Interim Report

**Energy Conservation
Indicators**

June 1982

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
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Interim Report

ENERGY CONSERVATION INDICATORS

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June 1982

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ABSTRACT

A series of Energy Conservation Indicators were developed for the Department of Energy to assist in the evaluation of current and proposed conservation strategies. As descriptive statistics that signify current conditions and trends related to efficiency of energy use, indicators provide a way of measuring, monitoring, or inferring actual responses by consumers in markets for energy services. Related sets of indicators are presented in some 30 one-page "indicator summaries." Indicators are shown graphically, followed by several paragraphs that explain their derivation and highlight key findings. Indicators are classified according to broad end-use sectors: Aggregate (economy), Residential, Commercial, Industrial, and Transportation. In most cases annual time series information is presented covering the period 1960 through 1981.

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INTRODUCTION

Pacific Northwest Laboratory early in 1981 began preparation of a series of Energy Conservation Indicators that could be used by the Department of Energy in evaluation of current and proposed conservation strategies. This work has been primarily sponsored by the Office of Policy, Planning, and Evaluation. Out of that preliminary work, a series of briefings were presented to various groups within DOE in the summer of 1981. This working paper represents an elaboration of this preliminary development effort; additional indicators have been constructed, data have been updated, and graphics have been improved.

Indicators are descriptive statistics that signify current conditions and trends related to energy conservation and the use of renewable energy resources. They are a way of measuring, monitoring, or inferring actual responses by consumers in markets for energy services. Indicators are not models or forecasts--they are designed to show what has happened with respect to the nation's use of energy, but not necessarily why something has happened.

Indicators can be used to provide rudimentary insights into what is currently happening in the marketplace. These insights are one valuable aid in program planning, policy analysis, and evaluation. Indicators can also be used to validate energy models and to point out areas in which refined data collection is needed. In many cases indicators can provide a base from which forecasts of future energy consumption can be made.

As implied above, conservation indicators are not designed to take the place of formal energy demand models. However, the indicators effort has not been limited to presenting raw data compiled by various statistical agencies. In a number of cases, adjustments have been made to normalize the influence of factors such as weather, capacity utilization, and compositional shifts. These adjustments are intended to allow underlying conservation trends to be more clearly observed over short time intervals.

The conservation indicators program is not designed to substitute for any of the various Energy Conservation Data Books (for buildings, transportation, industrial) that have been published by Oak Ridge National Laboratory

since 1977. These data books are compendiums of information related to energy use by these various end-use sectors. However, they do not directly focus on showing trends in energy efficiency; the emphasis is more on the characterization of energy use and the stock of energy-using equipment. In addition, because these data books are comprehensive in nature, their publication has been somewhat infrequent. Thus, the most recent changes in energy efficiency for most end-uses is often not available in the data books.

This report follows the basic classification of energy use as employed by the Energy Information Administration (EIA). Indicators are presented for four major end uses: Residential, Commercial, Industrial, and Transportation. Prior to these sectoral indicators, the second section of the report covers several key aggregate, macroeconomic indicators.

Each of the following sections begins with some general discussion that we have termed "preview and rationale." These introductory remarks help to put the indicators that follow into some context, but do not deal with actual quantitative results. Related sets of indicators in the report are presented in a one-page "indicator summary." Indicators are shown graphically, followed by several paragraphs that explain their derivation and highlight the most important trends or results. A data appendix presents numerical values of all indicators and key supporting data in tabular form. This appendix also contains detailed source explanatory notes that document the derivation of each indicator.

AGGREGATE MACROECONOMIC INDICATORS

Preview and Rationale

Energy conservation trends for the economy as a whole are shown in this section. Figure A.1 shows energy use as it relates to measures of production that are provided in the National Income and Product Accounts. The Energy/GNP ratio continues to be the most widely used measure of national energy productivity; however, the standard energy/GNP ratio includes household consumption of energy. The problem is that personal consumption expenditures for energy can alter the energy/GNP ratio irrespective of energy efficiency improvements. For example, a decline in driving activity leads directly to a reduction in the energy/GNP ratio, since the ratio of energy (in Btu) to personal consumption expenditures for gasoline and oil (in 1972\$) is so much higher than the energy/output ratios for other components of GNP. In Figure A.1 an adjusted energy/GNP ratio is shown that takes into account the changing share of energy personal consumption expenditures to total real GNP.

Another frequently cited aggregate indicator, energy consumption per capita, is shown in Figure A.2. The top graph in the figure is total energy per capita, the sum of direct (i.e., personal consumption) and indirect energy per capita. The bottom graph is an estimate of the direct component, the consumption of fuels for home use plus motor gasoline and oil. As compared to the energy/GNP ratio, the per capita measures cannot claim to reflect changes in energy productivity. Increases in real income to consumers are not accounted for. As total personal consumption rises, both direct and indirect energy use rises as well. This fact should be kept in mind as one studies the movement of this indicator over time.

The third set of aggregate indicators shown in Figure A.3 relate to direct energy use per household. Direct energy is defined to cover consumption expenditure for home use and for personal transportation. This category is broader than residential use, which is direct consumption as defined above, less transportation use. The graphs in Figure A.3 contrast the relative movements of the two major end uses over which the household has control.

Figure A.1 Energy and Gross National Product

Approach: In using the conventional energy/GNP ratio as an aggregate conservation indicator, household use of energy is not correctly taken into account. As an example, a decline in driving activity would result in a reduction in energy use by households and, thus, a reduction in energy/GNP ratio. This would be considered a curtailment of energy use, not improvement in the efficiency of energy use. However, curtailment would not be applicable if the use of the same number of vehicle-miles were travelled by the use of more fuel efficient automobiles.

To determine how much the change in household expenditures for energy have contributed to the overall energy/GNP ratio, the composition of 1972-dollar GNP expenditures between energy personal consumption and non-energy GNP components was held constant at their 1973 values. In 1973 total GNP was \$1209.1 billion, of which 51 billion was for energy personal consumption (4.1 percent of total GNP). By 1981, energy personal consumption was 52 billion (1972\$) compared total GNP of 1510 billion (3.4 percent of total GNP). The adjusted energy/GNP ratio, holding energy personal consumption expenditures at the 1973 fraction of real GNP, is shown in the dashed line in the figure.

Key Findings:

- The energy/GNP ratio declined 18 percent between 1973 and 1981.
- Roughly 25 percent of this drop can be attributed to a smaller percentage of GNP accounted for by personal consumption expenditures for energy.

Sources: Total energy and residential energy use from EIA. Personal use of energy for transportation based on worksheets provided by Bureau of Economic Analysis (BEA). GNP and personal consumption expenditures in 1972 dollars also from BEA. See appendix B for details.

Figure A.2 Energy Consumption Per Capita

Approach: Total energy use per capita was split into two components, "business" and "personal". The middle graph shows an estimate of "business" use (total energy less residential use less personal transportation use) per capita. Energy consumed directly by individuals for household and personal transportation use is shown in the bottom graph. All the graphs show the break in the trend that occurred in 1974 with the oil embargo and accompanying sharp rise in energy prices.

Key Findings:

- 1981 per capita consumption was 9 percent lower than in 1973; this trend is in sharp contrast to the 1960-73 annual growth rate of 2.8 percent.
- Energy consumption per capita for both business and personal use declined in both 1980 and 1981.
- Business use per capita is more volatile than personal use, reflecting more directly general economic conditions.

Sources: Total energy consumption from 1979 State Energy Data Report (SEDR), DOE/EIA, and Monthly Energy Review. Residential portion of personal energy use from 1979 SEDR, and updated through 1981 by PNL. Personal transportation use based on worksheets provided by Bureau of Economic Analysis, used in constructing Personal Consumption Expenditure estimates for "gasoline and oil." Population data for 1971-1981 from revised data based on 1980 census.

FIGURE A.3 Direct Energy Use per Household

Approach: Trends of energy used directly by households are shown. Residential use covers energy consumed primarily for space heating, water heating, air conditioning, cooking, and clothes drying. Residential consumption also includes those generation and transmission losses of electric utilities that are attributed to residential purchases of electricity. Transportation use includes gasoline and oil consumed in personal passenger vehicles.

Key findings:

- Since 1973, direct energy use per household has dropped by 14 percent.
- Energy consumption per household for residential use is about double that used for personal transportation.
- Since 1978, the percentage decline in transportation consumption was more than double that of residential use.

Sources: Home or "residential" energy use from the 1979 State Energy Data Report and updated to 1981 by PNL. Transportation use based on worksheets provided by Bureau of Economic Analysis, used in construction of Personal Consumption Expenditures estimate for "Gasoline and oil."

RESIDENTIAL

Preview and Rationale

The residential sector accounts for approximately 20 percent of the nation's total use of energy. Most of this energy is used in buildings for space heating and cooling, lighting, and hot water. Since space conditioning represents the dominant proportion of residential energy use in homes, a logical measure of energy productivity is Btu per square foot. In the residential sector, square footage measures of the housing stock are not available. As a proxy for square footage, the amount of housing in use is measured by the number of household units. Unfortunately, only separate metering can really yield good information as to the amount of energy devoted to individual energy services. Thus, although space conditioning may be reasonably correlated with square footage (or number of households if the average dwelling unit size remains constant), hot water and other energy consumption may be more directly related to the number of occupants. By this reasoning, energy use per household would be expected to decline as average household size declined. Another factor affecting national average household energy consumption is the movement of the households to the south and southwest. These factors should be kept in mind while looking at the residential indicators at the beginning of this section.

The first three figures in this section are related to observed energy consumption in the residential sector. Figure R.1 displays indexes of energy use per household over the past two decades. The most obvious indicator is simply an index of total Btu per household, normalized to unity in 1972. In addition to the conceptual issues discussed in the previous paragraph, a deficiency of this index is that it considers only the energy (Btu) content of various fuels. Other attributes such as transportability, cleanliness, safety, etc., are ignored. To the extent that these attributes are incorporated in the prices of fuels, an aggregate energy index using price weights was added to Figure R.1.

Gas consumption per customer is shown in Figure R.2. Since the predominant use of gas is for space heating, the annual observations have been defined to cover years beginning July 1. This indicator should be a

fairly valid measure of energy per square foot of residential space as long as the average home size heated by gas has remained approximately constant. These data cannot distinguish between reduction in energy use caused by lower thermostat settings versus those resulting from improved shell thermal efficiencies of homes. Year-to-year changes in the reported consumption figures are, of course, strongly influenced by weather variation. A simple regression analysis was used to normalize for the effect of heating-degree days. A "weather-adjusted" time series of gas consumption was then developed. The year 1979-80 was used as the reference year, since it corresponded reasonably close to the 50-year U.S. average of heating-degree days.

Energy consumption in relation to the consumption of all other goods and services, rather than on a per household or per customer basis is shown in Figure R.3. The data were taken from the personal consumption estimates available from the National Income and Product Accounts (NIPA). The ratio of residential energy consumption (covering NIPA categories, fuel oil and coal, gas, electricity) to total personal consumption expenditures is computed in both current and constant dollars. The ratio in current dollars, cannot be used to infer trends in energy conservation, but does, of course, indicate the increasing importance of residential energy expenditures relative to the total household budget.

We depart from the general topic of energy efficiency in Figure R.4 to display residential fuel prices over the past two decades. Consumer price indexes for gas, electricity, and fuel oil have all been divided by the total CPI, and then normalized to 1.0 in 1972.

Estimates of the trend in energy efficiencies of energy-using durables used by the household are shown in Figures R.5 and R.6. Since both are based on one-time surveys and computer models, the estimates must be termed as only suggestive. However, a suggestive estimate at least provides an indicator in an area where there is absence of comprehensive surveys conducted over a continuous interval.

An estimate of an efficiency index of appliance stock (including space conditioning equipment) over the period 1972 through 1980 is shown in Figure R.5. Efficiencies of various appliances for years 1972 and 1978 were

provided in a DOE survey of appliance manufacturers (CS-179) conducted in 1979. Manufacturers also provided estimates as to what efficiencies would pertain to projected sales for 1980. These data were incorporated in a special version of the ORNL Residential Energy Use Model developed by the Lawrence Berkeley Laboratory. Runs of the model were made first by holding the appliance efficiencies at 1972 levels and then allowing the efficiencies to change based on the survey data (and interpolation). The model output was converted to the aggregate efficiency index that is plotted in Figure R.5.

Figure R.6 makes use of a national residential survey (National Interim Energy Consumption Survey, NIECS) that was conducted by EIA in 1979. Information collected in the survey related to engineering characteristics of the home as well as the year in which it was built. The engineering data were then used as input to the DOE-2 energy use computer model to provide an estimate of the thermal efficiency of the dwelling unit. After conversion of these efficiencies to index form, they are plotted relative to the year in which the home was built.

The final group of figures related to the residential sector deal primarily with fuel switching trends in new residential construction. All data are from the Bureau of Census as part of their survey on the Characteristics of New Housing. However, some of the information shown here was collected in response to a DOE contract with the Census Bureau to expand the scope of questions related to energy use. Unfortunately, due to budget cutbacks, this contract has expired and the future availability of this data is in question. The data shown in this report extend through the third quarter of 1981.

Figure R.1 Btu and Value-weighted Indexes of Energy Consumption per Household

Approach: The most commonly used measure of total energy is in terms of Btu content. An alternative measure, a value-weighted index, was computed and compared with a Btu index on a per household basis. A value weighted index addresses the diversity of characteristics of energy--transportability, cleanliness, safety, and storage requirements--not simply energy content as measured in Btu. To the extent that price differentials reflect these other attributes, measurement of energy consumed in monetary terms provides a means of representing the value of the fuels bundle used by households.

The value-weighted index shown above is based on 1972 average prices for the major fuels consumed by households. It was constructed by computing the cost to consumers of each year's consumption of fuels, assuming constant 1972 prices per Btu for each fuel. This dollar cost summed across all fuels was then divided by the number of households and normalized to equal 1.0 in 1972.

Key Findings:

- Between 1972 and 1981 average energy per household, measured in either Btu or a value-weighted index of energy, fell roughly 15 percent.
- Prior to 1972, the value-weighted index was rising significantly faster than an index based on total Btu, reflecting the increasing share of household energy use from electricity (which has a higher cost per Btu than direct consumption of oil or gas).

Source: Energy consumption in Btu from EIA's 1979 State Energy Data Report, updated through 1981 by PNL. Residential prices from various sources, see Appendix B.

Figure R.2 Natural Gas Consumption per Customer

Approach: Data from the American Gas Association were used to compute average gas consumption per customer over the past decade. In order to isolate heating seasons, annual periods are defined in years starting July 1. Thus, the first year plotted is from July 1, 1970 - June 30, 1971.

A simple regression approach was used to adjust the reported consumption data for weather variation. Quarterly average consumption data were regressed against real gas prices (i.e., divided by the total CPI) and the population-weighted heating-degree days (HDD). The estimated coefficients on HDD were then used to normalize the data to the heating season 1979-80. (HDD for this period were very close to 50-year averages for the total U.S.).

Key Findings:

- Average natural gas consumption per customer has fallen approximately 17 percent compared with the years immediately preceding the 1974 oil embargo.
- Some deceleration of the decline since 1973 is suggested by the data for the most recent heating season, 1980-81. This may reflect fuel switching by consumers who previously used oil.

Source: Gas consumption and customer data from the American Gas Association. Price variables in regression adjustment from the CPI.

FIGURE R.3 Energy and Total Personal Consumption

Approach: Budget shares related to energy were computed with data from the U.S. National Income and Product Accounts. Energy expenditures cover Gasoline and oil, Fuel oil and coal, Gas, and Electricity.

The top graph shows the budget share as conventionally measured in current dollars. The sharp increases in petroleum prices experienced in 1974 and 1979 are clearly reflected in the figure.

The lower graph measures the budget share in "constant" 1972 dollars. Energy expenditures deflated to 1972 dollars were divided by total "real" (1972 dollars) personal consumption expenditures. This series thus provides a measure of how energy consumption has moved relative to total consumption of goods and services, after the effects of price changes since 1972 are removed.

Key findings:

- The share of consumer's budgets devoted to energy increased nearly 50 percent between 1972 and 1981.
- Relative to total real personal consumption expenditures, energy consumption in 1972 dollars fell by approximately 14 percent between 1978 and 1981.

Source: National Income and Product Accounts, Survey of Current Business, Tables 2.5 and 2.6 in July issues; Table 11 in March 1982 issue.

FIGURE R.4 Real Residential Fuel Price Indexes, 1960-81

Approach: "Real" price indexes were computed for the major residential fuels: fuel oil, natural gas, and electricity. All data were taken from the Consumer Price Index (CPI); each energy price was divided by the CPI for all goods and services and then normalized to a 1972 base.

Key findings:

- Prices for fuel oil have increased the most dramatically since 1972, almost tripling relative to the total CPI by 1981.
- The increase in gas prices (relative to the CPI) slowed slightly in 1981 as compared to 1980; however, this pause may be temporary as gas decontrol proceeds.
- The rise in average U.S. electricity prices since 1972 has been much smaller than gas or oil, increasing only around 13 percent relative to the CPI by 1981. However, the 4.4 percentage jump from 1980 to 1981 was the largest since 1974.

Sources: 1978 Handbook of Labor Statistics, Table 122. 1979-81 data from CPI Detailed Report, various monthly issues (Bureau of Labor Statistics, U.S. Department of Labor).

Figure R.5 Appliance Efficiency Index, 1972-1980

Approach: An estimate was developed of the contribution of improved appliance efficiencies to the reduction of household energy use. 1972 and 1980 energy efficiencies for various major energy-using appliances (weighted by sales) were provided in a survey of manufacturers (CS-179) conducted by DOE in 1979. These data were then incorporated in the Lawrence Berkeley Laboratory's version of the Oak Ridge National Laboratory (ORNL) Residential Energy Use Model. The ORNL Residential Model breaks down energy consumption by major end-uses and keeps track of appliance stocks by vintage.

The ORNL model uses 1977 as a base year. Assuming 1977 usage rates for appliances, energy consumption was computed for each appliance over the years 1972-1980 both by assuming constant 1972 efficiencies and then by allowing efficiencies to change as reflected in the CS-179 survey. Energy consumption was then summed over all appliances for the two cases and an index was computed by dividing the "constant efficiency" estimate of consumption into the survey-based estimate. This index, in turn, was divided into actual energy per household, to yield an estimate of what energy consumption would have been given constant 1972 energy efficiencies.

Key Findings:

- Based on the ORNL Residential Model and available survey data, residential energy use dropped approximately 0.3 percent between 1972 and 1978 due to improved appliance efficiencies. Total energy use per household dropped about 8.0 percent over the same period.

Source: Lawrence Berkeley Laboratory Version of the ORNL Residential Model. Efficiency index constructed by PNL.

Figure R.6 Interval Estimates of Mean Shell Efficiency

Approach : Interval estimates for the average shell efficiency of single-family detached residences in five different age groups were made by running building characteristics, as collected in the National Interim Energy Consumption Survey (NIECS), through the DOE-2 engineering-energy use model. The number of buildings in each category is shown above the 95 percent confidence interval for the mean efficiency. The statistically significant difference in the average efficiency between the 1950-1959 and pre-1949 groups could be due to differences in the geographic distribution of households in these two age groups, more extensive retrofitting in older homes, or in original construction practices.

Key findings :

- The shell efficiency of single-family detached residences built in the 1970s improved significantly over those built in the previous two decades.
- Very old homes, i.e., those constructed prior to 1949 may be slightly more efficient than those built during the 1950's.

Source : National Interim Energy Consumption Survey

Figure R.7 Distribution of Fuel Sources for Space Heating in New Single Family Homes

Approach: Trends are shown in the mix of primary fuels used for space heating in new single family homes. The percentage shares were calculated by holding the regional (major census regions: Northeast, North Central, South, and West) distribution constant at their 1978 annual values. The regional weights were held constant to eliminate the variance in the data caused by changes in the distribution of regional construction activity.

The category labeled "other" contains wood and solar prior to 1978-- unfortunately, this component cannot be disaggregated to the respective components. As the primary energy source, solar has not yet (and would not be expected to) displace other fuels to a great extent, but its share is now approaching one percent. The "other" category, which consists principally of wood, made up 6.5 percent of new units in 1981 (based on data for the first three quarters of the year).

Key Findings:

- The percentage of homes heated by fuel oil is declining rapidly due to the large increases in oil prices in 1979 and 1980.
- The share of new homes using wood as a primary heat source is continuing to rise.
- Fuel oil and electricity are being replaced by gas, wood, and solar in that order.

Source: Buildings Energy Use Data Book , Edition 2, Oak Ridge National Laboratory, and unpublished survey data from the Bureau of Census.

Figure R.8 Distribution of Fuel Sources for Space Heating
in New Multi-Family Housing Units

Approach: Recent trends are shown in the distribution of fuels used for space heating in new multi-family housing units. The percentage shares have been calculated by holding the regional (major Census regions: Northeast, North Central, South, and West) starts constant at annual 1978 values. This procedure eliminates changes in the national shares that are due solely to shifts in the distribution of regional construction.

Key Findings:

- In 1981, the percentage of new multi-family units using oil fell to roughly 1.7 percent, approximately one-third of the 1978-1979 average.
- Comparing the year 1978 and the first three quarters of 1981, the share of new multi-family units using gas rose by 37 percent.

Source: Characteristics of New Housing; 1980, U.S. Bureau of the Census, Construction Report--Series C25, 1981 data from unpublished Census data made available to Energy Information Administration by special arrangement.

Figure R.9 Central Air Conditioning, Installation in New Single Family Housing Units

Approach: Recent trends are shown in the installation of central air conditioning in new single family homes. The percentage shares have been calculated by holding the regional (major Census regions: Northeast, North Central, South and West) distribution of housing starts constant at annual 1978 values in order to control for differences in regional construction. The regional shift effect is mainly attributable to the relative increase in construction activity in the south, where approximately 85 percent of all new single family homes have central air conditioning.

The trend toward installation of central air conditioning seems to have slowed in the past three years. With record high mortgage costs the distribution of housing starts during this period may have favored lower priced units, lacking central air conditioning, not a regard for energy conservation.

Key Finding:

- Adjusted for shifts in regional construction, the percentage of new single-family houses with central air conditioning increased by 10 percentage points since 1976, but has leveled off since 1979.

Source: Characteristics of New Housing; 1980 , U.S. Bureau of the Census, Construction Report--Series C25, 1981 data from unpublished Census data made available to Energy Information Administration by special arrangement.

Figure R.10 Distribution of Fuel Sources for Water Heating

Approach: Quarterly trends are shown in water heating fuel shares in newly constructed single family residential units during the period 1978:1 through 1981:3. The regional distribution of construction has been fixed at 1978 annual values in the calculation of the national shares. As was true for space heating, the combined shares of electricity and fuel have fallen significantly over the last two years. Because the number of homes using solar or other fuels (principally wood, not shown in figure) for hot water is very small, the quarter-to-quarter movements are larger, reflecting a relatively large sampling variances. However, in a comparison of 1978 annual averages with 1981 averages, the shares of both solar and wood have both roughly doubled. Each source now accounts for approximately one percent of new single family homes built.

Key Findings:

- The replacement of electricity and fuel oil by gas continued in 1981-- nearly half of all new homes are now using gas for hot water reflecting the increased availability of natural gas as a result of partial decontrol.
- In 1981 nearly 2 percent of new homes used solar or wood as the principal energy source for hot water.

Source: Unpublished quarterly survey data from Bureau of Census, U.S. Department of Commerce, made available to Energy Information Administration by special arrangement.

COMMERCIAL

Preview and Rationale

The commercial sector accounts for approximately 15 percent of national energy consumption, primarily for use in buildings. Since the largest proportion of building energy is usually allocated to space conditioning, a logical measure of energy productivity is Btu/square foot. The principal problem is to obtain a reliable measure of the stock of (occupied) floor space in commercial buildings. We have chosen to use a set of national estimates constructed by Oak Ridge National Laboratory as part of their Commercial Energy Demand Model.* This series is probably the best that is presently available, although current opinion at ORNL is that the level of the stocks is probably underestimated. The energy per square foot calculations shown in Figure C.1 also require data on commercial sector energy consumption. These data were taken from the 1979 State Energy Data Report, DOE/EIA. Values for 1980 and 1981 of commercial sector energy use were derived by splitting the residential/commercial energy consumption as published in the Monthly Energy Review (see Methodological note to Figure A.3 in Appendix B).

Figure C.2 uses data from American Gas Association to calculate average annual gas consumption. Unfortunately, "average" commercial consumption is not easily interpreted. The problem is that the average or typical commercial account probably has not remained constant over time. Included on the commercial sector are retail businesses, office buildings, schools, churches, hospitals, etc. This indicator can only be meaningful if the mix of commercial buildings using gas does not change from year to year.

*The estimates from ORNL were from 1970-1977. On the basis of data on additions and assumed retirement rates, this series was extended by PNL to span 1960-1980.

Figure C.1 Energy Consumption Per Square Foot in Commercial Buildings

Approach: Various measures of energy consumption per square foot were constructed for commercial sector buildings. Aggregate data on commercial sector energy consumption were divided by estimates of total commercial floor space. Since no comprehensive survey of commercial floor space is available, the estimates are based on a perpetual inventory accounting procedure, and, as such, no level of confidence can be attached to the absolute levels of the floor space used.

Key findings:

- Direct fossil fuel consumption per square foot in 1981 was approximately 12 percent lower than in 1973.
- Electricity consumption per square foot rose after 1973 by approximately 5 percent, but has remained relatively constant over the past five years.

Source: Square footage data from ORNL for 1970-1977. Other years were estimated by PNL on the basis of additions to stock from F.W. Dodge and assumed retirement rates. Energy data from 1979 State Energy Data Report, DOE/EIA; updated by PNL for 1980 and 1981.

Figure C.2 Gas Consumption per Commercial Customer

Approach: American Gas Association (AGA) data were used to compute average gas consumption per commercial customer (U.S. average) over the past decade. In order to isolate heating seasons, annual periods are defined as years starting July 1. Thus, the first year plotted is from July 1, 1970 - June 30, 1971.

A clear trend does not emerge in the annual average consumption of commercial customers which is in contrast to the residential sector's use of gas. Real conservation trends may be masked by a shift of commercial gas sales toward larger customers. The use of regional data in the future may help to shed some light on this issue. The plots shown above certainly suggest caution in any interpretation of changes in consumption based on "raw" data from the AGA. First, trends based on only a few years can be misleading; reductions in average gas use since 1977 do not appear to be consistent with the longer term trend. Second, weather variation is critically important in explaining year-to-year movements in gas consumption.

Key Finding:

- No sharp reductions in national average commercial gas use per customer are evident from data covering the past decade. This result may stem largely from a shift in the national mix (of types and sizes) of commercial buildings.

Source: Data on gas consumption and customers taken from quarterly reports of the American Gas Association. Price variables used in regression adjustment for weather are from the CPI.

INDUSTRIAL

Preview and Rationale

The industrial sector of the economy accounts for approximately 35 percent of domestic energy consumption. In comparison with the other broad end-use sectors, the task of measuring energy productivity in the industrial sector is somewhat easier because of availability of data. The industrial sector is extensively monitored by the Department of Commerce (particularly the Census Bureau) and the Federal Reserve Board to determine the nation's economic performance. The Census of Manufactures has included questions regarding energy use since 1954 and each Annual Survey of Manufactures since 1974 has included a section on purchased fuels. Moreover, relatively few industries account for the bulk of energy use. Over 60 percent of total industrial energy use can be attributed to chemicals, iron and steel, paper, aluminum and cement.

The first three figures are key industrial indicators. Figure I.1 shows an aggregate industrial intensity index based on EIA energy data and Federal Reserve Board industrial production indexes. A key feature of the Figure is the presentation of an industrial production index whose components are weighted by relative energy use. This measure was developed by Robert Marlay in DOE's Office of Policy, Planning, and Analysis. The measure helps to distinguish those movements in aggregate industrial energy intensity that are due to process efficiencies versus those movements that are caused by a change in the composition of industrial outputs. Figure I.2 employs EIA published data to plot relative shares of industrial energy supplied by different fuels. The trend in total fossil fuel consumption (coal, gas, and oil) is clearly shown in contrast to the trend in electricity consumption. Figure I.3 plots 1972-1979 energy intensity changes with capital investment activity over the same period for 10 major energy-using industries. The purpose of this indicator is to show whether the data suggest that relatively high levels of investment have contributed to improvement in energy efficiency. Data on energy intensity change were taken from DOE's Industrial Energy Efficiency Improvement Program.

The remainder of the industrial section presents selected indicators based on the National Energy Accounts (NEA). The National Energy Accounts consolidates data from numerous sources into systematic set of energy

production and consumption accounts for the U.S. economy. The consumption account measures the use of various energy products for approximately 115 sectors for 1947, 1954, and 1958 through 1977. Data are presented in physical units, Btu, and purchaser's value.

NEA energy use data in manufacturing is provided primarily by the Census and Annual Survey of Manufacturers. This source provides information for energy used for heat and power; other sources are utilized to cover transportation and feedstock use of energy. Data from the 1978 Annual Survey of Manufacturers have been used to update the electricity and total fossil fuels categories for heat and power consumption.

Figures I.4 through I.13 show energy intensity trends based on the updated NEA values. Industry outputs are deflated value of production (1972 constant dollars) as developed by the Bureau of Labor Statistics' Office of Economic Growth. All intensities relate to energy used for heat and power. Three intensities are shown for each manufacturing industry: electricity, fossil, and total energy (the sum of electricity plus fossil). Electricity use incorporates an estimate of the generation and transmission losses; the loss rate was computed from aggregate data on the industrial sector provided by EIA's State Energy Data Report.

For each series of energy intensities (E/Q), the following trend regression was run: $\log (E/Q) = a_0 + a_1 \text{ TIME} + a_2 \text{ TIME}^2$. TIME is a time trend beginning in 1958 and TIME² is a trend beginning in 1973. Thus, the estimated coefficient on TIME² seeks to measure the incremental percentage growth rate in energy intensity over the period 1972 to 1978. The choice of period for the second time trend was dictated by the desire to cover, as well as possible, a full business cycle. A more complete regression model, including capacity utilization, would allow restriction of this second trend to the post-embargo period only. Nevertheless, the approach taken here does provide a rough measure of the change in energy intensity trends since 1973.

Petroleum refining, cement, iron and steel, and aluminum are four industries that have been investigated in some depth regarding recent progress in energy efficiency. These case study summaries are presented in Appendix A.

Figure I.1 Comparison of Annual Intensity Indexes for the Industrial Sector

Approach: Energy intensity for the aggregate industrial sector is influenced by both the composition of outputs and capacity utilization. The raw index shown is derived by dividing total industrial energy use by a value-added weighted measure of industrial production (similar to the Federal Reserve production index). The Marlay index replaces the value-added weights in the production index by weights based on the 1967 energy intensity of each of approximately 130 component industries, and, thus, corrects for the effect of output composition on the aggregate intensity measure. The "adjusted" Marlay index corrects for the influence of capacity utilization. This adjustment for capacity utilization reveals a much smoother pattern of changes in energy intensity.

Key Findings:

- Over the period 1972-1980 the raw index shows a decline of around 16 percent; the Marlay index suggests that roughly one-third of this change can be attributed to changes in output mix.
- Although the trend toward greater energy efficiency accelerates after 1973, the intensity index movements do not appear closely related in time to the sharp energy price rises in 1974 and 1979.

Source: The value-added ("raw") and Marlay index were provided by Robert Marlay of DOE's Office of Policy and Evaluation. Capacity utilization adjustment was carried out by Pacific Northwest Laboratory by means of a simple regression model.

Figure I.2 Fuel Mix in the Industrial Sector

Approach: Data from the Energy Information Administration were used to compute fuel shares for the industrial sector. The graphs in the figure show cumulative shares of various fuels. Thus, the middle curve shows coal plus gas and the top graph shows the share of total industrial energy accounted for by the three primary fossil fuels--coal, gas and petroleum. The area above the top graph represents the share of total energy attributable to electricity, including transmission and generation losses by the electric utilities.

Key Findings:

- A substantial degree of fuel switching has occurred in the industrial sector over the past two decades, especially among the major fossil fuels.
- 1980 and 1981 data suggest a renewed trend toward natural gas, reflecting gas price decontrol and/or sharply higher alternative fuel prices.
- The share of total industrial consumption supplied by electricity has exhibited a steady rise since 1960.

Sources: 1979 State Energy Data Report, and Monthly Energy Review, DOE/EIA.

FIGURE I.3 Relationship Between Efficiency Improvement and Post-Embargo Capital Stock

Approach: The Department of Energy's Industrial Energy Efficiency Program (IEEP) reports energy efficiency changes on an annual basis for major (2-digit SIC) manufacturing industries. Efficiency changes since 1972 (base year of the IEEP reporting system) were compared against the fraction of new capital stock installed since 1973. The fraction of new capital was computed by simply summing total gross investment from 1973 through 1979 and dividing this total into an estimate of gross capital stock in place at the end of 1979.

Key Findings:

- Although many variables are ignored, a simple cross sectional analysis supports the conjecture that new capital investment is a principal means of achieving greater energy efficiency within industry.
- Slow growth of new investment in the Primary Metals may be partially responsible for the relatively small gains in energy efficiency since 1972.

Source: The energy efficiency improvement data were taken from the 1979 Annual Report of the Industrial Energy Efficiency Improvement Program. A 1980 report prepared for the Office of Policy, Planning and Evaluation by the MTSC Corporation, "Energy Capital in the U.S. Economy" supplied information regarding the vintage of capital stocks by industry.

FIGURE I.4 Energy Intensity Trends for Textile Mill Products

Approach: Using trend regressions, annual rates of change of energy/output ratios for the Textile Mill industry were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	0.5	-1.7	2.4
1973-78	-3.0	-5.5	-1.5

Key findings:

- The changes in trends for both purchased fuels and electricity are both approximately 3.8 percent per year.
- The textile industry has been very successful in terms of housekeeping and process changes to reduce consumption for all energy inputs.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 by Annual Survey of Manufactures information. The Textile Mill sector is defined to include SIC's 221, 222, 223, 224, 225, and 228.

FIGURE I.5 Energy Intensity Trends for Paper Products

Approach: The Paper Products industry is one of the most energy intensive industries in U.S. manufacturing. Using trend regressions, annual percentage rates of change of key energy/output ratios for the Paper Products sector were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	-0.1	-1.0	3.2
1973-78	-1.8	-3.3	-1.8

Key findings:

- Fossil fuel use was declining prior to the 1973 oil embargo, but the rate of decline more than tripled in the succeeding six years.
- Electricity use has continued to grow during the post-embargo period, but only at a little more than half the growth rate up until 1972.
- Energy intensities in the paper industry are highly sensitive to the level of capacity utilization, suggesting caution in making comparisons over short time intervals.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 by Annual Survey of Manufactures information. Paper Products industry is defined to cover SIC 26 excluding SIC 265.

FIGURE I.6 Energy Intensity Trends for Industrial Chemicals

Approach: Using trend regressions, annual percentage rates of change of energy/output ratios for Industrial Chemicals were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	-3.3	-1.5	-6.0
1973-78	-0.7	-4.6	+5.0

The results of the simple trend analysis for this sector are difficult to interpret. This likely occurs for two reasons: 1) the composition of outputs may have changed significantly over the time period and 2) the energy intensities are highly sensitive to the level of capacity utilization.

Key findings:

- The use of electricity per unit of constant-dollar output has increased dramatically since 1969, although it appears to have stabilized somewhat since 1975.
- Fossil fuel use shows a decline over the six years ending in 1978 that is triple that of the prior 1958-72 trend.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. The Industrial Chemicals sector includes SIC 281, 2865, and 2869.

FIGURE I.7 Energy Intensity Trends for Petroleum Refining

Approach: In terms of energy use per 1972 dollar of production, Petroleum Refining, with the exception of the basic iron and steel, is the most energy intensive industry in manufacturing. Using trend regressions, annual percentage rates of change of energy/output ratios for Petroleum Refining were estimated as follows:

Period	Total Energy	Purchased Fuels	Electricity
1958-72	-0.9	-1.2	3.0
1973-78	-4.3	-4.7	-1.1

Key findings:

- Since 1973 the change in total energy use per dollar of output has been dramatic, declining by approximately 30 percent.
- The changes in the pre-embargo trends have been roughly equivalent for both fossil fuels and electricity.
- After growing at around 3 percent per year prior to 1973, electricity per dollar of output actually declined in the years following the embargo.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Account updated to 1978 with Annual Survey of Manufactures information. Petroleum Refining includes all of SIC 29.

FIGURE I.8 Energy Intensity Trends for Rubber and Miscellaneous Plastics

Approach: Using trend regressions, annual percentage rates of change of energy/output ratios for Rubber and Miscellaneous Plastics were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	0.0	-2.1	2.8
1973-78	0.6	-2.1	2.5

Lack of changes detected in trend in the post-embargo period may be caused by changes in composition of this industry's outputs. This sector is defined to include all of SIC 30 which includes tires as well as fabricated plastic products. Additional disaggregation and analysis will be required to determine the significance of this factor.

Key findings:

- Trends in energy intensities, as measured by Btu per 1972 dollar of gross output, have not changed significantly in the Rubber and miscellaneous Plastics industry since 1974.
- The time trend variables (starting with 1973) were not significantly different in any of the three regressions run.
- The pre-1973 trends show that the fossil fuel intensity has been declining while the use of electricity per unit of output has been growing.

Source: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. Rubber and Miscellaneous Plastics industry covers all of SIC 30.

FIGURE 1.9 Energy Intensity Trends for Glass Products

Approach: Using trend regressions, annual rates of change of energy/output ratios for Glass products were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	-0.3	-1.0	2.3
1973-78	-0.6	-2.5	3.6

The glass industry is one of the most energy intensive industries in U.S. manufacturing in terms of energy use per dollar of gross production. The reduction in total energy per 1972 dollar of production has proceeded at only a slightly faster rate since 1972. The estimated coefficient of -0.6 on the 1973-78 trend was not significant at the 10 percent level.

Key findings:

- In the glass industry the rate of increase in electricity use accelerated and the reduction in fossil fuels energy intensity has more than doubled since 1972.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. The Glass products sector includes SIC 321, and 322.

FIGURE I.10 Energy Intensity Trends for Iron and Steel

Approach: Using trend regressions, annual percentage rates of change of energy/output ratios for the Steel industry were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	0.1	-0.5	3.5
1973-78	-0.42	-1.1	2.8

Because of the influence of capacity utilization on energy intensities, one must use caution in the interpretation of trends based on short time series. Although the estimates of the change on trends between the two subperiods were negative, and were statistically significant at the 10 percent level, it is also clear that by inspection of the top two graphs that choice of starting year for the post-embargo trend is very important.

Key finding:

- Progress toward greater energy efficiency in the steel industry has been modest over the post-embargo period.

SOURCES: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. Iron and steel is defined here as SIC 331.

Figure I.11 Energy Intensity Trends for Nonferrous Metals

Analysis: Using trend regressions annual percentage rates of change of energy/output ratios for Nonferrous Metals were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	0.2	-1.3	1.3
1973-78	0.3	-5.0	3.8

Key findings:

- Electricity/output ratios are highly cyclical in the Nonferrous Metals sector; reflecting the importance of primary aluminum in this sector. (In 1977 primary aluminum accounted for some 90 percent of electricity consumption in this sector).

- For the six-year period ending in 1978, the rate of decline in use of fossil fuels was nearly triple that of the previous decade and a half.

Sources: Output data from the Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. Nonferrous Metals sector includes SIC's 333 through 338.

FIGURE I.12 Energy Intensity Trends for Metalworking Machinery

Approach: Using trend regressions, annual percentage rates of change of energy/output ratios for Metalworking Machinery were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	1.9	0.3	3.7
1973-78	-2.1	-4.7	1.2

Metalworking Machinery (SIC 354) is not a relatively energy intensive sector, but it is an important capital goods industry. Per dollar of gross output, energy requirements in metalworking are roughly a tenth of what they are in iron and steel or petroleum refining. Energy intensities in this cyclical industry are heavily influenced by the level of capacity utilization. The cyclical volatility of the intensities makes the interpretation of trends based on short time intervals precarious.

Key Findings:

- The trend in the fossil fuel intensity since 1973 has been clearly downward.
- The pre-1973 growth rate of nearly 4.0 percent per year for electricity has been reduced to around 1.0 percent in the last six years of available data.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufactures information. The Metalworking Machinery sector is defined as SIC 354.

FIGURE I.13 Energy Intensity Trends for Motor Vehicles

Approach: Although Motor Vehicles is not a relatively energy intensive industry, it is a large consumer of energy by virtue of its size. Using trend regressions, annual percentage rates of change of energy/output ratios for motor vehicles were estimated as follows:

<u>Period</u>	<u>Total Energy</u>	<u>Purchased Fuels</u>	<u>Electricity</u>
1958-72	-1.5	-2.8	0.2
1973-78	-3.1	-4.5	-2.0

Key Findings:

- Assuming that 1972 and 1978 represent roughly equivalent phases of the business cycle, (and, therefore, the trend over the 1972-1978 period is not distorted significantly by capacity utilization influences) the rate of decline in total energy per unit of output more than doubled during the 1973-78 period relative to the prior fifteen years.

- The achievements in greater efficiencies appear to have affected both fossil fuels and electricity about equally; the change in trends between the two sub-periods are both around -2.0 percent.

Sources: Output data from Bureau of Labor Statistics, Office of Economic Growth. Energy data from National Energy Accounts updated to 1978 with Annual Survey of Manufacturers information. The Motor Vehicle sector is defined as SIC 371.

TRANSPORTATION

Preview and Rationale

Transportation accounts for roughly one-quarter of all energy used in the U.S. Passenger automobiles are the dominant consumer of transportation energy; in 1979 the share of transportation energy attributable to passenger cars is estimated to have been 49 percent. Trucks are the next largest consumer of energy, responsible for some 24 percent of 1979 transportation energy. The remainder of transportation energy use was split among railroads, airplanes, and ships.

The first two figures are devoted to looking at recent trends in passenger automobile fuel efficiency. Figure T.1 plots average on-road fuel efficiency for the existing stock of cars from two sources. A time series from 1967 to 1980 on average MPG is from the Federal Highway Administration (FHWA). FHWA MPG figures are derived by dividing estimates of gasoline consumption into estimates of aggregate vehicle-miles traveled (VMT). The data on gasoline consumption is judged to be reasonably accurate, since it is based on state gasoline sales tax data collected at the wholesale level. More in question, however, are figures for vehicle-miles traveled. The basic problem is that FHWA collects the data from individual states that do not use a consistent collection method. However, since the FHWA is the only source for a comprehensive, national estimate of VMT, we display here the MPG figures derived from its use.

A second source on average MPG is from a computer model developed by Energy and Environmental Analysis, Inc. (EEA) for DOE's Office of Policy, Planning and Analysis. The average MPG figures generated by this model are based on assumptions about the use patterns of vehicles of various ages as well as characterization of the various vintages of automobiles by their fuel efficiency.

Figure T.1 also shows the average on-road fuel for new cars as estimated from the EEA model. The on-road MPG figures are developed by applying correction factors to the EPA mileage ratings according to engineering characteristics of cars of various models.

Average new car fuel efficiencies have obviously increased in recent

years. Figure T.2 sheds some light on whether this result is primarily due to sales shifts among various classes of cars or whether it is due to technological improvements on the part of manufacturers. Results of a decomposition analysis on EPA fuel efficiency data for new cars performed by Oak Ridge National Laboratory (ORNL) is shown for model years 1980 and 1981.

Figure T.3 shows recent trends (since 1970) in energy intensities for various freight transportation modes. These intensities have been developed by ORNL. A major problem is that it is difficult to maintain these indicators on an up-to-date basis. Because of the publication lag of the various regulatory agencies, most of these intensities can be calculated with no less than a two year lag.

The significance of the movements in Figure T.3 is hard to interpret since the various modes account for markedly different shares of total transportation energy use. Figure T.4 shows an aggregate freight transportation index based on the four individual components of Figure T.3. The index is based to the year 1979; the values of the index in prior years shows the relative amount of energy that would have been required to move the same amount and distribution of freight as in 1979.

Figure T.1 On-Road Fuel Efficiency of U.S. Passenger Cars

Approach: Recent trends in the on-road efficiency of new and existing passenger automobiles were developed and compared. The estimates for on-road (combined city and highway) efficiency of new cars (both imported and domestics) over calendar years 1975 through 1980 were constructed by Environmental and Economic Analysis, Inc. (EEA) for DOE's office of Policy, Planning, and Analysis. The EEA model also provides estimates of average on-road efficiency of the existing fleet of U.S., passenger cars (based on assumptions about the relative vehicle-miles driven by automobiles of various ages). Over the period 1975 to 1980, the model results correspond quite well to average MPG figures as provided by the Federal Highway Administration (FHWA).

Key Findings:

- In 1975 (the first year for which data were available from the EEA model), average new car fuel efficiency was only slightly above the fleet average of 13.8 miles per gallon.
- In 1980, the estimated on-road efficiency of new cars was over 20 MPG for the first time.
- Average gasoline consumption per vehicle could be cut by at least 25 percent in the long run, even if new car efficiencies did not improve beyond those achieved in 1980 with complete turnover of existing stock.

Sources: EEA model data taken from Fourth Quarterly Report of the Highway Fuel Consumption Model prepared by Energy and Environmental Analysis, July 2, 1981. Federal Highway Administration data on average MPG published in Highway Statistics, (Annual).

Figure T.2 Determinants of Improvements in New Auto Fuel Efficiency

Approach: An analysis was performed at Oak Ridge National Laboratory to decompose the changes in average new car fuel efficiency for model years 1980 and 1981. The "Total MPG Change" refers to the EPA mileage ratings averaged over all new domestic and imported cars sold in each model year. "Improved Efficiency" refers to the increased MPG ratings within the same model classes (EPA model classes: large, mid-size, compact, sub-compact, minor-compact, two-seater). "Add/Drop" Models" reflects the impact on the average MPG ratings due to the adding and dropping of models by manufacturers. "Shifts Among Classes" shows how much average MPG has changed as consumers have changed their buying habits among cars within the same class. "Shifts Among Classes" refers to the impact on average MPG, as consumers shifted their composition of new car purchases among classes.

Key Findings:

- Average new car fuel economy has increased in the past two model years primarily due to technological change that leads to improved MPG ratings in all categories.
- The shift to smaller cars, as represented by shifts across EPA classes, accounted for only a small fraction of the average MPG change in model years 1980 and 1981.

Source: Motor Vehicle Quarterly MPG and Market Share Newsletter , Oak Ridge National Laboratory, October, 1981.

Figure T.3 Energy Intensity Indexes for Freight Transportation

Approach: Energy intensity indexes for various transportation sectors were computed. Unfortunately, the index for trucking (1/mpg) could not be standardized by a unit of output such as a ton-mile. Furthermore, the data for this index are judgmentally separated from aggregate data by the Federal Highway Administration; therefore, the index should only be interpreted as indicative of the trend in energy use for trucking.

Key Findings:

- Energy use per ton-mile by air cargo carriers dropped by 15 percent in the period 1977-1979, accomplished primarily by substituting more fuel efficient aircraft and general route restructuring.
- Energy use per ton-mile by domestic waterborne carriers fluctuate greatly on a year-to-year basis, but the overall trend since the early 1970's is downward.
- Railroads have exhibited approximately a 7 percent decline in energy intensity from 1975 to 1979.

Source: Oak Ridge National Laboratory, Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, updated by ORNL, and the Federal Highway Administration, Table VM-1.

Figure T.4 Energy Intensity Index, Intercity Freight Transportation

Approach: Data for trucking, railroads, air cargo and waterborne commerce were used to develop an aggregate energy intensity for freight transportation. With the exception of trucking, all intensities are based in terms of Btu/ton-mile. Data for trucks was available only on a Btu/vehicle-mile travelled basis (see Figure T.3). The index was constructed by extrapolating estimates of 1979 energy use to prior years by the ratio of the given year's intensity to the 1979 intensity figure value. Summing across all modes, each year's computed energy use was that which would have occurred with 1979 levels of shipping activity, but with that year's energy efficiencies. The 1979 value was the estimated energy consumption in that year. The aggregate index was obtained by dividing each year's computed consumption figure by 1979 consumption.

Key Findings:

- Based on 1979 freight activity levels, an index of aggregate intercity freight energy intensity declined by approximately 8 percent from 1973 to 1978.
- The decline in the index from 1978 to 1979 was smallest since 1975; this deceleration may have been only temporary before the sharp rises in petroleum prices that occurred in 1979.

Source: Energy intensity for freight modes taken from Table 4.19 in Transportation Energy Conservation Data Book. Edition 5, Oak Ridge National Laboratory, 1981. Table 1.13 in same source provided information on energy use by mode.

APPENDIX A

INDUSTRY CASE STUDY SUMMARIES

Petroleum Refining: Case Study Summary

In nearly all petroleum processing, energy is required in the form of direct heat to raise the temperature of the oil being processed. Additional energy is required for mechanical drives to force the oil through the process. The basic distillation operation, which separates the crude into lighter or heavier fractions, is the least energy intensive of the refining processes. Crude distillation uses less than 15% of the total energy required by a modern refinery. As more gasoline, jet fuel, and distillate are produced in addition to or in place of heavy residual oils, more cracking, reforming, alkylation, and other processing is required.

Sixty-two refining companies, of 65 surveyed by the American Petroleum Institute, reported adoption of significant energy conservation measures during 1979, and 55 firms (of 61 surveyed) reported such adoption in 1980. The most common measures were process heater and boiler efficiency improvements, steam system improvements, heat exchange applications, insulation, and improved waste heat recovery. Other measures reported included:

- air coolers
- fractionation efficiency improvements
- pump and compressor efficiency improvements
- vacuum system improvements
- pressure energy recovery from process streams
- instrumentation and computer control
- process heat integration
- miscellaneous process developments and modified operating techniques
- refinery loss control
- housekeeping measures

ENERGY CONSUMPTION IN PETROLEUM REFINING, BY SOURCE (per barrel crude)

Notes: Based on API data for these years.
1978 data are the annualized data from the July-December 1978 report.

Purchased electricity, petcoke, and natural gas have increased as percentages of total energy consumed. Shares of refinery gas and residual oil have fallen. Some of these changes are substantial for a three-year period.

PERCENT ENERGY CONSUMPTION BY SOURCE
SELECTED YEARS AND SOURCES

Notes: Based on API data for these years.
1978 data are the annualized data from the July-December 1978 report.

Few consistent data points are available for energy consumption in petroleum refining. Below, API data for four years are presented. This figure shows that, while energy consumption per barrel of crude dropped from 1972 to 1978, the trend since 1978 has been slightly upward.

TOTAL ENERGY CONSUMPTION IN PETROLEUM REFINING, SELECTED YEARS (per barrel crude)

Notes: Based on American Petroleum Institute data, received for these years only. These data unadjusted for changes in product mix and other processing changes. 1978 data are based on reporting of 52 companies (91% of US capacity); 1979 data on reporting of 65 companies (93%); 1980 data on reporting of 61 companies (93%).

Cement: Case Study Summary

In cement manufacture, most of the energy is consumed in raw material grinding, kiln operation, and clinker grinding. Kiln operation takes about 80% of total energy, with 10% required for each of the grinding processes. Most of the fuel is used to supply heat to the kiln, while most electricity is used in grinding the incoming ore and finished clinker.

DOE's cement industry energy consumption target was a 15.7% reduction in 1980, over 1972. According to the U.S. Bureau of Mines, energy consumption per ton was reduced by 9.8% in 1978 and by 8.2% in 1979 (1972 base year). The industry consumed about 490×10^{12} Btu in 1979.

In general, energy conservation must involve modernization of plant. Much of the cement production capacity is quite old. As of 1974, 48% of operating kilns were 20 years old or older, although much expansion and modernization has occurred since then. Greatest energy reduction potential is offered by the substitution of dry for wet process kilns and the use of preheaters. In 1979, average fuel consumption per ton of clinker produced was 4.76 million Btu for the dry process, and 6.27 million Btu for the wet process. Dry plants are more commonly built now, but as of 1980 there were still more wet plants operating than dry: 88 wet and 64 dry. Six plants produced cement by both wet and dry processes.

Preheating involves reusing exit gases from kilns to preheat the ground ores and evaporate moisture from them. The U.S. Bureau of Mines in 1977 estimated that kilns using suspension preheaters burned an average of 4.77 million Btu/ton of clinker production, those with traveling grate preheaters burned 5.86 million Btu/ton, and those kilns without preheaters used 6.95 million Btu/ton.

Other energy conservation measures in the cement industry include improvements to kilns (chain section design inside the kiln, improved sealing and insulation), use of additives in the cement, and improving the efficiency of the grinding processes.

Energy conservation is reflected in the trends in per ton fuel consumption during the 1970s. Both the wet and dry process have become less energy intensive. Because of the energy intensity of cement manufacture, energy prices were of concern in the industry well before 1973.

APPROXIMATE TOTAL FUEL CONSUMPTION PER
TON OF CLINKER PRODUCTION, BY
TYPE PROCESS

In contrast to fuel consumption, per unit electric consumption has been increasing. However, increased electrical use is very small relative to the

ELECTRIC ENERGY CONSUMED PER TON OF FINISHED CEMENT,
BY PROCESS

Slowly but steadily the cement industry is investing in major capital improvements: additional dry process plants, and use of suspension preheaters.

NUMBER OF CEMENT PLANTS. BY TYPE PROCESS

NUMBER OF KILNS INSTALLED AND NUMBER OF KILNS INSTALLED INCLUDING SUSPENSION PREHEATERS

Note: Data for preheaters unavailable before 1972; no data on number of kilns installed for 1970, 1971.

Iron and Steel: Case Study Summary

The iron and steel industry consumes more fuel and electric energy in its production processes than any other U.S. industry. In 1980, it consumed approximately 2.67 quads, equal to 8.8% of all industrial energy consumption and 70% of the energy consumed by the primary metals industry (SIC 33).

Many of the fuels used for heat and power are produced as byproducts. These fuels include (in the order of predominance) coke and coke screenings, coke oven gas, blast furnace gas, and other byproduct fuels. "Other" includes tar and pitch obtained in the coking process. Purchased fuels include bituminous, anthracite, and lignite coal; coke and breeze; fuel oil (both distillate and residual); natural gas; and LPG. About one-third of all fuels are consumed in blast furnaces, and a little over one-third in heating and annealing furnaces. Under 5% of industry fuel consumption is in the steel melting furnaces, and the remainder is used in other processes. Electricity consumption depends largely on the type of steel furnace (electric versus basic oxygen or open hearth) being used.

Most large energy conservation opportunities in the iron and steel industry involve capital-intensive modernization of facilities. In 1979, nearly 46% of all coke ovens and 100% of the open hearth furnaces were over 20 years old. The two major areas in which energy conservation opportunities exist are increased use of (1) more energy efficient furnaces (both oxygen and electric), and (2) continuous casting. The basic oxygen process is about 55% more efficient than the open hearth, and produces higher quality steel with less pollution. The electric furnace is the most energy efficient furnace of the three types. It operates on scrap steel. The proportion of steel produced by the old open hearth furnaces has steadily declined from the 1960s; since 1957, all new furnaces have been oxygen or electric.

RAW STEEL PRODUCTION BY TYPE OF FURNACE
Note: Bessemer included with open hearth

Scrap consumption relative to that of pig iron has slowly been increasing, due to increased use of electric furnaces. Use of scrap improves energy efficiency since it eliminates the energy-intensive production of the pig in blast furnaces. In 1965 consumption of scrap was 83% that of pig; in 1980 the two were equal.

Continuous casting conserves energy through both elimination of energy intensive processes, and increased yield. Yield loss is 11-21% for the ingot method, and only 5% or less in continuous casting. One estimate is that 60-80%

less energy than with the ingot method is required, and that for each percentage increase in the rate of continuous casting to total steel produced, there is an absolute saving of 9020 Btu/ton of steel. The amount of steel continuous cast has slowly increased but still remains at around 18% of the total. Nonintegrated facilities, built relatively recently, are ahead in terms of continuous cast production (over 50% of nonintegrated production).

RAW STEEL PRODUCTION BY TYPE CAST

Total per unit energy consumption in the steel industry fluctuates substantially with percent of capacity utilized. After the 1975 peak, energy consumption per unit of production dropped rapidly, but troughed in 1978 and rose again in 1979 and 1980. Total energy use is dominated by the consumption of coal for coke. Fuel oil use per ton of production peaked in 1978, but is low compared to coal, natural gas, and other (generated) fuels used.

ENERGY CONSUMPTION PER TON OF RAW STEEL PRODUCTION

Aluminum: Case Study Summary

In 1979, the U.S. aluminum industry consumed just over one quad of energy (1.041×10^{15} Btu) to produce 54 million tons of aluminum metal (192.4 million Btu/ton). Sixty-eight percent of this energy was in the form of electricity, used almost entirely in smelting. The electrical energy for smelting was derived 41% from coal, 38% from hydropower, 14% from natural gas and oil, and 7% nuclear. By process, smelting accounted for 70%, fabricating for 19%, and bauxite and alumina production for 11% of total energy consumed.

Aluminum manufacture from scrap is much less energy intensive than processing from ore. About 6-25 million Btu are required to recover one ton of aluminum-base scrap, on the average only 5% of that needed to produce the molten metal from bauxite. The high of the range in scrap processing reflects the energy required to melt contaminated scrap, where recoveries may be only 60-70%.

Because the reduction process (smelting) accounts for more than two-thirds of the industry's energy requirements, it has been a primary focus for improvement. Since World War II energy usage in this process has been reduced nearly 33%. Recent or current conservation projects focused on the standard Hall-Heroult electrolytic reduction process include improvement of reduction lines, lowering of operating temperatures, new furnace designs, and improved insulation. Examples of alternative reduction processes being developed are the ALCOA $AlCl_3$ Electrolysis Process, the Toth Chemical Process, and the Plasma Reduction Process.

Examples of conservation projects in other areas of aluminum processes include the following:

o Bauxite Mining and Aluminum Production:

- optimization of ore combinations through computerization
- cogeneration
- improvement of digester heat exchange
- heat recuperation
- improved combustion control

o Holding, Casting, and Melting:

- heat recuperation
- improvements in combustion and flame management
- new furnace designs
- preheating

- increased adoption of continuous casting
- Fabrication:
 - housekeeping measures
 - new furnace designs
 - preheating
 - heat recuperation
 - improved combustion and flame management
 - computerized controls

Due to conservation measures implemented in the 1970s, per unit energy consumption in aluminum processing has been decreasing since 1975. The peak in per unit energy consumption in 1975 reflects the operation of machinery at low levels of capacity, as production plunged 21% during that year.

ENERGY CONSUMPTION PER TON OF PRIMARY ALUMINUM* PRODUCED

*includes energy consumed in bauxite and alumina production, smelting, holding, and casting.

According to the Aluminum Association, the aluminum industry exceeded its DOE goal of 10% energy efficiency improvement by 1980 (over 1972). A 20% efficiency improvement through 1985 is projected. If new facilities are built by the year 2000, using best available technology, the AA estimates potential savings at 36% (relative to 1972). However, tremendous amounts of capital investment will be needed.

ALUMINUM INDUSTRY PROGRESS UNDER THE VOLUNTARY INDUSTRIAL ENERGY CONSERVATION PROGRAM

Source: The Aluminum Association, Energy Conservation in the Aluminum Industry, September 1980

Smelting energy efficiency has been steadily improving, and consumption currently is an average of 8 kW/lb of metal produced. This average is an improvement of 8.2% over 1975. The newest plants use about 6 kW/lb; the new ALCOA process uses under 5 kW/lb.

Fig. 2.5-9 ALUMINUM INDUSTRY CONSERVATION PROGRESS IN SMELTING, 1920-1979

Source: The Aluminum Association, Energy and the Aluminum Industry, April 1980.

APPENDIX B

DATA AND NOTES FOR FIGURES

DATA USED FOR FIGURE A.1

YEAR	TOTEN	GNP	ENGNP	BUSENG	GNPBUS	ENGNPADJ	YEAR
1960	44080	737.2	59.793	31285	707.38	60.276	1960
1961	44723	756.6	59.11	31370	726.96	59.24	1961
1962	46798	800.3	58.475	32763	769.31	59.376	1962
1963	48605	832.5	58.385	34341	800.36	59.743	1963
1964	50776	876.4	57.937	35959	842.58	58.868	1964
1965	51939	929.3	57.02	37486	873.87	58.157	1965
1966	53922	964.6	56.785	39342	947.46	58.007	1966
1967	57392	1011.4	57.239	40628	972.7	58.331	1967
1968	61323	1058.1	57.956	43083	1017.3	58.964	1968
1969	64529	1087.3	59.348	44950	1044.3	59.959	1969
1970	68628	1085.6	61.559	46162	1040.7	61.319	1970
1971	68300	1122.4	60.851	46637	1075.8	60.626	1971
1972	71628	1185.9	60.4	48931	1126.7	60.138	1972
1973	74609	1255	59.449	51474	1204	59.593	1973
1974	72759	1248	58.3	50100	1139.4	59.173	1974
1975	70707	1253.9	57.304	47654	1186.3	57.364	1975
1976	74510	1300.4	57.298	50466	1247.8	57.519	1976
1977	76332	1371.7	55.646	51654	1317.4	56.231	1977
1978	78175	1436.9	54.405	52801	1380.4	55.196	1978
1979	78910	1463.3	53.199	53902	1427.4	54.571	1979
1980	75913	1480.7	51.268	51597	1427	53.241	1980
1981	73915	1510.1	48.947	50104	1458.2	51.762	1981

KEY:

- (1) TOTEN: Total energy consumption, trillion Btu.
- (2) GNP: Gross National Product, billions of 1972 dollars.
- (3) ENGNP: Energy/GNP ratio, for the whole economy, (1)/(2).
- (4) BUSENG: Consumption of Energy by the Business Sector, trillion Btu.
- (5) GNPBUS: GNP less personal consumption expenditures (PCE) for energy (1972 dollars).
- (6) ENGNPADJ: Adjusted Energy/GNP Ratio.

SOURCES:

- TOTEN: Annual Report to Congress, 1981, and Monthly Energy Review, DOE/EIA.
- GNP: National Income and Product Accounts, Department of Commerce.
- BUSENG: Derived as the difference between total national energy consumption (TOTEN) and household energy use (TOTHOU). See notes for Figure A.3 for derivation of TOTHOU.
- GNPBUS: Personal consumption expenditures for energy through 1979 taken from Table 2.5, July issues of the Survey of Current Business. Data for 1980 and 1981 from Table 1.2, Survey of Current Business, March 1982.
- ENGNPADJ: Composition-adjusted Energy/GNP ratio, base year is 1973. Computed as $0.959 * (BUSENG / GNPBUS) + 0.041 * (TOTEN - BUSENG) / (GNP - GNPBUS)$; where 0.959 and 0.041 are the 1973 relative shares of GNP less PCE for energy, and PCE for energy respectively (expressed in 1972 dollars).

DATA USED FOR FIGURE A.2

YEAR	TOTEN	POP	TEPC	TOTHOUS	REPC	BUSENG	BEPC	YEAR
1960	44000	177.93	247.12	11711	71.070	31205	175.13	1960
1961	44111	182.09	247.14	13153	72.133	31312	175.13	1961
1962	46798	185.77	251.81	14611	74.711	32763	177.14	1962
1963	46695	186.48	250.68	14122	73.681	34311	181.12	1963
1964	50776	191.14	265.14	14617	77.017	35955	188.13	1964
1965	52937	193.33	273.61	15714	80.711	37898	190.7	1965
1966	55922	195.33	285.44	16369	83.703	39542	192.18	1966
1967	57892	197.46	293.19	17064	85.419	40526	195.77	1967
1968	61323	199.4	307.34	18210	91.473	43083	216.07	1968
1969	64529	201.38	320.43	19577	97.205	44950	223.2	1969
1970	66526	203.98	327.31	20666	101.31	46162	226.3	1970
1971	68300	206.63	330.23	21661	104.73	46639	225.5	1971
1972	71628	209.28	341.25	22317	108.45	46931	233.8	1972
1973	74609	211.36	353	23135	109.461	51474	243.54	1973
1974	72759	213.34	341.04	22659	103.21	50100	234.35	1974
1975	70707	215.46	328.16	23053	106.97	47654	221.17	1975
1976	74510	217.56	342.48	24044	110.32	50466	231.96	1976
1977	76332	219.76	347.34	24416	112.27	51654	235.05	1977
1978	78175	222.09	351.99	25524	114.25	52901	237.74	1978
1979	78710	224.57	351.39	25966	111.36	53902	240.03	1979
1980	75913	227.16	334.19	24316	107.03	51597	227.14	1980
1981	73715	229.3	322.35	23811	103.64	50104	218.5	1981

KEY:

- (1) TOTEN: Total energy consumption, trillion Btu.
- (2) POP: Population in millions
- (3) TEPC: Total energy per capita, million Btu.
- (4) TOTHOUS: Total household energy consumption including transportation use, trillion Btu.
- (5) REPC: Household energy consumption per capita, (4)/(2)
- (6) BUSENG: Business portion of the energy consumption, trillion Btu, (1)-(4).
- (7) BEPC: Business energy consumption per capita, million Btu, (6)/(2).

SOURCES:

TOTEN: See source for Figure A.1

TOTHOUS: Residential energy use (TOTRES in Figure A.3) from State Energy Data Report, September 1981, and Monthly Energy Review, DOE/EIA, See Note.
Transportation use (TRANS in Figure A.3) based on worksheets provided by Bureau of Economic Analysis, used in constructing PCE estimates for "Gasoline and Oil."

POP: Figures for 1960-1969 from 1980 Statistical Abstract of the U.S., updated figures for 1970-1981, based on 1980 Census, Current Population Reports, Census Bulletin Series, P-25, No. 906, December 1981.

Note

To obtain residential energy use for 1980 and 1981, the residential/commercial figures as shown in the Monthly Energy Review (MER) had to be split. The major fuels were split according to the following procedures:

Electricity - Separate data for residential and commercial sales in Kwh as shown in the Monthly Energy Review's section on Electricity were used to split the residential/commercial consumption figures for electricity purchases (in Btu) and electricity losses (in Btu).

Gas - Separate figures for residential and commercial gas sales as shown in Table 46 of the EIA's 1981 Annual Report to Congress were used to allocate the MER total. The values for 1981 were scaled proportionately so that the sum would agree with the 1981 control total from the MER for residential/commercial.

Coal, Petroleum Products - The relative proportions between the residential and commercial sector were maintained at the latest values as implied in the State Energy Data Report.

DATA USED FOR FIGURE A.3

YEAR	TOTHOUS	HH	GEHH	TOTRES	TOTRESHH	TRANS	TRANSHH	TRANS
1960	12774	50.3	240.30	8302.1	167.27	4175.2	84.397	1960
1961	13153	53.46	216.04	8618.5	161.51	4534.8	84.806	1961
1962	13534	54.65	193.13	9138.4	167.13	4676.1	85.59	1962
1963	14263	55.79	208.46	1402.7	170.27	4861.7	87.17	1963
1964	14617	56	264.59	8712.2	173.43	5104.9	91.194	1964
1965	15304	57.25	270.21	10161	177.49	5342.3	93.316	1965
1966	16330	58.09	261.98	10793	184.25	5571	97.787	1966
1967	17064	58.65	289.96	11168	190.11	5676.1	99.847	1967
1968	18240	60.44	301.79	11903	196.95	6336.7	104.64	1968
1969	19579	61.81	316.77	12768	206.57	6811.1	110.19	1969
1970	20666	62.96	328.24	13363	212.32	7098.3	115.93	1970
1971	21661	64.3	335.31	13718	215.45	7741.7	119.86	1971
1972	22677	67.05	338.51	14530	216.7	8167.1	121.81	1972
1973	23135	68.77	336.41	14633	212.78	8502.3	125.63	1973
1974	22659	70.54	321.23	14370	203.71	8267.7	117.52	1974
1975	23053	71.69	320.68	14444	200.92	8609.5	119.76	1975
1976	24044	73.87	325.49	14972	202.68	9072.1	122.81	1976
1977	24678	75.29	327.77	15213	202.65	9466.2	125.72	1977
1978	25374	77.42	327.75	15524	200.81	9850.6	127.24	1978
1979	25008	78.9	316.96	15413	195.35	9595	121.81	1979
1980	24316	80.78	301.02	15272	189.06	9044	111.96	1980
1981	23811	82.34	289.18	15169	184.22	8642.2	104.96	1981

KEY:

- (1) TOTHOUS: Total residential energy consumption including transportation use, trillion Btu.
- (2) HH: Number of households, in millions.
- (3) GEHH: Total residential energy consumption per household, million Btu
- (4) TOTRES: Residential energy consumption excluding transportation use.
- (5) TOTRESHH: TOTRES per household, million Btu. (4)/(2)
- (6) TRANS: Energy used by household for transportation, trillion Btu.
- (7) TRANSHH: Transportation use per household, million Btu. (6)/(2)

SOURCES:

- TOTHOUS: See notes for Figure A.2
- HH: Data for 1960-1969 taken from Statistical Abstract of the U.S. Number of Households for 1971-1979 were estimated using the household size estimate found in Table 62, 1980 Statistical Abstract of the U.S., and 1980 Census based population figures (see source for POP for Figure A.2).
- TOTRES: See notes for Figure A.2.
- TRANS: See notes for Figure A.2.

DATA USED FOR FIGURE R.1

YEAR	BTUINDEX	VALINDEX	YEAR	BTUINDEX	VALINDEX
1960	.7262	.68235	1971	.99422	.98935
1961	.74393	.70095	1972	1	1
1962	.77146	.73028	1973	.98189	.97482
1963	.7862	.74631	1974	.94003	.93343
1964	.80031	.76612	1975	.92715	.94169
1965	.81904	.7875	1976	.90528	.94968
1966	.85024	.82609	1977	.93239	.95574
1967	.87728	.8499	1978	.92527	.95037
1968	.90882	.8878	1979	.90144	.90622
1969	.93324	.93785	1980	.87243	.85318
1970	.97976	.97241	1981	.85012	.857

KEY:

- (1) BTUINDEX: Index based on actual consumption in Btu per household.
- (2) VALINDEX: Laspeyres or value-weighted index of aggregate energy consumption per household.

SOURCES:

For sources of residential consumption and households, see notes for Figure A.3.

DATA USED FOR FIGURE R.2

YEAR	GASPC	GASPCWHR
1970	130.72	132.31
1971	124.82	131
1972	130.36	133.19
1973	119.09	125.56
1974	122.67	123.99
1975	115.49	122.38
1976	122.12	118.86
1977	120.74	115.58
1978	119.22	115.49
1979	109.21	110.65
1980	105.96	111.09

KEY:

- (1) GASPC: Gas consumption per consumer as reported by American Gas Association.
- (2) GASPCWHR: Gas consumption adjusted for weather variation measured by population-weighted heating degree days.

SOURCES:

Total residential gas consumption and number of customers taken from various issues of Quarterly Report on Gas Utility Industry, American Gas Association, Arlington, Va.

Heating degree days in constructing GASPCWHR from State Regional and National Monthly and Seasonal Heating Degree Days Weighted by Population, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, September 1981.

DATA USED FOR FIGURE R.3

YEAR	ENERGY	PCECURR	SHARE	ENERGY72	PCE72	SHARE72	YEAR
*****	*****	*****	*****	*****	*****	*****	*****
1960	24.129	324.9	7.4066	29.319	462	6.4063	1960
1961	24.542	335	7.326	29.642	461.4	6.4244	1961
1962	25.746	335.21	7.1479	30.987	451	6.4038	1962
1963	26.787	374.56	7.1512	32.143	500.3	6.1202	1963
1964	28.051	400.6	7.004	33.823	528	6.4089	1964
1965	29.784	430.38	6.7669	35.432	557.5	6.3555	1965
1966	32.118	465.12	6.9053	37.341	585.7	6.3754	1966
1967	34.021	490.26	6.7394	38.699	602.7	6.4297	1967
1968	36.394	536.88	6.7788	40.751	634.4	6.4205	1968
1969	39.448	581.78	6.7806	42.972	657.1	6.5356	1969
1970	42.258	621.72	6.7969	44.727	672.1	6.6646	1970
1971	45.424	672.24	6.7571	46.62	696.8	6.6916	1971
1972	49.23	737.05	6.6793	49.23	737.1	6.6797	1972
1973	53.333	811.96	6.8147	51.016	763.5	6.6384	1973
1974	68.356	888.11	7.6763	46.803	763.6	6.065	1974
1975	77.788	976.45	7.9664	50.411	789.2	6.4613	1975
1976	86.71	1084.3	7.9971	52.625	803.7	6.5389	1976
1977	96.998	1205.5	8.0464	54.314	863.9	6.2871	1977
1978	106.87	1348.7	7.9235	56.464	904.6	6.2405	1978
1979	131.68	1510.9	8.7154	55.9	730.1	6.0101	1979
1980	164.5	1672.8	9.8338	53.7	935.1	5.7427	1980
1981	178.6	1857.8	9.6135	52	958.8	5.4234	1981

KEY:

- (1) ENERGY: Personal consumption expenditures on energy, billions of current dollars.
- (2) PCECURR: Total personal consumption expenditures in billions of current dollars.
- (3) SHARE: Percentage share of consumption on energy, (1)/(2).
- (4) ENERGY72: Personal consumption expenditure on energy, billions of constant 1972 dollars.
- (5) PCE72: Total personal consumption expenditures billions of constant 1972 dollars.
- (6) SHARE72: Percentage share of consumption on energy, constant 1972 dollars, (4)/(5).

SOURCES:

All expenditure data obtained from National Income and Product Accounts, published by the Department of Commerce in various issues of the Survey of Current Business.

DATA USED IN FIGURE R.4

YEAR	FOIL	NGAS	ELEC	YEAR	FOIL	NGAS	ELEC
1960	1.0782	1.1285	1.1857	1971	1.0005	1.42145	1.98346
1961	1.1106	1.152	1.1775	1972	1	1	1
1962	1.0495	1.1134	1.1645	1973	1.14258	1.3845	1.9589
1963	1.1066	1.1061	1.1574	1974	1.0417	1.2817	1.0824
1964	1.07	1.0951	1.1078	1975	1.5373	1.0665	1.0917
1965	1.0735	1.0783	1.1051	1976	1.558	1.049	1.0977
1966	1.0713	1.0562	1.0744	1977	1.557	1.0006	1.0791
1967	1.0746	1.0045	1.0553	1978	1.5813	1.3725	1.097
1968	1.0643	.97307	1.0005	1979	2.0603	1.4388	1.0821
1969	1.0316	.95921	.98664	1980	2.5241	1.5106	1.082
1970	1.0099	.95532	.96231	1981	2.7778	1.5605	1.1277

KEY:

- (1) FOIL: Index of price of fuel oil relative to the Consumer Price Index.
- (2) NGAS: Index of price of natural gas relative to the Consumer Price Index.
- (3) ELEC: Index of price of electricity relative to the Consumer Price Index.

SOURCES:

All the relative prices are constructed as ratios of the corresponding Consumer Price Indexes regularly published by the U.S. Department of Labor, Bureau of Labor Statistics. Prices through 1978 obtained in Handbook of Labor Statistics, Table 122. More recent data based on the CPI Detailed Report, issued monthly by the Bureau of Labor Statistics.

DATA USED FOR FIGURE R.5

YEAR	TOTBTU	HH	BTUPHH	EFFINDEX	BTUPHHC	YEAR
*****	*****	*****	*****	*****	*****	*****
1973	15124	88.77	219.92	1	219.92	1973
1974	14806	79.54	209.9	1	209.9	1974
1975	14392	71.89	207.15	1	207.15	1975
1976	15445	73.87	209.08	.99908	209.28	1976
1977	15649	75.29	207.85	.99816	208.23	1977
1978	15946	77.42	205.97	.99724	208.54	1978
1979	15407	78.9	195.27	.99373	196.5	1979
1980	15433	80.776	191.06	.98971	193.05	1980

KEY:

- (1) TOTBTU: Total residential energy consumption, trillion Btu.
- (2) HH: Number of households, in millions.
- (3) BTUPHH: TOTBTU per household, million Btu, (1)/(2).
- (4) EFFINDEX: Index of appliance efficiency.
- (5) BTUPHHC: Energy use per household assuming constant 1972 appliance efficiencies, (3)/(4).

SOURCES:

For sources of TOTBTU and HH, see notes in Figure A.3. See text accompanying Figure R.4 for derivation of EFFINDEX.

DATA USED FOR FIGURE R.7

TIME	YEAR	ELEC	GAS	OIL	SOLAR	OTHER
1968	1968	.22568	.55377	.097121	0	.121278
1969	1969	.25246	.55171	.080011	0	.115817
1970	1970	.27121	.53307	.069924	0	.124756
1971	1971	.29544	.51994	.072102	0	.117521
1972	1972	.36053	.56045	.071661	0	.0063581
1973	1973	.40915	.4889	.072102	0	.0066437
1974	1974	.48573	.4502	.075327	0	.0077352
1975	1975	.49392	.4077	.078287	0	.019091
1976	1976	.48822	.39946	.074375	0	.016912
1977	1977	.50739	.37879	.091399	0	.021418
1978	1978	.51311	.37509	.07716	.0037277	.024913
1979	1979	.51243	.37154	.064805	.0026631	.027535
1980	1980	.48376	.42653	.03115	.0066419	.050314
1981	1981	.46796	.43923	.018311	.0076314	.065876

KEY:

- (1) ELEC: Share of single family houses using electricity for space heating.
- (2) GAS: Share of single family houses using gas for space heating.
- (3) OIL: Share of single family houses using oil for space heating.
- (4) SOLAR: Share of single family houses using solar energy for space heating.
- (5) OTHER: Share of single family houses using other forms of energy for space heating.

SOURCE

Figures for the years 1968-1977 from Building Energy Use Data Book, Edition 2, ORNL-5552, December 1979, Table 2.66. For years 1978-1981 figures were updated from unpublished quarterly survey data from Bureau of Census; made available to Energy Information Administration by special arrangement.

DATA USED FOR FIGURE R.8

YEAR	ELEC	GAS	OIL	OTHSOLAR
1976	.6215	.3081	.0682	.0022
1977	.6832	.2615	.0463	.0089
1978	.6936	.2408	.0396	.0089
1979	.6834	.2593	.0470	.0082
1980	.6485	.3105	.0259	.0103
1981	.6438	.3271	.0170	.0110

KEY:

- (1) ELEC: Share of multiple family units using electricity for space heating.
- (2) GAS: Share of multiple family units using gas for space heating.
- (3) OIL: Share of multiple family units using oil for space heating.
- (4) OTHSOLAR: Share of multiple family units using solar and other energy sources for space heating.

SOURCE

Data for 1976-1980 based on Characteristics of New Housing, 1980, U.S. Bureau of the Census, Census Report Series C25. Data for 1981 based on unpublished quarterly survey information (averaged over first three quarters) from Bureau of Census U.S. Department of Commerce; made available to Energy Information Administration by special arrangement.

DATA USED FOR FIGURE R.9

YEAR	INSTALD	NONE
****	*****	*****
1976	.59118	.49882
1977	.54072	.45928
1978	.5806	.4194
1979	.60582	.39418
1980	.60234	.39766
1981	.61639	.38361

KEY:

- (1) INSTALD: Share of new single family housing units with central air conditioning.
- (2) NONE: Share of new single family housing units without central air conditioning.

SOURCES:

See notes for Figure R.8

DATA USED FOR FIGURE R.10

YEAR	ELEC	GAS	OIL	SOLAR	OTHER
78.1	.588	.36188	.037817	.0106471	.005251
78.2	.5834	.37181	.037237	.0044009	.003343
78.3	.58218	.36634	.041125	.0037384	.0056076
78.4	.58952	.37588	.039773	.0035375	.0074878
79.1	.58218	.36717	.040694	.0043468	.0048313
79.2	.58151	.38952	.040887	.0036222	.0036376
79.3	.58168	.39939	.036612	.0054423	.0039745
79.4	.58331	.38709	.033464	.0042446	.0058901
80.1	.52262	.44153	.022029	.0063639	.0044679
80.2	.53779	.41806	.020806	.013425	.0089172
80.3	.5237	.43046	.014402	.0053188	.024927
80.4	.53449	.43585	.0124	.0089279	.0073258
81.1	.51657	.45127	.013219	.012172	.0057315
81.2	.53153	.43707	.019147	.011585	.0086716
81.3	.51373	.45216	.0064932	.0050786	.020675

- (1) ELEC: Share of new single family units with water heaters using electricity.
- (2) GAS: Share of new single family housing units with water heaters using gas
- (3) OIL: Share of new single family housing units with water heaters using oil.
- (4) SOLAR: Share of new single family housing units with water heaters using solar energy.
- (5) OTHER: Share of new single family housing units with water heaters using other energy sources.

SOURCE:

Unpublished quarterly survey data from Bureau of Census; made available to Energy Information Administration by special arrangement.

DATA USED FOR FIGURE C.1

YEAR	SQFTOT	TOTPSF	ELCPSF	FOSPSF
1960	17191	235.43	110.57	174.87
1961	17358	233.33	113.3	174.83
1962	17746	229.7	117.83	173.05
1963	18531	223.73	125.63	163.08
1964	19210	213.31	129.91	163.6
1965	19936	202	134.46	167.54
1966	20721	190.42	141.23	169.19
1967	21443	185.66	146.57	179.09
1968	22250	180.5	154.39	177.61
1969	23138	171.35	163.17	178.18
1970	23696	159.43	172.75	176.66
1971	24732	153.84	179.24	174.59
1972	25315	150.18	187.94	171.23
1973	26603	150.72	195.33	164.36
1974	27502	142.06	189.16	152.93
1975	28139	136.9	194.39	142.31
1976	28746	149.11	193.6	150.31
1977	29474	146.08	204.16	141.72
1978	30347	145.3	204.32	140.97
1979	31268	141.1	202.44	138.66
1980	32186	129.68	202.54	127.15
1981	33000	117.36	203.09	114.27

KEY:

- (1) SQFTOT: Total floor space in the commercial sector, billions of square feet.
- (2) TOTPSF: Total energy per square foot, including electricity losses, thousand Btu/sq. ft.
- (3) ELCPSF: Electricity Use (including losses) per square foot, thousand Btu/sq. ft.
- (4) FOSPSF: Total fossil fuel energy per square foot, thousand Btu/sq. ft.

SOURCES:

Square footage data from ORNL Commercial Energy Use Model data base for 1970-1977. Retirement rates were computed for 1970 and 1977 on the basis of ORNL data on gross and net additions to stock. These retirement rates for each of seven major building categories together with additions data from F.W Dodge, were used by PNL to extend the series back to 1960 and forward to 1980. Gross additions for 1960-1969 (from F.W. Dodge survey) were provided by ORNL. Additions for 1978 and 1979 taken from table 1388 in 1980 Statistical Abstract of the U.S. 1980 data based on extrapolation of 1979 data with construction information from the National Income and Product Accounts. Energy data for commercial sector for 1960-1979 from 1979 State Energy Data Report, DOE/EIA. 1980 and 1981 data estimated by PNL; see notes for Figure A.2.

DATA USED FOR FIGURE C.2

YEAR	GASPC	GASPCWHR
1970	680.14	681.06
1971	685.12	685.74
1972	707.68	707.06
1973	671.26	690.55
1974	696.16	685.59
1975	676.80	690.23
1976	717.51	691.58
1977	731.75	700.35
1978	715.84	696.69
1979	671.16	671.16
1980	673.88	689.83

KEY:

- (1) GASPC: Gas consumption per consumer as reported by American Gas Association.
- (2) GASPCWHR: Gas consumption adjusted for weather variation measured by population-weighted heating degree days.

SOURCES:

Total residential gas consumption and number of customers taken from various issues of Quarterly Report on Gas Utility Industry, American Gas Association, Arlington, Va.

Heating degree days in constructing GASPCWHR from State Regional and National Monthly and Seasonal Heating Degree Days Weighted by Population, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, September 1981.

DATA USED FOR FIGURE I.1

YEAR	EOVMM	EOEMM	EOEADJ
1960	1.1364	1.1182	1.0864
1961	1.1326	1.1118	1.0797
1962	1.1335	1.0909	1.0663
1963	1.1272	1.074	1.0579
1964	1.1362	1.0694	1.0521
1965	1.0706	1.0392	1.0472
1966	1.0434	1.0443	1.0368
1967	1.0396	1.0311	1.0467
1968	1.0289	1.0422	1.0402
1969	1.0341	1.0333	1.028
1970	1.0939	1.0714	1.066
1971	1.0788	1.0495	1.0113
1972	1.0311	1.0181	1.0004
1973	1	1	1
1974	.97959	.98415	.97086
1975	1.0033	1.0135	.95739
1976	.96235	.97327	.94565
1977	.92639	.95350	.93305
1978	.87947	.91471	.90142
1979	.86317	.90654	.89889
1980	.84301	.90355	.87255

KEY:

- (1) EOVM: Value-added weighted energy intensity index.
- (2) EOEM: Energy-weighted (Marlay) energy intensity index
- (3) EOEAJ: Marlay Index adjusted for changes in capacity utilization, reference year, 1972.

SOURCES:

The value-added and Marlay indexes were provided by Robert Marlay of DOE's Office of Policy and Evaluation. Capacity utilization adjustment was carried out by Pacific National Laboratory.

DATA USED FOR FIGURE I.2

YEAR	COAL	GAS	PETROL	FOSSIL	ELEC	1982
1960	.25368	.2941	.28218	.80873	.15107	1960
1961	.22176	.3023	.2814	.80548	.11454	1961
1962	.21541	.30431	.2826	.80222	.11778	1962
1963	.21654	.30474	.28105	.80233	.11767	1963
1964	.21849	.30304	.27933	.80085	.11715	1964
1965	.21937	.3001	.2772	.79667	.11533	1965
1966	.21261	.30248	.2759	.79499	.11901	1966
1967	.19996	.30964	.27424	.78563	.21617	1967
1968	.16848	.31743	.27318	.77809	.22191	1968
1969	.17376	.3251	.27066	.77151	.22549	1969
1970	.17229	.32856	.26906	.76969	.23011	1970
1971	.14854	.34169	.27131	.76147	.23653	1971
1972	.1429	.32695	.26323	.75308	.24692	1972
1973	.13653	.32617	.26575	.74646	.25155	1973
1974	.13122	.32429	.26203	.73773	.26227	1974
1975	.13296	.29876	.26671	.71843	.28157	1975
1976	.12455	.2862	.26918	.71192	.28819	1976
1977	.11236	.27733	.31448	.70421	.29579	1977
1978	.10738	.27195	.31986	.69919	.30081	1978
1979	.11262	.26479	.31878	.69619	.30381	1979
1980	.10474	.2764	.30535	.68649	.31351	1980
1981	.10803	.2799	.28001	.66794	.33206	1981

KEY:

- (1) COAL: Share of coal to total energy used in the industrial sector.
- (2) GAS: Share of natural gas to total energy used in the industrial sector.
- (3) PETROL: Share of petroleum products to total energy used in the industrial sector.
- (4) FOSSIL: Share of total fossil fuel energy to total energy used in the industrial sector.
- (5) ELEC: Share of electricity to total energy used in the industrial sector.

Note: As of the March 1982 issue of the Monthly Energy Review, asphalt and road oil consumption were included as part of the industrial energy consumption. Total here excludes asphalt and road oil.

SOURCES:

1979 State Energy Data Report and Monthly Energy Review, DOE/EIA.

DATA USED FOR FIGURE T.1

YEAR	NEW	EEA	FHA
1970	0	0	13.57
1971	0	0	13.57
1972	0	0	13.49
1973	0	0	13.1
1974	0	0	13.43
1975	13.89	13.31	13.53
1976	14.89	13.49	13.72
1977	15.67	13.76	13.94
1978	16.68	14.12	14.06
1979	17.41	14.53	14.29
1980	20.42	15.11	15.15

KEY:

- (1) NEW: Average on-road new passenger car fuel economy (MPG), EEA model.
- (2) EEA: Average on-road fleet passenger car fuel economy (MPG), EEA model.
- (3) FHA: Average on-road fleet passenger car fuel economy (MPG), FHA source.

SOURCES:

Variables NEW and EEA:

Data taken from Fourth Quarterly Report of the Highway Fuel Consumption Model prepared by Energy and Environmental Analysis, Inc. for Office of Vehicle and Engine R&D., DOE, July 2, 1981. Data values were from Appendix B of the report for line items corresponding to total passenger automobiles.

Variable FHA:

FHA data from November 1981 issue of Monthly Energy Review, p. 17; original source is Table VM-2, in Highway Statistics, Federal Highway Administration, U.S. Department of Transportation.

DATA USED FOR FIGURE T.2

	1980	1981
Total Change	2.50	2.40
Technology	1.33	1.20
Add/Drop Models	0.30	0.53
Shifts within classes	0.53	0.50
Shifts among classes	0.35	0.10

SOURCES:

Data from tables 10 and 11 in Motor Vehicle Quarterly MPG and Market Share Newsletter, Oak Ridge National Laboratory, October 1981.

DATA USED FOR FIGURES T.3 and T.4

YEAR	RAIL	WATER	AIR	TRUCK	TOTAL	INDEX	YEAR
1970	650	540	29400	13404	2619.8	1.0833	1970
1971	700	500	29400	15448	2636.6	1.0903	1971
1972	710	520	29770	15237	2640.1	1.0917	1972
1973	660	530	27190	15247	2642.8	1.0928	1973
1974	680	480	24620	15108	2561	1.059	1974
1975	680	550	25610	14894	2598.6	1.0745	1975
1976	680	470	24150	15055	2546.8	1.0531	1976
1977	670	460	26860	14890	2516.9	1.0408	1977
1978	640	380	25400	14961	2438.9	1.0044	1978
1979	620	440	23600	14570	2418.3	1	1979

KEY:

- (1) RAIL: Btu/ton-mile traveled, Class I railroad freight
- (2) WATER: Btu/ton-mile traveled, Domestic waterborne commerce
- (3) AIR: Btu/ton-mile traveled, Air cargo (all-cargo carriers only)
- (4) TRUCK: Btu/vehicle-mile traveled
- (5) TOTAL Total energy to move 1979 volume and distribution of freight
- (6) INDEX Index of (5), 1979 = 1.0

SOURCES:

Table 4.19, Transportation Energy Conservation Data Book: Edition 5, Oak Ridge National Laboratory, November 1981.

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