either petroleum or coal products.

⁹²Losses occurring in the extraction and production phases for coal, petroleum, and natural gas are accounted for in mining, which pertains to the nonmanufacturing industrial sector. Energy losses at refineries are also generally included in the industrial sector.

⁹³See "Nonutility Generator" in the U.S. Economy section of the Glossary for a description.

⁹⁴See "Primary Conversion Factors for Site Electricity" in the U.S. Economy section of Appendix A, "Methodology."

Development of Primary Energy Estimates

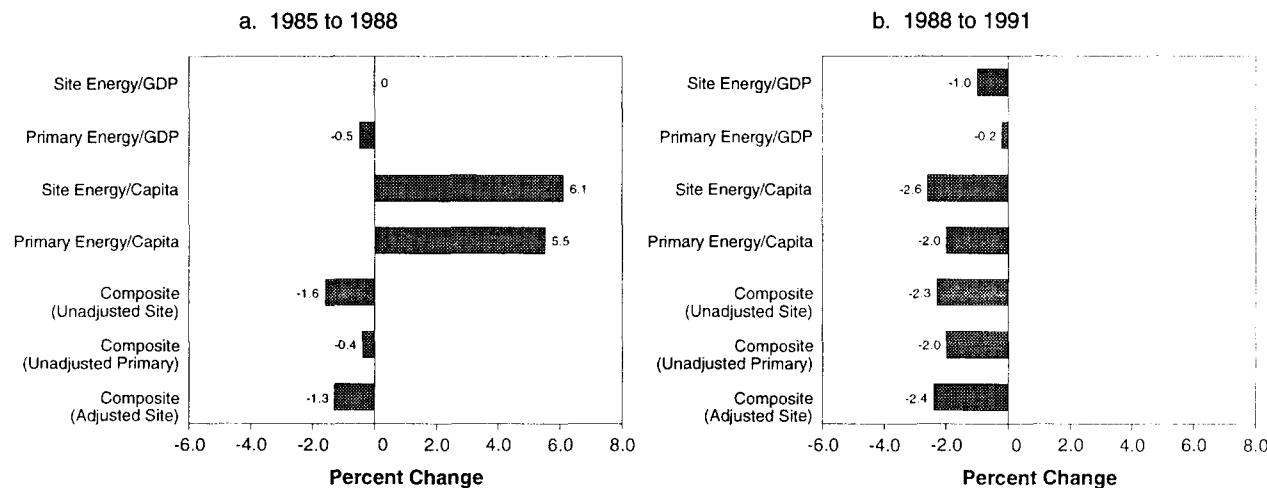
Primary energy can be estimated by summing the site energy consumption for each sector, multiplied by the primary conversion factors at the regional level.⁹⁵ This represents approximately 86 percent of the primary energy reported by EIA in Table 2.1 in the *Annual Energy Review 1993* (AER 93). The only energy estimates omitted by this method are primary energy estimates used in mining, agriculture, forestry, recreational boats, and military transport vehicles. Comparing percent changes over time for the derived primary energy and AER93 primary energy consumption data for 1985-1988 and 1988-1991 reveals the following:

	<u>1985-1988</u>	<u>1988-1991</u>
Derived	10.0 percent	-1.3 percent
AER93	8.4 percent	1.1 percent

Energy-Intensity Indicators for the U.S. Economy: The Economy Composites

For 1985, 1988, and 1991 economy composites have been developed using site energy, adjusted site energy, and the primary energy estimates described in the last section. Figure 7.2 shows the changes in these composites during both the intervals of growth/growth and growth/recession. Additionally, this figure also shows the changes in the two energy-intensity indicators depicted earlier in Figure 7.1.

Figure 7.2. Change in U.S. Energy-Intensity Indicators



Note: In these figures GDP stands for Gross Domestic Purchases. Gross Domestic Purchases is in constant 1987 dollars and includes imports and not exports.

Sources: •Energy Information Administration, Office of Energy Markets and End Use, *Annual Energy Review 1993*, Tables 1.5 and 2.1; 1986, 1989, and 1992 Commercial Buildings Energy Consumption Surveys; 1984, 1987, and 1990 Residential Energy Consumption Surveys; 1985, 1988, and 1991 Manufacturing Energy Consumption Surveys. •U.S. Department of Commerce, Bureau of Economic Analysis, National Trade Data Bank, National Income and Products Accounts, Quality series. •U.S. Department of Energy, Oak Ridge National Laboratory, *Transportation Energy Data Book*, Editions 11 and 14. •U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics* (September 1993), Tables 1, 4, and 6. •Eno Transportation Foundation, Inc., *Transportation in America 1994*, pp. 44 and 49.

⁹⁵The methodology and an example can be found under "Development of Primary Energy Estimates" in the U.S. Economy section of Appendix A.

During both intervals, Gross Domestic Purchases grew faster than primary energy consumption, resulting in declining energy per dollar of Gross Domestic Purchases. During periods of economic growth, the primary energy per dollar Gross Domestic Purchases ratio overestimates the true reduction in energy-intensity, whereas in periods of recession, the primary energy per dollar Gross Domestic Purchases ratio underestimates the reduction in energy-intensity. In the latter case, the energy per Gross Domestic Purchases ratio may simply eliminate the impact of weather, behavior, or other structural effects that may have occurred during the recession rather than representing true efficiency improvements.⁹⁶

Population growth remained very steady, averaging approximately 3 percent over both intervals. The major contraction in primary energy growth during the growth/recession interval (down to 1.1 percent from 8.4 percent in the growth/growth interval) resulted in very distinct percent changes in primary energy per capita ratios. Another interesting finding is that the economy's primary energy composite registers the same percent change as the primary energy per capita ratio during recessionary times. This could be interpreted to mean that without strong economic growth, population is the strongest variable influencing energy-intensity changes. Population is an important demand indicator in residential and passenger transportation energy consumption.

Energy-intensity changes are the smallest economy-wide when examined in terms of primary energy, especially during the growth/recession interval, highlighting the effects of increases in electricity consumption by end users.

Site energy-intensity indicators need to be examined without weather, behavior, and other structural effects that camouflage the true efficiency improvements in the sectors. In Figure 7.2, note how adjusting for weather in the commercial and residential sectors, occupancy in the commercial sector, and inventory changes and capacity in the manufacturing sector reduces the magnitude of the change in the energy composites during growth/growth interval and increases it during the growth/recession interval.

Strengths and Limitations of the Economy-wide Energy-Intensity Indicators

Building a composite from the specific energy-intensity changes in each sector provides far greater insight than energy per GDP or energy per capita. A composite using population is inappropriate since not all sector activity responds to changes in population; e.g., the industrial sector's output cannot be related directly to population growth. Likewise, it would be difficult to build a composite using GDP since the estimation of each sector's contribution to GDP is not an exact science.

Using demand indicators such as ton miles allows each sector to be measured uniquely. A limiting factor is that the availability of consumption survey data used to create the composite are available only every 3 years. Additionally, the available 3 years are not the same 3 years for each of the surveys. Thus, the composite developed in this chapter is far from perfect, but indeed is a "beginning" in the development of energy-intensity indicators for the economy as a whole.

⁹⁶If Gross Domestic Product was used as the demand indicator instead of Gross Domestic Purchases, the percent changes would not be too different. From 1985 to 1988, Site Energy/Gross Domestic Product decreased by 1.1 percent and Primary Energy/Gross Domestic Product decreased by 1.6 percent. From 1988 to 1991, Site Energy/Gross Domestic Product decreased by 1.7 percent and Primary Energy/Gross Domestic Product decreased by 1.0 percent.

8. Future Directions

The Energy Information Administration presents this publication as a beginning attempt to obtain a consensus on the definition of energy efficiency and on the development of energy-intensity indicators that are precise, valid, reproducible, and as robust as possible for each economic sector, within the limits of data and resource availability.

Energy efficiency is a vital component of the Nation's energy strategy. One of the Department of Energy's mission objectives is to promote energy efficiency to help the Nation manage its energy resources. The ability to define and measure energy efficiency is essential to this objective. In the absence of defensible energy efficiency measures, any change in consumption might be equated with change in energy efficiency even if such fluctuations are caused by structural or behavioral effects.

The preceding chapters illustrate some of the obstacles to measuring energy efficiency on an economy-wide basis: lack of consistent data, difficulties in establishing demand indicators, and absence of clarity in identifying structural and behavioral influences on efficiency. However, this initial attempt to establish energy-efficiency measures for each economic sector can serve effectively as a "straw man," a way to stimulate discussion and draw in wide participation.

EIA is the logical agency to undertake this task. It has the expertise and the credibility to gather and analyze data, convene experts, and develop consensus. However, more work needs to be done by EIA and its customers. Feedback from our customers, by mail, telephone, fax, or e-mail is highly welcomed. Future in-house and bulletin board workshops are additional avenues for customer participation.⁹⁷

⁹⁷Please refer to the Contacts Page in the front of this report.

Appendix A

Methodology

Data availability were not consistent over the sectors. The data used for the residential analysis (RECS), for example, were sufficient to undertake this analysis. However, other sectors such as the transportation sector had limited data availability. Several sources of data had to be used to develop energy-intensity indicators. Also, adjustments were made where possible to eliminate influences that were not related to energy efficiency. It was necessary to develop primary energy estimates from the energy supply sector. Additionally, a composite was used to create an economy-wide energy-intensity indicator. This appendix documents these methodologies and other methodologies that could be used but were not used in this report. It provides this documentation individually for each of the following sectors: residential, commercial, transportation, manufacturing, and the U.S. economy as a whole. For each sector, the methodologies are presented in alphabetic order for ease of location.

Residential Sector

Degree-Day-Adjusted Estimates

A degree-day-adjusted estimate of annual site energy consumption explains what would have been consumed if the weather had conformed to normal or the 30-year average.⁹⁸ For the residential sector, space heating and cooling are degree-day adjusted and added to the other unadjusted end uses, water heating and appliances.

It is calculated by the following method:

- Obtain heating degree-day (HDD) factors—the variation between HDD for a specific year and normal HDD, e.g., if HDD equals 5,219 and normal HDD equals 6,043 then the HDD factor equals $6043/5219 = 1.158$
- Obtain cooling degree-day (CDD) factors—the variation between CDD for a specific year and normal CDD, e.g., if CDD equals 609 and normal CDD equals 630 then the CDD factor equals $630/609 = 1.034$
- Adjust the amount of each major fuel used for space heating by multiplying heating consumption by the respective HDD
- Adjust the amount of electricity and natural gas used for air-conditioning by the respective CDD factor
- Add these weather-adjusted consumption estimates with the other end-use energy estimates, water heating and appliances.

Table A.1 presents an example for the South Census region. Degree-day-adjusted total residential energy consumption for the United States is the sum of the adjusted energy consumption by type of housing unit over all four Census regions.

Commercial Building Sector

Degree-Day-Adjusted Estimates

For the commercial buildings sector, space heating, cooling, and ventilation are degree-day adjusted and added to the remaining unadjusted end-use consumption.

⁹⁸Heating degree-days, cooling degree-days, and normal degree-days are defined under "General Terminology" in the Glossary.

Table A.1. Degree-Day-Adjusted Residential Site Energy Consumption, South Census Region, 1990

End-Use Adjustment	Type of Housing Unit						Total	
	Mobile Home	Single-Family		Multifamily				
		Detached	Attached	2 to 4 Units	5 or More Units			
a. Space Heat (Trillion Btu)	45	810	34	46	40	975		
b. HDD Factor	1.251	1.251	1.251	1.251	1.251	1.251		
c. Adjusted Space Heat (Trillion Btu) (a * b)	56	1,014	43	58	50	1,220		
d. Air-Conditioning (Trillion Btu)	15	253	19	19	38	344		
e. CDD Factor928	.928	.928	.928	.928	.928		
f. Adjusted Air-Conditioning (Trillion Btu) (d * e)	14	235	18	18	35	319		
g. Appliances (Trillion Btu)	38	659	38	40	60	835		
h. Water Heating (Trillion Btu)	18	337	19	30	46	450		
I. Total Adjusted Consumption (Trillion Btu) (c + f + g + h)	126	2,245	118	146	191	2,824		

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1990 Residential Energy Consumption Survey, Public-use Data Files. •Normal and annual cooling and heating degree-days provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

End-Use Estimate Calculation. In order to adjust for the influence of weather, end-use estimates were needed for the commercial buildings sector. The only CBECS end-use consumption estimates by energy source were available are for the 1989 CBECS. End-use data were needed for the other CBECS years. It was assumed that the percent shares for the end uses by energy source, principal building activity, and Census region were the same for all the CBECS years as they were in 1989.

Total energy consumption in each Census region by principal building activity was multiplied by these shares to obtain end-use consumption for the other CBECS years. Table A.2 provides an example for office buildings in the Northeast in 1992. As an illustration, the total consumption of electricity in 1992 was 125 trillion Btu. The percent share of electricity used for space heating in 1989 was 2.4 percent. One hundred twenty five trillion Btu * .024 = 3 trillion Btu used for electric space heat in 1992.

Degree-Day Adjusted Estimate Calculation

The following method is used to calculate the degree-day adjusted estimate:

- Obtain HDD factors—the variation between HDD for a specific year and normal HDD, e.g., if HDD equals 6,193 and normal HDD equals 6,043 then the HDD factor equals $6,043/6,193 = .976$
- Obtain CDD factors—the variation between CDD for a specific year and normal CDD, e.g., if CDD equals 412 and normal CDD equals 609 then the CDD factor equals $609/412 = 1.478$
- Adjust the amount of each major fuel used for space heating by multiplying heating consumption by the respective HDD factor
- Adjust the amount of electricity and natural gas used for air-conditioning by the respective CDD factor
- Adjust the amount of electricity used for ventilation by the respective CDD factor
- Add these weather-adjusted consumption estimates with the remaining end-use energy estimates.

Table A.2 also presents an example of the calculation of the degree-day adjusted consumption estimates. As an illustration, an estimated 8 trillion Btu were used by office buildings in the Northeast Census region in 1992 for air-conditioning. The CDD factor is 1.478. In 1992, $1.478 * 8 = 11$ trillion Btu of degree-day adjusted electricity was used for air-conditioning.

All office buildings in the Northeast used 238 trillion Btu of energy in 1992, adjusted for weather effects.

Degree-day adjusted commercial buildings total energy consumption for the United States is the sum of the adjusted energy consumption by principal building type over all four Census regions.

Table A.2. Calculation of End-Use Energy Consumption in Northeast Office Buildings, 1992

Energy Source	End Use					Total Consumption, 1992 (Trillion Btu)
	Space Heating	Air-Conditioning	Ventilation	Other	Total	
Percent Share, 1989						
Electricity	2.4	6.0	17.9	73.8	100.0	125
Natural Gas	63.6	2.0	0.0	34.4	100.0	32
Fuel Oil	89.6	0.0	0.0	10.4	100.0	37
District Heat	65.3	9.5	0.0	25.2	100.0	30
Estimated End-Use Consumption, 1992 (Trillion Btu)	76	11	22	115	--	224
Electricity	3	8	22	92	--	125
Natural Gas	20	1	0	11	--	32
Fuel Oil	33	0	0	4	--	37
District Heat	20	3	22	8	--	30
Degree-Day Factors976	1.48	1.48	--	--	--
Degree-Day Adjusted End-Use Consumption, 1992						
(Trillion Btu)	75	16	33	115	--	238
Electricity	3	11	33	92	--	139
Natural Gas	20	1	0	11	--	32
Fuel Oil	32	0	0	4	--	36
District Heat	19	4	0	8	--	31

Sources: •Energy Information Administration, Office of Energy Markets and End Use, 1989 and 1992 Commercial Buildings Energy Consumption Survey, Public-Use Data Files. •Normal and annual cooling and heating degree-days provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Occupancy-Adjusted Estimates

Adjustments were made to eliminate vacant or mostly vacant buildings from the estimates for the survey years. Adjustments were made to both total site energy consumption and demand indicators for each principal building activity and Census region.

Demand Indicator Adjustment. Adjustments were made to the following demand indicators: floorspace, buildings, floorspace-hours and employees. Vacant buildings that were classified as vacant as well as those that were more than 50 percent vacant at least 3 months during the survey year were removed. An example is presented in Table A.3.

Table A.3. Occupancy-Adjusted Total Commercial Floorspace in the Northeast by Principal Building Activity, 1992

Principal Building Activity	Total Floorspace (Million Square Feet)	More than 50 percent for 3 Months During Survey Year	Occupied
Assembly	1,229	122	1,107
Education	1,968	239	1,729
Food Sales/Service	565	68	497
Health Care (inpatient)	348	0	348
Health Care (outpatient)	38	0	38
Laboratory	77	0	77
Lodging	616	60	556
Mercantile/Services	2,798	26	2,772
Office	2,525	85	2,440
Other, excluding Vacant	496	9	487
Public Order/Safety	269	3	266
Vacant	08	708	0
Warehouse	1,763	92	1,672
All Buildings	13,400	1,412	11,988

Source: Energy Information Administration, Office of Energy Markets and End Use, 1992 Commercial Buildings Energy Consumption Survey, Public-Use Files.

Occupied Commercial Buildings Total Site Energy Consumption Adjustment. The total site energy consumption is adjusted by major fuel for each principal building activity (PBA) in each Census region by removing the site energy used in vacant buildings and buildings that were more than 50 percent vacant for at least 3 months (Table A.4).

Occupied and Degree-Day Commercial Buildings Site Energy Consumption Adjustment. This methodology adjusts for both vacancy and weather. First, the occupied site energy consumption is determined as explained above. Then the occupied site energy consumption is adjusted for weather. An example of this methodology was presented in Table A.2.

Table A.4. Occupancy-Adjusted Total Commercial Site Electricity Consumption in the Northeast, by Principal Building Activity, 1992

Principal Building Activity	Total Site Energy Consumption (Trillion Btu)		
	All Buildings	Vacant Buildings	Occupied Buildings
Assembly	24	2	22
Education	42	4	38
Food Sales/Food Service	37	< 1	36
Health Care (Inpatient)	24	--	24
Health Care (Outpatient)	1	--	1
Laboratory	3	--	3
Lodging	21	1	20
Mercantile/Services	77	< 1	77
Office	125	3	122
Other	12	< 1	12
Public Order	8	< 1	8
Vacant	7	7	0
Warehouse	38	< 1	38
Total	419	--	401

-- = No cases.

Source: Energy Information Administration, Office of Energy Markets and End Use, 1992 Commercial Buildings Energy Consumption Survey, Public-Use Data Files.

To determine the U.S. total occupied and degree-day total site energy consumption use the following method:

- Adjust at the PBA level by Census region for vacancy and obtain occupied total site energy consumption by PBA within each Census region (Table A.3)
- At the level of Step 1, using 1989 percent shares, obtain the end-use estimates for the occupied buildings (Table A.2)
- At the same level degree-day, adjust the end-use estimates using the appropriate degree-day factor (Table A.2)
- Sum up end-use estimates for each major energy source by PBA in each Census region
- Sum across major energy sources to obtain the total occupancy and degree-day adjusted total site energy consumption for each Census region PBA
- Sum across the PBA to obtain the Census region totals
- Sum across the Census regions to obtain U.S. occupancy and degree-day adjusted total site energy consumption.

Transportation Sector

Domestic Air Energy Use for Passenger and Freight: Derivation

The available data for aviation energy demand is for both the passenger and freight transportation sectors combined. In many aircrafts, freight is carried in the hull of the craft while passengers ride in the cabin. Although the passenger-miles traveled by air cannot be separated into passenger and freight components, the revenues (in millions of dollars) received for different types of air travel can be separated.

The relative share of revenue dollars was used to estimate the portion of energy consumed for passenger and freight movements by air. Table A.5 presents the methodology.

Table A.5. Calculating U.S. Domestic Passenger and Freight Air Travel Energy Consumption

Indicators	Units	1985	1988	1991
U.S. Domestic Passenger				
Revenue per Passenger Mile	Cents	12.21	12.31	13.22
Passenger Miles	Million	277,836	334,291	338,085
Passenger Revenues	Million Dollars	33,924	41,151	44,695
U.S. Domestic Freight				
Freight Revenue per Ton Mile	Cents	102.23	111.31	103.50
Freight Ton Miles	Million	6.71	9.33	9.96
Freight Revenues	Million Dollars	6,860	10,385	10,309
Total Operating Revenues	Million Dollars	37,629	50,155	56,165
Air Travel Energy Use	Trillion Btu	1,366	1,609	1,542
Air Passenger	Trillion Btu	1,231	1,320	1,227
Air Freight	Trillion Btu	134	289	315

Notes: •Passenger and freight revenues may not add to total operating revenues, due to calculations and differences in data sources. •Air passenger energy use calculated as the multiple of its revenue ratio and total air travel energy use, e.g., in 1985 the equation is $(33,924/37,629) * 1,366 = 1,231$. •Air freight energy use calculated as the remainder after air passenger energy use is subtracted from total air travel energy use, e.g., in 1985 the equation is $(1,366 - 1,231) = 134$.

Sources: •Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics* (September 1993), Tables 1, 4, and 6. •Eno Transportation Foundation Inc., *Transportation in America 1994*, pp. 44 and 49.

Site Energy Consumption Conversion: Electricity consumption is reported for pipelines and passenger rail in the Oak Ridge National Laboratory *Transportation Energy Data Book*. The primary electricity volumes were converted to site electricity by applying conversion factors. See "Primary Conversion Factors" in the economy section in this appendix. Table A.6 presents the methodology.

Table A.6. Calculating U.S. Transportation Site Electricity Consumption

Electricity Variables	1985	1988	1991
Primary Electricity (Trillion Btu)			
Pipeline	239.0	244.8	243.4
Passenger Rail	55.4	59.9	59.5
Electricity Conversion Factor	3.292	3.311	3.30
Site Electricity (Trillion Btu)			
Pipeline	72.6	73.9	73.8
Passenger Rail	16.8	18.1	18.0

Note: Site electricity is calculated as primary electricity divided by the conversion factor, e.g., in 1985 the equation for pipelines is $(239.0 / 3.292) = 72.6$.

Sources: •Department of Energy, Oak Ridge National Laboratory (ORNL), *Transportation Energy Data Book* (ORNL-6798), Editions 11 and 14, Table 2.6 and unpublished 1985 data from ORNL.

Industrial Sector

Capacity-Utilization Rate

The capacity-utilization rate equals the seasonally adjusted index of industrial production divided by a capacity index (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule). The Federal Reserve Board weights the capacity indexes by value-added proportions.

Capacity-Adjusted Value of Production Method. This method adjusts the value of shipments for changes in capacity after the value of shipments has been adjusted for changes in inventories (value of production). See "Inventory Adjustment" in this section of the appendix. The method is as follows:

- Divide the 26-year average capacity-utilization rate (average) by the annual reported rate (t) to calculate factors for each major industry group (Table A.7 presents these rates by SIC)
- Multiply this factor by the value of production estimate in constant 1987 dollars.

Constant-dollar Capacity-Adjusted Value of Production $=$

$$\frac{\text{Capacity-Utilization Rate}_{\text{ave}}}{\text{Capacity-Utilization Rate}_t} * \text{Constant-dollar Value of Production}$$

Table A.7. Capacity-Utilization Rate: 26-Year Average and Annual for 1985, 1988, and 1991, by SIC

SIC	Major Industry Group	Capacity Utilization Rates			
		1967-1993	1985	1988	1991
20	Food and Kindred Products.....	82.3	81.0	81.8	81.4
21	Tobacco Manufactures	NA	NA	NA	NA
22	Textile Mill Products	86.2	83.0	88.7	83.3
23	Apparel and Other Textiles Products.....	81.1	80.4	82.8	77.6
24	Lumber and Wood Products.....	83.1	84.6	89.7	79.3
25	Furniture and Fixtures	81.7	79.8	84.2	74.2
26	Paper and Allied Products.....	89.7	89.7	93.2	88.4
27	Printing and Publishing.....	86.5	87.0	89.9	79.7
28	Chemicals and Allied Products.....	80.0	77.1	83.9	80.6
29	Petroleum and Coal Products.....	85.5	78.6	85.2	86.0
30	Rubber and Miscellaneous Plastics.....	83.6	85.3	87.7	80.3
31	Leather and Leather Products.....	81.9	75.6	79.5	78.5
32	Stone, Clay, and Glass Products.....	77.9	75.6	82.2	73.2
33	Primary Metal Industries.....	80.1	74.0	87.5	77.9
34	Fabricated Metal Products.....	77.2	74.9	81.1	73.2
35	Industrial Machinery and Equipment.....	80.8	73.4	80.5	72.6
36	Electronic and Other Electric Equipment.....	80.4	80.7	83.7	78.0
37	Transportation Equipment	74.9	78.8	79.4	73.4
38	Instruments and Related Products.....	82.0	83.6	80.5	77.2
39	Miscellaneous Manufacturing Industries.....	75.6	67.7	79.5	74.6

NA = Not Available.

Sources: •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).

Inventory Adjustment

Changes in inventories need to be considered when using a demand indicator such as the value of shipments. If inventories are being drawn down, the value of shipments will overestimate the actual value of production. If inventories are being built, then the value of shipments will underestimate the value of production.

Inventory-adjusted Value of Shipments or Value of Production. The inventories used in the adjustment are year-end inventories at cost or market value, deflated to 1987 constant dollars using value of shipments implicit price deflators reported by the U.S. Department of Commerce, Bureau of Economic Analysis. The following steps were followed to adjust the value of shipments for the effects of changes in inventories:

- Determine the implicit price deflator by dividing current dollar into constant dollar value of shipments for each major industry group in each year
- Multiply this deflator by the year-end inventories of the year preceding and the current year
- Add to the deflated value of shipments the deflated current year inventory and subtract the deflated prior year inventory.

$$\text{Value of Shipments Deflator }_t = \frac{\text{Constant-dollar Value of Shipments }_t}{\text{Current-dollar Value of Shipments }_t}$$

$$\text{Constant-dollar Value of Production }_t =$$

$$\text{Constant-dollar Value of Shipments }_t + (\text{Value of Shipments Deflator }_t * \text{Current-dollar Inventories }_t) - (\text{Value of Shipments Deflator }_{t-1} * \text{Current-dollar Inventories }_{t-1})$$

Table A.8. Value of Production Methodology Example

Calculations	Preceding Year (t-1)	Current Year (t)
a. Value of Shipments (million 1987 dollars)	307,345	319,212
b. Value of Shipments (million current dollars)	255,723	303,270
c. Implicit Price Deflator (a/b)	1.20	1.05
d. Year-End Inventories (current million dollars)	24,397	24,023
e. Year-End Inventories (million 1987 dollars) (c*d)	29,276	25,224
f. Value of Production (million 1987 dollars) (319,212 + 25,224 - 29,276 = 315,160)	315,160

Note: This example is for illustrative purposes only. Although, MECS-weighted value of shipments data (adjusted to 1987 SIC) were used throughout Chapter 6, "Industrial Sector," confidentiality does not permit EIA to release value of shipments data that have been revised by MECS weights.

U.S. Economy

Energy-Weighted Index

One way for removing effects such as geography and housing unit type effects is to index from a "two-way" disaggregation of characteristics to develop an index for total U.S. housing.

As an example, for the Northeast Census region in the residential sector, start with consumption per household for each of the five housing types indexed to 1 in the first year as follows:

Northeast Census Region	1984	1987	1990
Mobile Homes	1	x	x
Single-Family Detached	1	x	x
Single-Family Attached	1	x	x
Multifamily (2-4 Units)	1	x	x
Multifamily (5 or More Units)	1	x	x

Compute an energy-weighted index (preferably Tornqvist index) of the individual energy-intensity indices for 1987 and 1990 for each of the Census regions. This index will be devoid of mix issues relating to housing type and geography. While there will still be other behavioral and/or structural effects in the five disaggregated indices, a layered procedure that moves down the chain to include measures that disaggregate end-uses (for example, an index of space-heating consumption per square foot, not household, since housing sizes are changing, or an index of water heating per occupant rather than per household, since persons per household are changing, etc...) and to exploit all of the detail available from the energy consumption surveys is a "good measure" of energy intensity. These effects might be relatively minor over the 3 surveys years being compared, but without the calculations such as these, only qualitative judgments as to the potential effects can be made. This proposed approach is for all intents and purposes has been used for the transportation and economy composites. Indices can be developed for each sector and weighted by shares of total energy consumption in the economy.

Primary Conversion Factors for Total Site Electricity

Primary energy estimates include losses in the generation, transmission, and distribution of electricity. In this report, conversion factors are developed to account for these losses. Total site electricity estimates are multiplied by these conversion factors to obtain primary electricity estimates.

The methodology for developing the conversion factors and obtaining primary electricity estimates is shown in the following steps:

Step 1. Calculate gross inputs:

- Convert utility-site generation by energy source and region in kWh to equivalent gross-generation estimates in kWh (including generator or shaft losses) by multiplying site generation by the appropriate gross/site ratio plus the transmission and distribution losses estimated at 8 percent by the Department of Energy, Office of Energy Management.
- For each year, the gross-generation estimates, by Census region, are multiplied by the appropriate annual heat rate for each energy source to obtain gross inputs for electricity generation by utilities such that:

$$\text{Gross Inputs} = (\text{Net Generation} * (\text{Gross/Site Ratio} + \text{T&D Losses}) * \text{Heat Rate}) / 1000.$$

Data on energy sources used by nonutilities and net exporters to produce electricity purchased by U.S. utilities are not available. Since electricity from these sources is primarily produced from either fossil fuels or hydro resources, the heat rates of fossil-fueled steam generators are applied to the purchased energy. Table A.9 presents an example of the calculation of gross inputs for the Northeast Census region in 1992.

Table A.9. Example of Calculating Gross Inputs for the Northeast in 1992

Calculation Inputs	Generation Energy Sources						
	Fossil Fuels	Nuclear	Hydropower	Geothermal	Other	Nonutility Purchases	Net Imports
a. Site Generation (Billion kWh)	218.4	144.4	30.6	0	0.5	52.5	12.1
b. Gross/Site Ratio	1.07	1.06	1.01	1.06	1.07	1.07	1.07
c. T&D Losses	0.08	0.08	0.08	0.08	0.08	0.08	0.08
d. Heat Rates (Btu/kWh)	10,302	10,678	10,302	20,955	10,302	10,302	10,302
e. Gross Inputs (Trillion Btu) (a * (b + c) * d)/1000	2,588	1,757	344	0	6	622	143

Note: Fossil fuel heat rate is used also for hydropower, nonutility purchases, net imports, and other.

Sources: ●Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternative Fuels, *Electric Power Annual 1993* (DOE/EIA-0348(93), Tables 13, 61 and 62. ●Energy Information Administration, Office of Energy Markets and End Use, *Monthly Energy Review* (DOE/EIA-0035(94/08)), Table A8; *Production Annuelle Brute et Nette d'Electricité*, p.16.

Step 2. Add utility-plant use to electricity sales for each sector.⁹⁹

Step 3. All regional estimates of electricity sales and plant use in kWh are converted to Btu using 3,412 Btu per kWh.

Step 4. Divide gross energy inputs by the total site electricity (sales and plant use) for each Census region to obtain conversion factor.

Step 5. Site electricity consumption for each end-use sector and Census region are multiplied by the primary electricity conversion factors to obtain the corresponding primary electricity estimates. The data source is the consumption survey data as developed in each of the sector chapters.

There are three main advantages to using the method described above:

- Generation, transmission and distribution losses are accounted for
- Includes electricity consumption that was generated by both utilities and nonutilities
- Since the heat rate used varies from year to year and by fuel source, changing efficiencies over time are captured.

⁹⁹Electricity sales data are obtained from EIA's *Electric Power Annual 1993* (DOE/EIA-0348(93), Table 26. Plant use electricity is the difference between gross inputs and site electricity.

Regional Manufacturing Estimates: The 1985 estimate of total inputs for heat, power, and generation was based on EIA's revised 13,631 trillion Btu total. This total was distributed regionally by using regional shares based on Table 3 in the EIA publication, *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* (DOE/EIA-0512(85)).

The analysis of the manufacturing sector used revised 1985 estimates to match the revised 1987 SIC standards. Electricity was not considered separately. Therefore, electricity consumption for heat, power, and generation in Btu were calculated from the kilowatthour estimates in Table 3 of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1985* and *Manufacturing Energy Consumption Survey: Consumption of Energy, 1988* (DOE/EIA-0512(88)) by multiplying the estimates by 3,412 Btu per kWh. Natural gas consumption for heat, power, and generation in Btu were calculated from the cubic-foot estimates in the same tables. The natural gas estimates for the respective surveys were multiplied by 1,031 Btu/cubic feet.

Both the 1991 electricity and natural gas estimates in Btu were provided in Table A.4 of *Manufacturing Energy Consumption Survey: Consumption of Energy, 1991*, DOE/EIA-512(91) report.

Regional Passenger Transportation Estimates: Passenger transportation data are not available by Census region. On the advice of Oak Ridge National Laboratory, it was decided that since household vehicles account for over 70 percent of the total energy for passenger travel, regional shares based on the Residential Transportation Energy Consumption Survey (RTECS) would be an adequate proxy for passenger transportation energy estimates.¹⁰⁰

There has been very little change in the RTECS regional distribution across survey years. For 1985, 1988, and 1991, the total U.S. passenger transportation energy estimates were multiplied by the percent shares by Census region to obtain regional energy consumption estimates for passenger travel. The percent shares were based on the 1988 RTECS. The 1988 shares were: 17 percent for the Northeast; 25.2 percent for the Midwest; 36.0 percent for the South, and 21.8 percent for the West.

Regional Freight Transportation Estimates: Freight transportation data are not available by Census region. On the advice of Argonne National Laboratory, it was decided that since most of the energy source used for freight transportation was fuel oil, EIA data could be used instead of Department of Transportation, Bureau of Transportation Statistics data.

EIA's Petroleum Marketing Division annually surveys State-level distillate fuel oil consumed by trucks, rail, and marine vehicles and residual fuel oil consumed by rail and marine vehicles, benchmarking to the petroleum product supplied data published by EIA's Petroleum Supply Division. The report, *Fuel Oil and Kerosene Sales*, provides State-level data on the number of gallons consumed, which were converted to trillion Btu using Oak Ridge National Laboratory conversion factors, in order to derive percent shares.

Since there has been little fluctuation in regional distribution year-to-year, it was determined to apply 1988 regional percent shares to all annual estimates. The regional percent shares used were: 12.5 percent for the Northeast; 20.2 percent for the Midwest; 42.0 percent for the South, and 25.3 percent for the West.

Quantity Index

A quantity index measures changes in quantity over time. The Index of Industrial Production, developed by the Federal Reserve Board, is a quantity index.

The weighted aggregate quantity index is computed similar to the weighted aggregate price index.

The Price Index. The price index is a weighted average of expenditures, as a percentage of expenditures existing in a base year. A price index may be calculated for a single good or can be calculated as an aggregated price index for a "basket" of several goods. Price indices can be unweighted or weighted. The unweighted aggregated approach is heavily influenced by those goods with higher prices which dominate the index. To reduce this sensitivity of the unweighted index, a weighted price index is used. Each good in an weighted aggregate price index is weighted according to its importance.

One way to weight a price index is to use base-year quantities, the Laspeyres price index.

¹⁰⁰Business fleets are operated very differently from household vehicles, but adequate data are not available on fleet vehicles.

Laspeyres price indices are calculated by comparing the current and base year cost of a basket of goods of fixed composition. As an example, the "basket" can be several "goods" such as energy, clothing, food, housing, etc. that we find in the "basket" used to calculate the Consumer Price Index (CPI) or one "good" such as the major energy sources that is used to calculate the energy component of the CPI. The Producer Price Index (PPI) developed and maintained by the Bureau Labor Statistics, is also a base-weighted price index.

Laspeyres base-weighted price index (ratio of today's cost using base-year quantities to the base-year cost of the goods) equals:

$$\sum p_t^i q_o^i / \sum p_o^i q_o^i * 100$$

where the base-year quantities of the various goods = q_o^i ,

the base-year prices of the various goods = p_o^i , and

present prices of the various goods = p_t^i .

Quantity Index. Similar to the Laspeyres price index, quantities for each item are measured in the base year $_o$ and year $_t$, with q_o^i and q_t^i , representing these quantities for item I (e.g., end use or energy source). The quantities are then weighted by a fixed price (w_i^i) such as value added, value of shipments, etc. where the quantity index I equals

$$\sum q_t^i w_i^i / \sum q_o^i w_i^i * 100$$

In some quantity indexes, the weight for item I is the base-period price (p_o^i).

Glossary

The Glossary is divided into six distinct sections: General Terminology, Residential Sector, Commercial Buildings Sector, Transportation Sector, Industrial Sector, and the U.S. Economy.

General Terminology

Behavioral Change: As it affects energy efficiency, behavioral change is a change in energy-consuming activity originated by, and under control of, a person or organization. An example of behavioral change is adjusting a thermostat setting, or changing driving habits.

British Thermal Unit (Btu): The quantity of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit at or near 39.2 degrees Fahrenheit.

Census Region: A geographic area consisting of several States defined by the U.S. Department of Commerce, Bureau of the Census. The four Census regions are:

Northeast: Connecticut, Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, New Jersey, New York, and Pennsylvania

Midwest: Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota

South: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, and Texas

West: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Hawaii, Oregon, and Washington

Cooling Degree-Days (CDD): A measure of how hot a location was over a period of time, relative to a base temperature. In this report, the base temperature is 65 degrees Fahrenheit; the period of time is 1 year. The CDD for a single day is the difference between that day's average temperature and 65 degrees, if the daily average exceeds the base temperature, and zero if the daily average is less than or equal to the base temperature. The CDD for a longer period of time is the sum of the daily CDD from the days in the period.

Demand Indicator: A measure of the number of energy-consuming units, or the amount of service or output, for which energy inputs are required.

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**.)

End Use: Any specific activity performed by a sector (residential, commercial, industrial, or transportation) that requires energy, e.g., refrigeration, space heating, water heating, manufacturing process, feedstocks, etc.

Energy Efficiency: A value-based, philosophical concept. In this report, two different concepts of energy efficiency are discussed, a technical and a more broad, subjective concept. In the technical concept, increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs. In the more subjective concept, energy efficiency is the relative thrift or extravagance with which energy inputs are used to provide goods or services.

Energy Intensity: The ratio of energy consumption to a measure of the demand for services (e.g., number of buildings, total floorspace, floorspace-hours, number of employees, or constant dollar value of Gross Domestic Product for services).

Floorspace: The area enclosed by exterior walls of a building, including parking areas, basements, or other floors below ground level. It is measured in square feet.

Heated Floorspace: The area within a building, which is space heated.

Cooled Floorspace: The area within a building, which is air-conditioned.

Gross Domestic Purchases: The total purchases by U.S. residents for all goods and services wherever produced, including imports, but excluding exports. The scope of energy expenditures and price is more consistent with that of gross domestic purchases than gross domestic product. Gross domestic purchases figures are reported in real 1987 dollars, using the implicit price deflator published by the U.S. Department of Commerce, Bureau of Economic Analysis. See Appendix A, "Additional Measures of Energy Consumption, Expenditures, and Prices" in *State Energy Price and Expenditure Report 1992* (DOE/EIA-0376(92)) for a further treatment of the usage of gross domestic purchases.

Gross Domestic Product (GDP): The total value of goods and services produced by the Nation's economy before deduction of depreciation charges and other allowances for capital consumption labor and property located in the United States. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade. GDP figures are reported in real 1987 dollars, using the implicit price deflator published by the U.S. Department of Commerce, Bureau of Economic Analysis.

Heating Degree-Days (HDD): A measure of how cold a location was over a period of time, relative to a base temperature. In this report, the base temperature is 65 degrees Fahrenheit; the period of time is 1 year. The HDD for a single day is the difference between that day's average temperature and 65 degrees, if the daily average is below the base temperature, and zero if the daily average exceeds or equals the base temperature. The HDD for a longer period is the sum of daily HDD for days in that period.

Normal Cooling Degree-Days: Annual cooling degree-day average over 30 years from 1961 through 1990 as calculated by U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA).

Normal Heating Degree-Days: Annual heating degree day average over 30 years from 1961 through 1990 as calculated by U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA).

Primary Energy Consumption: Primary energy consumption is the amount of site consumption, plus losses that occur in the generation, transmission, and distribution of energy (See **Site Energy Consumption**).

Sector: The broadest category for which energy consumption and intensity are considered within the U.S. economy. For this report, four major energy-using sectors are considered: residential, commercial buildings, transportation, and industrial.

Site Energy Consumption: The Btu value of energy at the point it enters the home, building, or establishment, sometimes referred to as "delivered" energy. (See **Primary Energy Consumption**.)

Structural Change: As it affects energy efficiency, structural change is a change in the relative levels of energy-consuming subsectors within a sector. An example of structural change is change in product or industry mix in the industrial sector.

Residential Sector

End Use: A function for which energy sources or fuels are used in the household. Any specific activity performed requires energy. For the residential sector, the following main energy end-use categories are estimated using RECS data. See Appendix D, "End-Use Estimation Methodology," in Household Energy Consumption and Expenditures 1990 (DOE/EIA-0321(90)).

Space Heating: The use of mechanical equipment to heat all or part of a building to at least 50 degrees Fahrenheit. Includes both the main space-heating and secondary space-heating equipment, but excludes energy used to operate appliances that give off heat as a byproduct.

Air-Conditioning or Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air-conditioner or heat pump) or by circulating chilled water through a central cooling or district cooling system.

Appliances: Energy-consuming equipment used in the home during the year for purposes other than condition of air or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, color televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other noncooking applications of hot water. An automatically controlled, thermally insulated vessel designed for heating water and storing heated water at temperatures less than 180 degrees Fahrenheit.

Household: A family, individual, or group of up to nine unrelated persons, occupying the same housing unit. "Occupancy" means the housing unit was the person's usual or permanent place of residence at the time of the survey. By definition, the number of households is the same as the number of occupied housing units.

Household Member: Any eligible person who belongs to a household. Members include babies, boarders, lodgers, employed persons who live in the housing unit, and persons who usually are part of the household but are away traveling or in a hospital. Excluded are college students who live elsewhere, members of the armed forces, corrections inmates who used to live in the residence, or others who remain away from the residence for extended periods of time.

Housing Unit: A house, apartment, group of rooms, or a single room if it is occupied or intended for occupancy, as separate living quarters by a family, individual, or group of one to nine unrelated persons. Prisons and nursing homes are excluded.

Mobile Home: A housing unit built on a movable chassis and moved to the site. It may be placed on a permanent or temporary foundation and may contain one or more rooms.

Multifamily (2-4 units): A unit in a building with two to four housing units—a structure that is divided into living quarters for two, three, or four families or households and in which one household lives above another.

Multifamily (5+ units): A unit in a building with five or more housing units—a structure that contains living quarters for five or more families or households and in which one household lives above another.

Single-Family Attached: A structure that provides living space for one family or household that is not divided into multiple housing units and has an independent outside entrance. Townhouses, rowhouses, and duplexes are considered single-family attached housing units, as long as there is no household living above another one within the walls that go from the basement to the roof to separate the units.

Single-Family Detached: A stand-alone structure that provides living space for one household or family. A manufactured house assembled on site is a single-family detached unit, not a mobile home.

Income Level: The income grouping for the total combined income (before taxes and deductions) of all members of the family from all sources, for the 12 months prior to the survey. Sources of income include wages, salaries, tips, commissions, interest, dividends, rental income, social security or retirement, pensions, food stamps, Aid to Families with Dependent Children, unemployment compensation, and other public assistance. Income from unrelated household members is not included.

Main Heating Fuel: The fuel used most for space heating.

New Construction: The amount of square footage constructed in the survey year and two years prior, e.g., 1988-1990 for the 1990 Residential Energy Consumption Survey.

Personal Consumption Expenditures: All household expenditures on durable goods such as stoves, and nondurable goods such as energy, and on services such as day care.

Residential Building: A structure used primarily as a dwelling for one or more households. A building typically containing less than 1,000 square feet of floorspace and intended for human occupancy. More than 50 percent of its floorspace must be used for residential activities.

Unadjusted Energy Consumption: Site energy consumption as provided in the RECS Public-Use Files. No adjustments were made to account for weather variations, behavioral, or structural effects.

Commercial Building Sector

Air-Condition or Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air-conditioner or heat pump) or by circulating chilled water through a central cooling or district cooling system that circulates chilled water.

Commercial Building: A building with more than 50 percent of its floorspace used for commercial activities. Commercial building include, but are not limited to, stores, offices, schools, churches, gymnasiums, libraries, museums, hospitals, clinics, warehouses, and jails. Government buildings are included except for buildings on sites with restricted access, such as some military bases or reservations. A building is an enclosed structure containing over 1,000 square feet of floorspace and intended for human occupancy. Agricultural, industrial, and residential buildings are excluded from commercial sector surveys.

Employee: A worker in a building during the main shift on a typical workday during the year, including self-employed and volunteers. Excluded are customers, patients, and students, unless they are working for the business. Also excluded are employees who work out of the office, e.g., salespeople, delivery people, and messengers.

Major Fuels: The energy sources or fuels for which consumption and expenditure data were collected on four CBECS surveys. These include electricity, natural gas, fuel oil, and district heat. Propane is excluded from all totals.

New Construction: The amount of square footage constructed in the survey year and 2 years prior, e.g., 1990-1992 for the 1992 CBECS.

Occupied Floorspace: The area of all commercial buildings excluding those buildings classified as vacant and all other buildings that were more than 50 percent vacant during the three months preceding the survey.

Principal Building Activity: The activity or function occupying the most floorspace in the building. The categories were designed to group buildings that have similar patterns of energy consumption. While all calculations in this report were performed using 13 categories, the results were aggregated into the following 10 categories:

Education: refers to buildings that house academic or technical classroom instruction. Certain buildings in educational facilities are excluded from this category, e.g., administration (office), dormitory (lodging), gymnasium (assembly), etc.

Food: refers to buildings used for retail or wholesale of food. Includes establishments that sell food retail or wholesale (e.g., grocery stores) and establishments that prepare and sell food and beverages for consumption (e.g., restaurants). (Combines Food Sales and Food Service)

Health Care: covers diagnostic and treatment facilities for both inpatient (e.g., hospitals, rehabilitation facility) and outpatient (e.g., dental, medical, and mental health clinics) care.

Lodging: includes establishments that offer multiple accommodations for short- or long-term residents (e.g., hotels, nursing homes).

Mercantile and Service: refers to buildings used for the sales and displays of goods or services, including automotive, retail, laundry, and shopping centers, but excluding food.

Office: refers to buildings used for general office space, professional offices, and administrative offices.

Assembly: signifies buildings used for gathering of people for social, recreational, cultural, or religious activities, whether in private or public meeting halls. (Combines assembly with religious buildings.)

Warehouse: describes buildings used to store goods, products, merchandise or raw materials, including both refrigerated storage and unrefrigerated warehouses.

Vacant: designates buildings in which more floorspace was vacant than was used for any other single activity.

Other: includes parking garages, public order and safety buildings used in the preservation of law and order or safety, laboratories that use equipment for experimental testing or analysis, and Other buildings not elsewhere classified (e.g., hangars, public restrooms). (Includes the Public Order and Safety Building category.)

Unadjusted Consumption: Major site fuel consumption as provided in the CBECS Public Use Files, excluding consumption of propane and consumption by small floorspace (less than 1,000 square feet) and noncommercial (agriculture, industrial, or residential) buildings.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Vintage: The year of origin or age since the construction of a commercial unit, as calculated from the CBECS survey year.

Transportation Sector

Air Travel: Include both general aviation and commercial air carriers. General aviation refers to the use of non-commercial air carriers for several purposes, including business, flight instruction, and other personal activities. Air carriers include both scheduled and non-scheduled flights.

Alternative Fuels: Methanol, denatured ethanol, and other alcohols, mixtures containing 85 percent or more (or such other percentage, but not less than 70 percent) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; and electricity, including electricity from solar energy.

Automobiles: Includes household, government, and commercial cars. The RTECS includes company vehicles if used for personal travel in addition to the business usage and the vehicle is ordinarily kept at home.

Buses: Includes commercial, school, and transit buses. It does not include trolley buses.

Combination Trucks: Consists of a power unit (a truck tractor) and one or more trailing units (a semi-trailer or trailer).

Freight Modes: Includes truck, air, marine, rail, and pipeline freight modes. It does not include gas and water pipeline.

Heavy-Duty Vehicles: Combination of all high passenger occupancy modes of transportation, including buses, trains, general aviation, and air carriers.

Light-Duty Vehicles: Include automobiles, motorcycles, and light trucks.

Light Trucks: All single unit two-axle, four-tire trucks, including pickup trucks, sports utility vehicles, vans, motor homes, etc. This is the Department of Transportation definition. The Energy Information defined light truck as all trucks weighing 8,500 pounds or less.

Marine Freight: Freight transported over rivers, canals, the Great Lakes, and domestic ocean waterways.

Other Single-Unit Truck: A motor vehicle consisting primarily of a single motorized device with more than two axles or more than four tires.

Passenger-Miles Traveled: The total distance traveled by all passengers. It is calculated as the product of the occupancy rate in vehicles and the vehicle miles traveled.

Passenger Modes: Includes Light-Duty Vehicles and Heavy-Duty Vehicles. See **Light-Duty Vehicles** and **Heavy-Duty Vehicles** in this section of the glossary.

Passenger Rail: Includes short- and long-distance passenger rail, commuter rail, and light and heavy rail. Heavy rail is electric transit vehicle with capacity for heavy "volume" traffic. It is more generically referred to as subway. Light rail is a type of electric transit railway with a light-volume capacity, with generic names like "streetcars," "trolley cars," and "tramways."

Pipeline Freight: Refers to freight carried through pipelines, including natural gas, crude oil, and petroleum products (excluding water). Energy is consumed by various electrical components of the pipeline, including, valves, other, appurtenances attaches to the pipe, compressor units, metering stations, regulator stations, delivery stations, holders and fabricated assemblies. This report presents only oil pipeline freight.

Rail Freight: Refers to intercity freight movement by trains.

Site Energy Consumption: This includes gasoline, distillate fuel oil, liquefied petroleum gas, jet fuel, residual oil, natural gas, and electricity converted to their Btu equivalent. **Primary energy consumption** also includes electrical losses.

Site Energy Consumption Conversion: Electricity consumption is reported for pipelines and passenger rail in the Oak Ridge National Laboratory *Transportation Energy Data Book*. The primary electricity volumes were converted to site electricity applying conversion factors. See Appendix A for the methodology.

Sport-Utility Vehicle: Includes light trucks that are similar to Jeeps. Other common terms for these vehicles are sport, special purpose, utility, or off-the-road vehicles. They may have a four- or two-wheel drive.

Ton Miles: The product of the distance freight is hauled, measured in miles, and the weight of the cargo being hauled, measured in tons. Thus, moving one ton one mile generates one ton mile.

Truck Freight: This is freight carried by single-unit, non-two-axle, four-tire trucks (Other single unit trucks) and combination trucks.

Two-axle, four-tire trucks: A motor vehicle consisting primarily of single motorized device with two axles and four tires.

Vehicle-Miles Traveled: One vehicle traveling a distance of one mile. Total vehicle miles is the total mileage traveled by all vehicles.

Industrial Sector

Byproduct Fuels: Secondary or additional products resulting from the feedstock use of energy or the processing of nonenergy materials. For examples, the more common byproducts of coke ovens are coal gas, tar, and a mixture of benzene, toluene, and xylene (BTX). Byproduct fuels are produced by the use of both energy and nonenergy raw material input, but they appear differently on various measures of energy consumption, depending on which one is being considered. For instance, total input for heat, power, and electricity generation include both types of byproduct fuels. In order to avoid double counting of primary energy, however, primary energy consumption for all purposes does not include byproduct fuel resulting from the use of other energy, but includes those resulting from the use of nonenergy sources as raw material input.

Capacity-Utilization Rate: Equals the seasonally adjusted index of industrial production divided by a capacity index (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule). The Federal Reserve Board weights the capacity indexes by value-added proportions. This methodology is described in Appendix A.

Feedstock Energy Consumption: Includes all energy sources consumed as a raw material, and it is definitionally equivalent to total primary consumption of energy for nonfuel purposes described in the Manufacturing Energy Consumption Survey (MECS).

Gross Output: Gross output equals shipments, minus cost of resale, plus changes in business inventories, coverage adjustment, commodity taxes, and new force account construction (value of construction undertaken with own labor, capital, etc.). All components are deflated to 1987 dollars. The Bureau of Economic Analysis considers this to be the most comprehensive measure of manufacturing production.

Gross Product Originating (GPO): The attribution of gross domestic product to industries or sectors of origin, as provided by the National Income and Product Accounts of the Bureau of Economic Analysis. GPO is compiled by summing income components—wages and salaries, capital, profits, etc.—and corresponds in concept to value added. GPO deflators are used to convert current dollar-denominated value added into 1987 constant dollars.

High-Energy Consumers: Consists of the major manufacturing groups Food and Kindred Products, Paper and Allied Products, Chemicals and Allied Products, Petroleum and Coal Products, Stone, Clay and Glass Products, and Primary Metal Industries. These firms convert raw materials into finished goods primarily by chemical (and not by physical) means. Heat is essential to their production, and steam provides much of the heat. Natural gas and byproduct and waste fuels are the largest sources of energy for this group.

High-Value Added Consumers: Producers of 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 for these firms.

Industrial Production: The Federal Reserve Board calculates this index by compiling indices of physical output from a variety of agencies and trade groups, weighting each index by the Census' value added, and adding it to the cost of materials. When physical measures are not available, the Federal Reserve Board uses the number of production workers or amount of electricity consumed as the basis for the index. To convert industrial production into dollars, multiply by the "real value added" estimate used by the Federal Reserve Board.

Industrial Sector: As defined by EIA, Comprises manufacturing industries, which make up the largest part of the sector, along with mining, construction, agriculture, fisheries, and forestry. Establishments in the sector range from steel mills and small farms to companies assembling electronic components. The SIC codes 20 through 39 are used to classify establishments as industrial. A subdivision of U.S. economic activity defined by EIA to include manufacturing, construction, mining, agriculture, fishing, and forestry (nonmanufacturing) establishments.

Inventories: Year-end inventories at cost or market value, deflated to 1987 constant dollars using value of shipments implicit price deflators reported by Bureau of Economic Analysis.

Low-Energy Consumers: This group is the smallest energy consuming sector and represents a combination of end use requirements. Motor drive is one of the key end uses. Included in this group are tobacco firms, textile mills, lumber mills, rubber and plastics plants, printing and publishing operations, and furniture, apparel, and leather makers.

Major Industry Groups: Two-digit SIC industries, 1-39.

Manufacturing Establishment: An economic unit at a single physical location where mechanical or chemical transformation of materials or substances into new products are performed.

Manufacturing Sector: One of 10 fields of economic activity defined by the *Standard Industrial Classification Manual*, including two-digit SIC industries 20-39. It includes all establishments engaged in the mechanical or chemical transformation of materials or substances into new products. The establishments in the manufacturing sector constitute the universe for MECS.

Total Consumption of Energy for All Purposes: This measure includes offsite-produced energy, feedstocks energy, and onsite byproduct fuels resulting from the use of a nonenergy materials as feedstocks. It excludes electricity losses, as well as byproduct fuels resulting from the use of energy sources as raw materials.

Nonmanufacturing: Includes agriculture, construction, mining, and resource extraction.

Offsite-Produced Energy for Heat, Power and Electricity Generation: This measure of energy consumption, which is equivalent to purchased energy includes energy produced off-site and consumed onsite. It excludes energy produced and consumed onsite, energy used as raw material input, and electricity losses.

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

Total Inputs of Energy for Heat, Power, and Electricity Generation: This measure of energy consumption includes offsite-produced energy and byproduct fuels resulting from the use of both energy and nonenergy materials as feedstocks. However, it excludes feedstocks and electricity losses. Reported in trillion or quadrillion Btu and referred to as **Inputs of Energy** in this report.

Value Added: For the manufacturing and mining sectors, 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 (products manufactured or mined plus receipts for services rendered). This calculation is adjusted by adding the value added by merchandising (mark-up) and the net change in finished goods and work-in-progress inventories. For industries in which value of production is collected instead of value of shipments, value added is adjusted by the change in work-in-progress inventories. Deflated to 1987 constant dollars using GPO deflator.

Value of Production: Calculated as the value of shipments plus inventory change during the year (subtract prior year-end from current year-end inventories) in constant 1987 dollars.

Value of Shipments: Received or receivable net selling values (exclusive of freight and taxes) of all primary and secondary products shipped, as well as all miscellaneous receipts for contract work performed for others, installation and repair, sales of scrap, and sales of products bought and resold without further processing. Deflated to constant 1987 dollars using GPO deflators.

Structurally-Adjusted Estimates: Aggregate energy-intensity changes in the manufacturing sector, from which energy efficiency changes may be inferred, include real efficiency changes, changes due to structural shifts in the economy, and interaction effects. Separation of structural effects from manufacturing energy-intensity is achieved by characterizing the economy in such a way that changing composition of the manufacturing sector is measured by changes in the relative output (or changes in the share of output).

It must be emphasized that the extent to which structural shifts can be eliminated from intensity measurement depends on the level of disaggregation. For instance, disaggregation at the four-digit SIC level would yield a better result than that at the three-digit SIC level, while disaggregation at the three-digit SIC level would yield a better result than that at the two-digit level.

U.S. Economy

Energy Source: Any substance that supplies heat or power, e.g., petroleum, natural gas, coal, renewable energy, and electricity, including the use of a fuel as a non-energy feedstock.

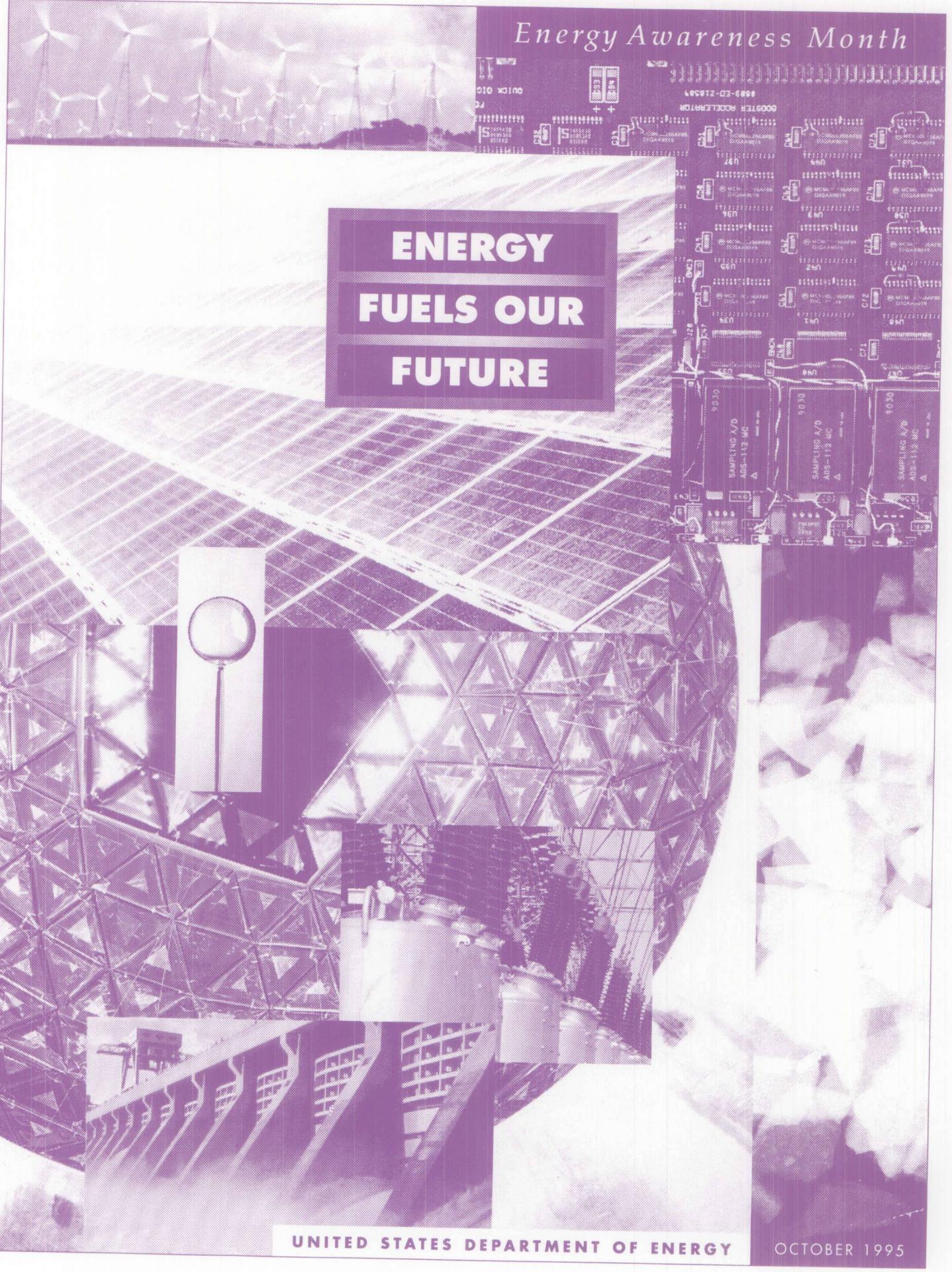
Fossil Fuel: Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

Gross Generation: The total amount of electric energy produced by the generating units at a generating station(s), measured at the generator terminals.

Gross Inputs: The heat value (Btu) of the energy sources used to generate electricity, measured at the generator terminals, including energy used at the generating station.

Net Generation: Gross generation less megawatt hours consumed out of gross generation for station use or auxiliary equipment the electric energy consumed at the generating station for station use.

Nonutility Generator: A corporation, person agency, authority, or other legal entity or instrumentality that owns electric generating capacity and is not an electric utility. Include qualifying cogenerators and small power producers, and other nonutility power producers without a designated franchised service area.



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